AEGIS D8.5

Public recommendations for waterborne transport to West Coast of Norway

Fjørtoft, Kay; Tangstad, Espen; Johanson, Kenneth; Erik Mørkrid, Odd; Meisler, Terje R. ; Bakke, Magnus; Coelho, Nelson F.

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Kay Fjørtoft
SINTEF Ocean

Espen Tangstad
SINTEF

Kenneth Johanson
North Sea Container Line

Odd Erik Mørkrid
SINTEF

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Editors and main contributors	**Company**
Kay Fjørtoft (KF)	SO
Espen Tangstad (ET)	SO
Kenneth Johanson (KJ)	NCL
Odd Erik Mørkrid (OEM)	SO
Terje R. Meisler (TM)	TRH
Magnus Bakke (MB)	NCL
Nelson F. Coelho (NFC)	AAU

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Executive Summary

This report provides *public recommendations for waterborne transport to West Coast of Norway*, with the focus on the specified transport system in use case A in the AEGIS project. The complete background for this report is only achieved by reading all the other deliverables related to the use case, however these are confidential. Therefore, it is recommended to read the ICMASS 2022 paper "Development of an advanced, efficient and green intermodal system with autonomous inland and short sea shipping – AEGIS"[1] to get a better overview of the project and specifically use case A. The transport system of use case A consists of mother vessel(s) together with one or more daughter vessels, connected by several ports. The mother vessel transports containers from Rotterdam via Hitra Kysthavn and into ports in the Trondheimsfjorden. The rationale for this use case is to enable a more flexible and cost-efficient waterborne transport solution for fjords and smaller ports.

An overview on public policy recommendations applicable to the overall European context can be found in the AEGIS report D6.1 Public policy recommendations for a new European waterborne transport system [1].

A transport system consists of several operators controlling different parts of the transport chain, such as shipping lines and terminal operators. Typical examples on exchange of information are route information, sailing frequency, estimated cargo volumes, distances and sailing time, status reports, and information on regulatory hindrances with specific focus on transhipment. Each of these elements could be associated with different obstacles. If these obstacles are not dealt with in a proper manner this could make the transport system less efficient and reduce the competitiveness towards the established road-based transport. Flexibility and trust in the transport system are key to success.

Based on the European Green Deal, there is also a Norwegian goal to shift at least 30 % of cargo which travels more than 300 km, from road to rail and waterborne by 2030. The Office of the Auditor General of Norway has conducted a thorough evaluation of the national transport goals and concludes that these national targets are not yet achieved. The major reason for this is a lack of financing, prioritisation, and few governmental initiatives to achieve this goal. In contrast to waterborne infrastructure, there are large investments in road and rail infrastructure. As a result, this has caused road-based transport to be faster, cheaper, and more flexible compared to waterborne and rail. The pressure on road-based infrastructure is also significant and leads to more pollution, a higher risk picture because of truck accidents, and it causes an increase in the demand for new and upgraded infrastructure, which enables even more transport. Waterborne transport does not have the same challenges, but still it is not prioritised as an alternative transport mode.

Some stakeholder perspectives based on interviews and discussions in the AEGIS project:

1 **Capital Expenses (CAPEX) and investments:**

a. Shared investments in infrastructure development between users in the transport system

b. Long time contracts with ports, that stimulates for technological investment in the port.

c. Investment in sustainable energy, collaboration between provision and consumption

[1] https://aegis.autonomous-ship.org/wp-content/uploads/2022/09/krause_2022_j-_phys-__conf-_ser-_2311_012031.pdf

2 **Operational Expenses (OPEX):**

a. The port fees must be reduced and be more correct according to the service received in a port.

b. The ports should document the fees and services that are included, what the users are paying for.

3 **Strategic and long-term planning to enable automation and sustainability:**

a. Punctuality is not always aligned with sustainability. Loading time is not always critical, but just-in-time is a driver for more sustainable transport. The sailing time is estimated based on fixed schedules. A more just-in-time approach is recommended.

b. ICT systems should be highlighted as part of infrastructure. The different ICT systems must have standardised communication protocols to allow for easy integration between stakeholders in the transport system.

c. When introducing autonomy in transport it is crucial to follow the planning hierarchy (strategic – tactical – operational – executional). At Hitra Kysthavn, which is a new port, the strategic planning will have to consider automation and the collaboration between different stakeholders at all levels in this hierarchy.

d. A transport system should also include storage possibilities at terminals.

4 **Closer collaboration between operators:**

a. More collaboration on utilization issues, such as shared use of containers should be prioritised. The balance of containers in the transport chain is not currently optimal.

b. Stimulate for sharing of loading and discharging equipment in terminals.

5 **Governmental incitements and instruments:**

a. The Norwegian government should intensify stimulation of maritime transport. AEGIS recommends a similar arrangement as for the introduction of electric cars regards implementation of autonomous and green transport solutions.

b. Governmental incitements for use of green solutions where pioneers must be compensated for the risk related to investing in new technology and alternative fuels. New alternative fuels are currently more expensive than conventional fuels. One incitement proposal is to cover the price difference between alternative fuels and MGO.

c. Ports and waterborne transport should have a stronger position in the national funding programs.

d. Waterborne fees should be comparable with land-based dues.

e. Stimulate for more collaboration between port users-owners-providers.

f. Stimulate for a better multimodal integration between maritime, road and rail.

g. A transport system should investigate possibilities to allow different transport opportunities, such as fast vs. slow track cargo transport. The prices should be regulated accordingly.

h. AEGIS recommends that the Norwegian Research Council continue prioritising maritime transport, at the same time it is important that the introduction of new technology and autonomy must be aligned between the service providers, technology developers, research, and the regulatory stakeholders.

6 Research and development:

a. It is recommended to perform further studies on the combination of mother and daughter vessels constellations. The case in Trondheimsfjorden can easily be adopted to other regions, not only in Norway, but also the rest of Europe.

Definitions and abbreviations

DFDS:	Det Forenede Dampskibs-Selskab
ICT:	Information and Communication Technology
IPA:	Integrated Planning for Autonomous operations
ITS:	Intelligent Transport System
LNG:	Liquefied Natural Gas
LoLo:	Load on Load off
MASS:	Maritime Autonomous Surface Ship
MGO:	Marine Gas Oil
MSW:	Maritime Single Window
NCL:	North Sea Container Line
RoLo:	Roll on Lift off
RoRo:	Roll on Roll off
ROC:	Remote Operations Centre
SO:	SINTEF Ocean
TEU:	Twenty feet equivalent unit
TOS:	Terminal Operating System
TRH:	Trondheim Havn
WP:	Work Package

1 Introduction

This report is covering the results from work on task 8.5 *Public recommendations*. The work aims to identify factors that make it difficult to introduce automation to the Use Case A transport system, and to why road-based transport is selected instead of waterborne. The result has addressed factors identified in previous deliveries and have attempted to find the recommendations to strengthen the success of introducing an AEGIS transport system.

As a background for this work, it is important to understand use case A and its deliverables:

Task 8.1 Cargo volume analysis. This task investigated available transport volumes within the use case A route, including total volumes transported within the chain and not only by the AEGIS partners. The analysis has included an estimation of possible increase in volumes given that a better waterborne service can be provided to users. The volumes are based on literature studies, interviews with the main cargo type owners (fish export, retail goods, building material, etc.), and from statistics materials. The analysis is limited to cargo that fits into standardized cargo units, in this case containers. The task also looked at effects of possible weight and size restrictions on cargo units/load units, and how to achieve more standardization.

Task 8.2 Specification of the transport system. This task utilised the knowledge and competence within the AEGIS consortium to define a transport corridor in and out of the west coast of Norway, following the AEGIS objectives. The specification covered ICT systems, ship types, number of vessels to be used, and suggested vessel sizes; shuttle sizes and numbers; routes, terminal structures, and cargo handling. Also, regulatory hindrances were included in the analysis.

Task 8.3 This task covered identification of bottlenecks and other obstacles for use case A. It focused on identification of factors that make users prefer trucks over waterborne. The task quantified these factors and attempted to find the tip-over point when waterborne gets more competitive compared with road-based transport. This was partly reviewed following data from previously published papers and reports but was also based on interviews and statistical data to provide an updated and detailed picture.

Task 8.4 Detailing and validation of the AEGIS solution. This is a review of the design and modifications of the transport system through simulations so that it fits with findings from other tasks and WPs. The final transport system was put through cost-benefit analysis tools from WP2 to find quantitative proof of its viability, comparing the new transport system to traditional means of transporting goods in the region through the KPIs from WP7 as well as assessing its external costs impact.

1.1 The Transport system in use case A

The proposed transport system in use case A has been described in deliverable *D8.2 Transport system specification – Case A [2]* but a summary is given below. The use case A transport system will, as indicated in Figure 1, consist of terminals, mother and daughter vessels, terminals, exchange of cargo at Hitra/Sandstad Norway, ICT-systems and administrative routines. Some of these elements already exist and others do not.

The use case can be divided into three main segments:

1. Daughter vessel operation - Transport within the Trondheimsfjorden region, Norway

2. Mother vessel operation - The transport between Rotterdam, Netherlands and Hitra Kysthavn (Sandstad), Norway
3. Terminal activities at pickup locations and drop-off locations. These terminals can be further categorised as small, medium sized and large, i.e.,
    a. Small ports/terminals (Steinkjer, Follafoss and Verdal)
    b. Medium ports/terminals (Hitra Kysthavn, Orkanger, Trondheim, Skogn, Holla)
    c. Large ports/terminals (Rotterdam and Moerdijk)

The map in Figure 1 shows the ports and terminals involved in use case A.

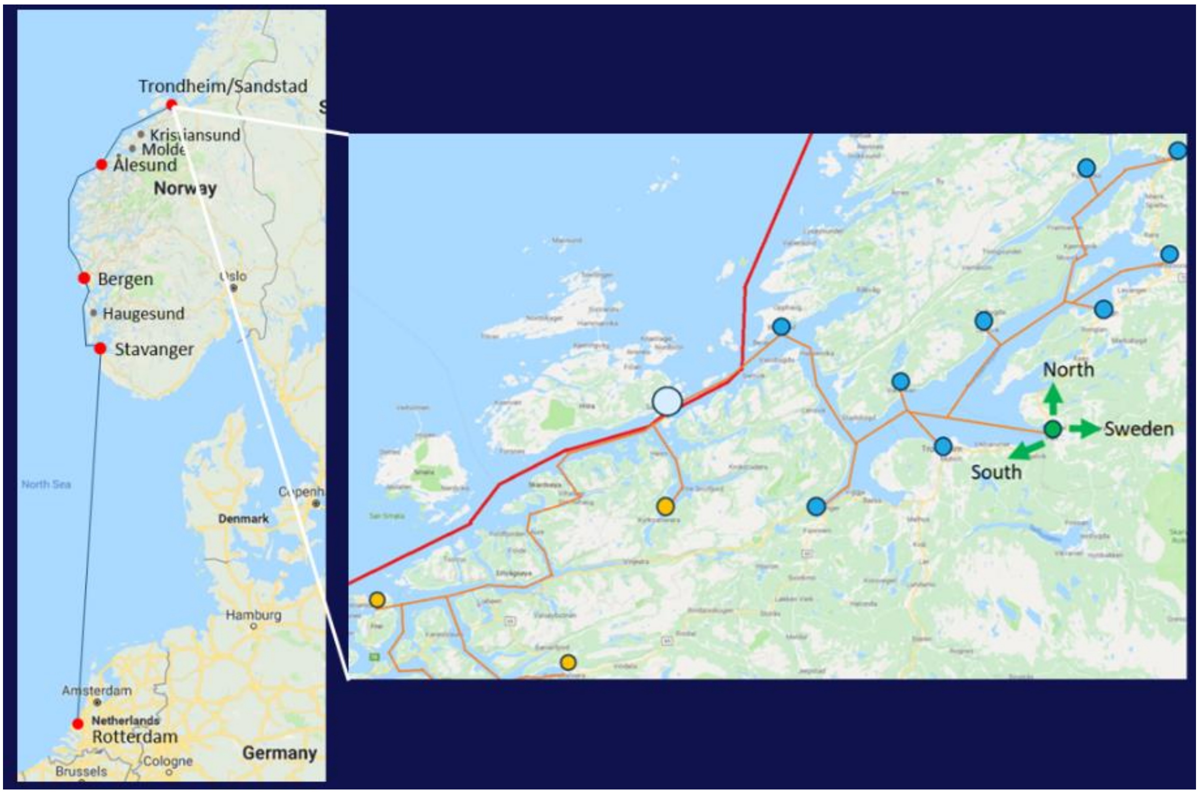

Figure 1 - The ports and terminals in use case A.

There have been several projects dealing with transport between the Rotterdam area in the Netherlands and West Coast of Norway. The AEGIS concept differs from them since a combination of mother and daughter vessel working together to build a transport system. The mother vessels sailing between Rotterdam and Norway with large cargo volumes, of approximately 1000 TEU on one sailing. The cargo is transhipped through coastal transshipment terminals in Hitra, where it is suggested to use several smaller daughter ships, carrying possible 60 – 100 TEU.

There are several reasons for introducing a mother – daughter concept. The distance between Rotterdam and Mid-Norway will not allow operation by only one vessel with a fixed regular weekly schedule. The distance is significant, about 800 nm, which is estimated to take more than two days of sailing one direction with a speed of 15 knots. The distance from Hitra to Trondheim is 48 nm, which means an added three hours to the sailing time. Sailing further into the fjord all the way to Skogn will add on 72 nm, which means additional 5 hours at a speed of 15 knots (one direction). A roundtrip between Hitra Kysthavn and Skogn takes about 16 hours with a speed of 12 knots. Time for mooring, loading and discharging will come on top of this.

Regarding economic issues, the daily operational cost of a mother vessel is higher than for a daughter vessel, and its operation requires more energy. A daughter vessel will be significantly smaller and will also allow to operate at a lower speed, which reduces energy consumption. Another factor is that some of the smaller ports are too small for a mother vessel, and the quay capacities or infrastructure cannot allow port calls by bigger vessel. Simulation studies have been performed, where different mother and daughter vessels constellations have been analysed. The studies have also allowed for comparison between the waterborne and road-based transport.

To secure a successful transport system with mother and daughter vessels, the transhipment of cargo must be efficient, cost controlled, and optimised. This requires an efficient transhipment terminal that can provide services for both mothers and daughters, as well as the cargo owners. The use case has studied an existing terminal in Orkanger and the new terminal Hitra Kysthavn, and has identified how to retrofit and prepare the terminals for new technology and the new AEGIS transport system concept.

2 The new transport system

Norway has a strong position in the maritime sector, that includes ship operation and providers of advanced maritime technology. Prioritisation from the Norwegian shipping associations is to stimulate for sustainable alternatives, to become a more climate-friendly transport sector. This is primarily driven by a political ambition to reduce emissions of greenhouse gases, where Norway through the climate statement has set a working target for emission cuts in the transport sector with 35-40% in 2030 compared to 2005 figures. Fit-for-55 has a similar approach. The ambition and the development are also driven by a wish for factors like less noise and reduced local pollution, such as NO_X and particles from diesel engines, as well as reduced operating costs. The report written by PwC, Energibruk i transportsektoren i Norge (*English: the energy usage in the transport sector in Norway*) pointed to following factors, that also are of relevance for use case A [3]:

Quoted from the PwC report: *In 2018, the total Norwegian energy used in the transport sector was 63 TWh. Of this, land transport accounted for 41 TWh. The remaining 22 TWh was evenly distributed between sea and air transport for domestic transport. Despite the fact that the total amount of transport is expected to increase towards 2030, only a limited increase in total energy use is expected. This is due to a greater proportion of means of transport with electric propulsion technology, which have a higher degree of efficiency than conventional drivelines and can thus use the energy more efficiently.*

PwC considers it likely that in 2030 biofuel, biogas, hydrogen and electricity will be used as energy, but still a relatively high proportion will be diesel. Mixable biofuel is expected to be able to function as a "*bridge fuel*" and can extend the time horizon of diesel-powered heavy transport. In total, renewable energy carriers are expected to account for 60% of energy use in the passenger car segment, and 40% of energy use in goods transport in 2030.

PwC says that the expected distribution of energy carried per transport sector will probably include several different fuel types in use in sea transport in 2030. PwC has assumed that half of Norway's 140 ferry connections will be electrified by 2030, and that 10 connections will be operated with hydrogen. For high-speed boats, certain sections will also be able to be electrified, but due to high speed, weight is critical and hydrogen will therefore be a more relevant alternative. PwC believes it is likely that around half of Norway's 100 fast boats/ferries will be using hydrogen in 2030. Also for cruise ships and other vessels, the trend is towards renewable energy, including biofuel and hydrogen. In total, PwC expects that renewable energy will account for approximately half of total energy use in 2030. Biofuel is expected to be the largest, closely followed by hydrogen, electricity and biogas.

PwC says further that the energy use in waterborne transport in Norway is currently around 11 TWh per year, primarily MGO (Marine Gas Oil). Norway has been early adopters of LNG and batteries for hybrid and electric solutions. There are also ventures exploring hydrogen. The Norwegian government's ambition is to halve emissions from domestic shipping and fisheries by 2030, and to stimulate the development of zero- and low-emission solutions in all vessel categories. To address this, they presented an action plan for green shipping in June 2019. The main move in the action plan is to look at possible measures and tools within different vessel categories. Measures implemented as a result of green shipping could have a major impact on developments in energy use within maritime transport in Norway. For sea transport, the report is divided into the following four areas: Ferries, Speedboats, Cruise ships and other vessels.

From the AEGIS cargo volume studies in Use Case A, it is expected that there will be growth in transport the coming years. The Norwegian governmental ambitions are to move more than 30 % of the cargo to waterborne. Waterborne transport can transport a high cargo volume and is the best option for longer distances, but it requires intermodal connections with road and rail. An efficient transport system should facilitate multimodality and ease integration between the transport modes.

AEGIS has pointed on the challenge with different providers who are heading in different directions regarding choice of energy to be used/offered. This is also a challenge from a port or terminal perspective, where it will be almost impossible to offer all types of energy sources required from the maritime sector, because the CAPEX investments will be too high. High investments costs in ports result in higher port fees to the end users. New energy also requires significant land areas, that are not normally available.

Standardisation and common strategies between the stakeholders are key, and the whole transport system must be seen as a whole to avoid non-optimal costly investments. As PwC mentioned, not only new energy sources must be provided, but also conventional energy for a long period. In Use Case A, NCL who is operating internationally, must follow international trends regards type of energy. NCL has selected green methanol for their new mother vessels that will be launched in 2024. Battery-electric propulsion is the chosen solution for the daughter vessels in Use Case A, one reason is that a daughter vessel has a shorter sailing distance and are close to the infrastructure providing electric energy.

One factor from the AEGIS project worth mentioning is that the Norwegian governmental support instrument ENOVA has stopped funding installation of shore power in the ports, with the reason that the technological maturity level has reached a high technology readiness level (TRL), and the market uptake potential is considered adequate.

A successful example from Norway on the importance of governmental incitements is shown through the introduction of electric cars. The government has supported the users with lower road taxes than conventional cars, have allowed driving in restricted lanes, have offered free parking and reduced price on ferries as examples. They have also supported the car owners with zero VAT on the procurement cost. Today those incitements have led to a new car sale of more than 80 % for electric cars in Norway. Use case A very much favour a new governmental incitement supporting the maritime industry with sustainable alternatives.

3 Key Performance Indicators

This chapter highlights key performance indicators (KPIs) from *WP7 Cost-Benefit Analysis and environmental assessment* that are of interest for Use Case A. These KPIs have been the foundation for the cost benefit analyses and validation performed in the AEGIS project. The following section presents the main findings and recommendations from this work. The lists of the KPIs are presented in another AEGIS deliverable, more specific in the D7.2[4].

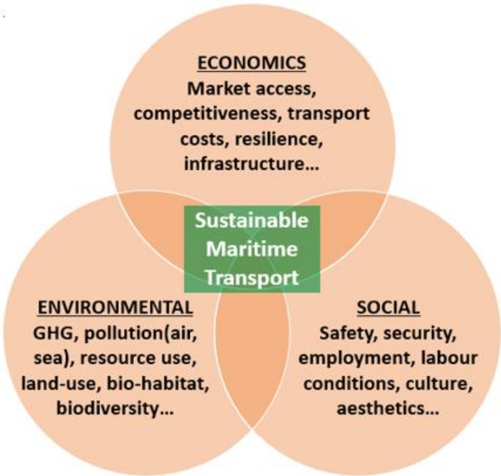

Figure 2 – UNCTAD sustainability pillars (Economics, Environmental and Social) and related KPIs [4]

Figure 2 shows the three sustainability pillars defined by UNCTAD[2] and how these can be assessed by certain KPIs to ensure sustainable maritime transport.

Economics: The Economics KPIs, with reference to WP7 and D7.6 [5] D7.7 [6] and D7.8 [7], describes the commercial aspect of the transport system. For use case A the following KPIs are highlighted:

- **Costs:** CAPEX, OPEX, Port charges, Waterway dues, Energy cost, Infrastructure development, Cargo unit cost
- **Time:** Loading time, Sailing time, Unloading time, Waiting time, Punctuality rate, Cargo handling time
- **Others**: Energy consumption, Cargo carried, Percentage of load, Cargo damaged, Frequency of service, Number of container moves, Road going transport impact

Environmental: To mitigate global warming and a possible climate disaster, emissions from shipping should be reduced by 30 % by 2030, and in 2050 there should be zero emissions from shipping. EU has introduced many requirements in its plan for green transition. This is one of the main reasons for AEGIS to introduce a new, advanced, efficient and green intermodal transport system. This is further explored in D7.7 [6].

Any transport system that does not fit these new environmental standards is not sustainable and set to fail. Environmental issues must therefore be at the core of any future transport system. The following KPIs reflect possible challenges but used correctly these environmental requirements lead to development and use of new solutions. Environmental issues are not considered as bottlenecks or obstacles in AEGIS, but rather enablers.

[2] https://sdgpulse.unctad.org/sdgs/

The most relevant environmental KPIs regards Use Case A are:

- Emissions: CO_2, NO_X, SO_X, Particulate matter, Acoustic emissions - noise
- Others: Terminal area per cargo unit, Use of renewable energy sources

Social KPIs: As with the environmental regulations health and security are not considered as obstacles in this work. From the list Use Case A have selected following KPIs that are important for use case A:

- **Security/Safety:** Accident rate, fatality rate
- **Work-life:** Labour conditions, employment, income, training

In the following table a description on how Use Case A as used the different KPIs are listed

Economics: North Sea Container Line (NCL) has ordered two new container vessels (1300 TEU) to be operating short-sea between West Coast of Norway and Rotterdam in 2024, and one daughter with the capacity of 250 TEU to be operating in Norwegian waters. Those will be the most expensive investments in use case A. But it is also costly to invest in a new terminal and loading equipment, as well as to land-based infrastructure, such as facilities to support new energy as hydrogen. Regards OPEX, Energy and Port handling are important costs for a ship operator, together with the fairway and infrastructure costs. At the same time, from a port operator perspective, those costs are needed for a terminal operator to be able to invest in new equipment, sensors and software for a sustainable and efficient operation of a terminal. A mother vessel has a much higher daily rate than a daughter, that favours use of a daughter vessel to smaller ports. There are many considerations to make in use case A regarding time constraints. Some of the cargo to be transported are time critical, such as fish transport, and other cargo types are more on-demand cargo. The combination of a daughter and mother might take longer loading time at a terminal, but the consolidation of transport from a main or transhipment port such as in Hitra can save transport time between Norway and Rotterdam in total. Another challenge for a short-sea provider is that deep-sea transport has the highest priority in intercontinental ports, which means if a deviation occurs with a deep-sea vessel, a short-sea vessel must wait and adapt its plans accordingly. The punctuality KPI in this example is often negative for a short-sea vessel. **Environmental:** Use case A has analysed different energy carriers and compared the AEGIS mother daughter solution with road-based transport alternatives. Results show that a maritime solution is competitive and is a more environmentally friendly solution than road. NCL will be using green methanol for their new vessels, next generation daughter vessel is planned to be battery powered. Comparing battery-powered daughter ships to the more typical diesel-powered trucks, that do most of the transport work in the Trondheimsfjorden region today, shows a lowering of two magnitudes of CO_{2eq} per transported container. In parts of the transport system the acoustic emission can be a problem. In Trondheim as an example, houses and new buildings are pressing industry activities out of the city centre since acoustic restrictions is a challenge for 24/7 operation. At the same time the ports involved in our studies show that the use of new environmentally friendly energy sources is coming, battery powered transport generates less noise. At the Port of Trondheim, they are planning for future investments at the terminals to be able to support the maritime industry in this shift. For example investments related to the regional plan of building a new hydrogen factory close to Hitra Kysthavn is part of their ongoing work. AEGIS also investigates how the terminals can be reorganised to be more efficient, and how new autonomous technology can operate together with humans and today's practices. This has been addressed in two cases, for the new terminal at Hitra Kysthavn, and to retrofit the terminal in Orkanger.

Social KPIs: AEGIS results will be further used by Port of Trondheim in modernisation of their terminals, where use of new technology and autonomy are considered. In the studies it was highlighted the importance of standardisation of solutions, such that investments don't ended up being proprietary and only serving one specific type of vessels. This is especially of relevance when offering energy to the vessels, with reference to energy type and needed equipment at a terminal to load energy to the vessels. AEGIS also recommends use of electric energy on the loading equipment, to reduce acoustic emissions.

The traditional road-based way of transporting cargo from Norway to the continent is a safety matter. In the winter season, the roads are icy and consequently slippery, which causes a high number of accidents. This is an KPI of concern, the total number of accidents in the transport sector must be reduced. Maritime transport is safer and will not be subject to societal KPIs to the same extent as road-based transport. However, when looking at cargo operations, the risk picture is different for the maritime transport. Still there have been regional maritime accidents during the project period, that mainly was related to the loading and discharging of cargo operations. AEGIS underlines the risk in transport and the loading process and recommend using technology and autonomy where possible to lower the total risk picture. Concrete examples are to use automated cargo handling equipment that are controlled remotely, and if possible, removing the workers away from the high-risk areas.

4 Integrated Planning for Autonomous Transport Operations

Introducing new technology and autonomy into the supply chain is expected to result in more efficient, safe, and environmentally friendly transport operations. Autonomy is likely to change the transport operations, and especially the way of planning. There will likely come new threats, unfamiliar events, and new types of incidents, and the rapid pace of technological and societal change introduces the need for new competencies and work practices. These are necessary to exploit the benefits of the new technology, without operating at an unacceptable risk level. In this chapter it is elaborated on the different planning needs and what will be important for a successful implementation of Integrated Planning for Autonomous transport operations (IPA). The IPA is a suited framework when planning and addressing the resilience perspective, in addition to identify criticalities within the transport system when new technology is introduced.

A new challenge associated with autonomy is the realization of new ways of planning, working and collaborating in a transport system. This requires new routines and practices. Hence, the authors introduce IPA as a framework towards successful implementation of autonomy into the transport system. The procedures for conventional planning must be changed from being a human based process, to a scenario where the collaboration between humans and technology will become stronger. IPA is based on the Integrated Planning and Logistics (IPL) that initially was developed for the offshore petroleum industry in a previous Norwegian research centre (The Centre for Integrated Operations) and is based on the concept of IO (Integrated Operations), where principles of integrating people, work processes, and technology was developed for the purpose of making smarter decisions and achieve better execution. This enabled by real-time data, collaborative techniques, and sharing of expertise across disciplines, organizations, and geographical locations [8].

When working with autonomy it is important to understand the threats along the transport chain, to identify different barriers, and to plan for actions if anything deviates from the plan. Increasingly, automation is being implemented in vessels and infrastructure (e.g. at ports and terminals), and it is therefore important to consider the impact of an even more widespread use of such advanced technology across the whole transport chain. Resilience is of high importance for being able to prepare and plan for the unknown, what can happen, how to enter back to normal or adapt to changed premises if something deviates from a plan. This requires an integration of plans across the transport chain, covering different planning stages and geographical areas. However, increased digital transformation and exchange of real-time data may lead to increased brittleness. For example, studies on cyber resilience of ship information systems, indicate that the increasing use of remotely controlled autonomous technology used on ships today will likely lead to an increase in worldwide new types of cyberattacks [9]. Zhou et al. [10] examined sea transport from a resilience perspective. They tried to improve safety based on comprehensive risk assessment at the theoretical and operational levels concerning the specificities of water transport, Stene et al. 2021 [11].

Moreover, the current transport domain experiences a lack of coordination between different organisations, technologies, and transport operations. Execution of activities are often sub-optimal, in addition to being difficult to prioritise in case of conflicts of interest. One main challenge in this context is that changes to plan often results in a win - lose situation, where the consequences of a change are not addressed to all involved stakeholders. Weak planning may affect inefficient utilization of means as example.

Integrated planning (IPL) and the planning hierarchy must be designed from a holistic perspective. Illustrated by the plan hierarchy, both horizontal and vertical integration must be accounted for (Figure 3). Different companies define levels of planning in various ways, but they all define the boundaries of long, medium- and short-term planning, each involving different levels of the organization and different planning horizons. This tells that one planning level will be input to another. Planning across one level means that there will be several plans within the same time horizon, which will be beneficial to share across systems and companies. Executional planning is a new level introduced by the writers, to allow for planning based on real-time data.

Figure 3: The four planning levels

Strategic planning has a long-time perspective. This is normally CAPEX intensive costs planning. Important factors to be considered are market and financial issues, infrastructure and governmental decisions, and laws and enforcement that must be followed. Typical stakeholders involved in this planning process are infrastructure owners/managers, strategic planners, transport service providers and owners, regulators and government (financial issues, funding, needs for new means/technology/infrastructure etc.). Examples of plans that will be of importance for IPA are technological investments, operational management, safety and security, CONOPS (Concept of Operation), risk assessment, resilience assessment, standards, and emergency preparedness.

Strategic planning	
Definition	Planning for development and investment in technology, infrastructure, resources and partnerships. Important factors to be considered are market and financial issues, infrastructure and governmental decisions, and laws and enforcement.
Stakeholders involved	Infrastructure owners/managers, strategic planners, transport service providers, Regulators, Government
Plans	Technological investments, Operational management, Safety and Security, CONOPS, Risk assessment, Standards

In UCA Strategic planning addresses following:

- The port technical infrastructure to support an automated or autonomous vessel operation (daughter, mother)
- The regulations that allow for autonomous operations in Norway
- The regulations that allow for sailing in the North Sea partly supported by a ROC
- The regulations that allow for remote or autonomous crane operation

- The regulations that allow for remote operation of technology in a port or terminal
- The collaboration between the operators, cargo owners, infrastructure providers, government to allow for autonomous investment and operations

The tactical planning has a shorter time-horizon than the strategic. It includes a more detailing and updated planning quality with reference to strategic plans. It will also be important to include more human oriented planning, such as training and competence building at this level.

Tactical planning	
Definition	Planning use of critical resources, transport demands, scheduling of fleet and terminal activities, transport strategies, risk and safety evaluation, financial issues, market changes, technological robustness, maintenance, resilience, infrastructure and governmental decisions, and laws and enforcement issues.
Stakeholders involved	Cargo owners, Infrastructure owners/managers, Strategic planners, Transport service providers, Regulators, Operators, Government
Plans	Schedules, sailing plans, terminal operational plans, risk and safety plans, security plans, updated CONOPS, investment plans

In UCA Tactical planning addresses the following:

- Commitment to use autonomous and sustainable transport
- Commitment to support and serve autonomous technology
- Commitment to share operational plans, for example use of loading technology and resources
- Regulations of areas that allows autonomous equipment to operate without presence of humans
- Commitment to offer maintenance support in port areas
- Commitment to offer a robust communication infrastructure

Operational planning has an even shorter time-horizon, where the plans include detailed instructions for the transport and how the execution should be done. It is a continuation from tactic planning, but where the planning quality is more accurate with more detailed information and instruction regards operations of means and handling of the cargo to be transported. For IPA this planning data will be used when designing the operational envelopes [12]. For an autonomous ship system this includes the definition of what conditions the ship can operate under, with operational boarder and constraints as examples.

Operational planning	
Definition	Planning of resource management, stowage plans, daily production and distribution plans, status reports, scheduling, risk and safety evaluation, operations in different weather pictures and in dynamic traffic pictures.
Stakeholders involved	Cargo owners, Infrastructure owners/managers/operators, Strategically planners, Transport service providers, Regulators, Traffic managers
Plans	Technological investments, Operational management, Safety and Security, CONOPS, Risk assessment, use of operational envelopes

In UCA Operational planning addresses following:

- Commitment to share resource management plans
- Commitment to share stowage, manifest, loading and unloading plans
- Commitment and regulations of CONOPS
- Commitment to Operational Envelopes, that also includes terminal operations

In an IPA framework a new fourth level is likely to be included, called the executional planning level, which is a definition set by the authors. The planning focus will be on a short time horizon, more digital driven, where normally real-time data is used for decisions making. It focuses on technological operations, such as to provide commands/instructions for how the autonomous execution of the technology should be done. In some cases the technology is capable to do their own decisions based on sensor data (i.e. traffic, weather, positioning). It is still important that it has a high explainable degree such that humans can understand the reason for a decision taken by the technology, at the same time as the humans should be better prepared to take control of technology if needed, i.e. from a Remote Operation Centre (ROC). The hand-over processes between technology and ROC must be planned for, for example by use of operational envelopes where the state and activity diagrams are designed.

Executional planning	
Definition	Planning of technological operations, which means the commands/instructions to be given to the autonomous technology. In some cases the technology is capable to do their own plans, that should be informed to stakeholders of concerns.
Stakeholders involved	ROC, Transport service providers, Traffic managers, Operators
Plans	Sailing plans, Cargo loading instructions

In UCA Executional planning addresses following:

- Commitment to install sensors and technologies that can monitor, give status, and be used for executional control
- Commitment to close areas such that autonomous technology can work without risk of humans entering the operational sones (geofencing)
- Commitment that cargo flows are following instructions (placed on correct geo-areas etc)

From the SFI project "Integrated Operations within the oil & gas sector in Norway" [13], a Capability Model was defined. The main objective was to support design and implementation integrated planning and to discover best practices by focusing on key capabilities. The model proposes a focus on two main groups of capabilities: (1) enabling capabilities, and (2) human and cultural capabilities. The cultural approach focuses on human interaction, communication, reflection, sense-making (knowledge-as-meaning), and practice-based issues (knowledge-as-practice). The (1) enabling capabilities are structural and can be designed according to the specific needs of the organization or system: Roles and

Processes, Information and Communication Technologies (ICT) and Arenas for Coordination. The (2) human and cultural capabilities are features that need to be cultivated and stimulated through continuous attention and focused leadership.

AEGIS has used this methodology as inspiration when also working with integrated planning for autonomous operations (IPA). The ideas are to identify how new technologies can be adopted to the transport domain, and how humans and technologies can operate safely together. In use case A the emphasis is on the human and cultural capabilities, and less focus on the enabling capabilities. Central

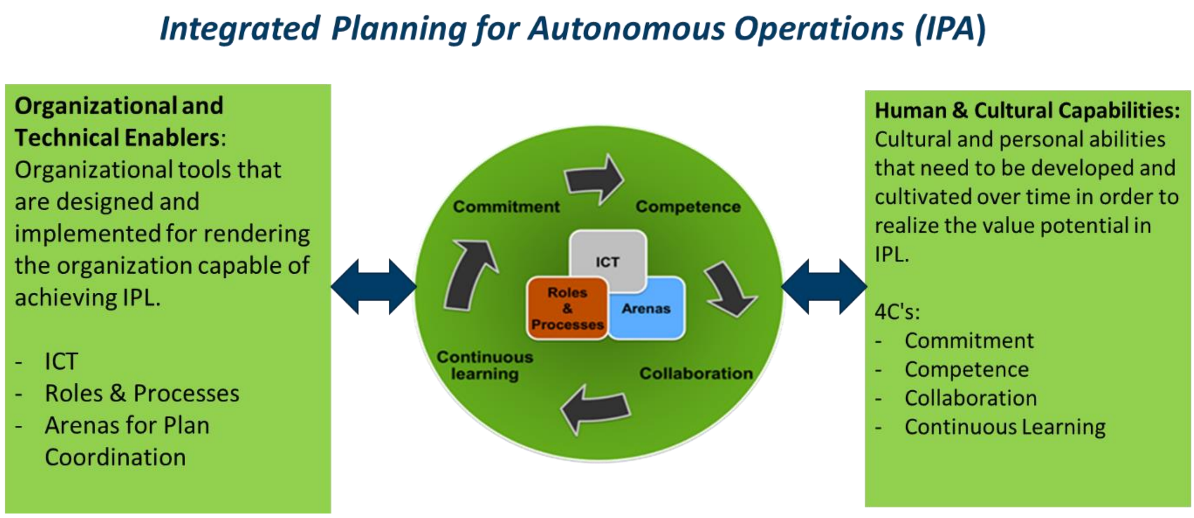

Figure 4: The IPA framework including the 4 Cs.

questions are related to autonomy and resilience: How will the capabilities change with implementation of more automated vessels and autonomous technologies within a transport chain. In Figure 4 the 4Cs are presented; Commitment, Competence, Collaboration and Continuous Learning. In use case A these have been used to understand challenges regards new technology, which are described below.

Competence – The ability to do something well, effectively, following professional standards. Competence will require different skills when comparing autonomous operations with conventional transport. Competence is here defined as to know how to do certain things. This involves both knowledge and skills to perform work tasks and operations in practice. Several aspects are found to be crucial when it comes to IPA and competence as a holistic and shared understanding of IPA among the involved parties. Examples are competence in utilizing ICT tools sufficiently, and competence in cross-domain collaboration and communication. In addition, competence in terms of learning and change has also been emphasized by the industry professionals when it comes to planning.

UCA Competence	
Autonomous competence	The competence skills must be on the technology (enabler) and its capabilities. Some technologies are designed to take decisions by itself, without human interaction, but the humans should understand the reason for the decisions. The systems can be designed to learn from data, for example by utilising machine learning in systems where an increasing amount of data will be used to improve the algorithms involved in

	decision processes. But it is likely that these systems will have their limitations, where human decision support is needed when the system cannot make decisions itself. The competence of the staff at a remote operation centre is another issue. Since the humans are moving from a present location at sea where it is locally involved in the operation, to be located remotely from the operation, it is important to understand what kind of awareness and information the operator needs to make an adequate decision. This requires a clear understanding of the time windows that must be calculated for in case of a hand-over process from the technology to the ROC operator. As an example, the minimum time available for an action to be taken by the ROC operator before the technology goes to a fall-back state. When it comes to the planning competence, it is important to understand where to build enough awareness to a plan, how to exchange plans with the technology and other organisations, and not at least how to plan for resilience.

Commitment – A strong belief in an idea or system and the ability to act on that belief. Commitment is a central theme in IPA and can prove particularly challenging in the planning of transport operations, where changes in activities and prioritizations occur frequently and often unexpected. This challenges critical aspects such as quality of input and ownership. Commitment in this context is therefore more than commitment to the given plan, it is also commitment to the planning process and to the overall business model in which the operations take place. Commitment in planning means responsible action that acknowledges the interdependencies between one's own work and that of others. It means taking responsibility for one's own workload, but also for communicating issues or problems to others who are dependent on it. Commitment is further intimately linked to ownership and trust between different actors and technologies. Therefore, efforts for establishing trust within and across disciplines, companies, and organisations are essential. In essence, trust is a strong belief that others will do as agreed and promised. In the context of planning logistics operations, trust can be that the activities listed in a plan will be performed as scheduled, and that the necessary resources to do so are readily available.

UCA Commitment	
Commitment on ***autonomous technology***	Commitment on ***autonomous technology*** is a new and unproven issue. It will be important to understand the technological capabilities, to understand how to give instruction to be followed by the technology, as well as to understand the reasons for a decision made by the technology. It is also important to understand how to exchange information with the autonomous technology, either directly with the technology or through a ROC, and not at least understand how to exchange information with other external systems or operators, for example ICT at another vessel. In autonomous operations it will most likely be harder to do changes to plans than for conventional. The technology is planned to deliver according to pre-defined agreements. The commitment will be to other technologies, to people or groups of people involved in the operation, to external stakeholders, and between technologies. The interdependencies between the activities and plans must be emphasized. Commitment is also about communicating issues or

	problems/deviations to others who are dependent on it, which is very important when talking about autonomy.

Collaboration is the act of working together to achieve the desired goals and objectives. Collaboration is a process in which different entities share information, resources, and responsibilities to jointly plan, implement, and evaluate a program of activities to achieve a common goal. However, there are several challenges associated with collaboration across boundaries (organizations, disciplines, and locations), involving advanced collaboration technologies and limited face-to-face interaction. Especially IPL at operational level is characterized by collaboration between participants located at different locations, often representing challenges related to different local cultures and lack of commitment to common goals. Nevertheless, commitment and trust in both colleagues and technologies are needed because collaborative work rests on shared understanding of objectives, each other's position and contributions. Collaboration for early coordination and prioritizations should be supported by methods for structured collaboration, facilitation of interdisciplinary communication involving the relevant stakeholders and expertise. In addition is it crucial to motivate people to collaborate and remove barriers to employee participation in virtual knowledge-sharing communities of practices.

UCA Collaboration	
Collaboration on ***autonomous technology***	Regarding **autonomous collaboration** there will be new elements to be included. The technology will to a larger extent be managed from someone located away from the operation, for example from a ROC. The technology should collaborate with other technologies, and with conventional systems. Sometimes an autonomous vessel will meet another autonomous vessels, that means two technologies must collaborate to avoid conflicts. Other times the vessel will meet another vessel with a physically captain onboard. In both cases it is important to understand each other's decisions such that unwanted situations do not occur, and how the concept of operations and regulations are practiced. It is about increasing performance, safety, and efficiency. It is also about how to solve deviations and conflicts such that the consequences become as low as possible. In the future where many autonomous technologies are working together, it will be important to understand the way of collaborating in the digital transmission of information, as well as to understand where humans must take part in the process in case the challenges cannot be solved by the systems themselves. To understand the technological decisions is also an issue.

Continuous Learning is an ongoing learning process that seeks to incorporate lessons learnt into a continuous improvement process. In this context continuous learning is promoted as an important capability regarded as one fundamental requirement for all organizational changes, sustained existence, and continuous improvement of practices. Continuous learning is both related to developing and implementation of IPL practices in general but also learnings for improving the plan quality based on feedback and sharing of experience. According to the practice-based learning theories learning must be connected to practice and the people involved in practice if the ambition is to change the way people and organizations work. In the context of integrated planning this includes people involved in IPL where key roles are planners, planning managers, discipline leaders, project leaders and project controllers.

UCA Continuous learning	
Continuous learning on ***autonomous technology***	**Continues learning regarding autonomous technology** and operation will address new elements. The technology in use is often developed as a self-learning system, where artificial intelligence and machine learning is used. It is designed to learn by examples and to achieve more-and-more knowledge to be used for decisions. From a human operator's point of view it will be important to understand the decisions made by the technology, which is called explainable AI. From a ROC perspective it will require skills to manage the technology, to understand the decisions made, to learn the capabilities and to understand the interaction with the technology and with the stakeholders involved. It will be different needs for expertise's compared with traditional knowledge for operations.

In AEGIS and within the other transport systems it is important to not only focus on the technology, but also on how the technology should be used together with humans. The planning hierarchy is important to understand, and how the different strategies can be planned for and collaborated on when a new transport system is to be introduced. This counts for the strategical planning level, where long time investment and often CAPEX intensive costs are included, down to an executional level where the ICT systems and sensors are used for real time operation decisions.

The 4 Cs described have been used, and it has been pointed to the importance for each of them, that also have been pointed out when working with the use case:

From the **competence** work following elements was addressed:

a. To understand the different stakeholders knowledge, capabilities and competence
b. To stimulate for common training
c. To integrate technology such that the decisions are based on same platform/data source
d. To understand and estimate risk when the operational control is somewhere else than physical operation
e. To plan for barriers that prevents an unwanted event to happen
f. To define the fall-back states where both operators, providers and infrastructure owners are aware of the minimum risk condition that can be launched in case of an unwanted event

The **commitment** work studied have following possible take aways:

a. To ensure that the autonomous technology can work together with humans, to identify safe areas technological operation areas that avoids conflicts (i.e. operation of a autonomous truck in a terminal)
b. To understand the technological capabilities and barriers
c. To understand how to operate together with the technology when it is managed by another stakeholder
d. To understand the hand-over process between ROC and technology

e. To understand the different planning levels (strategic to executional) and how to build commitment as early as possible, where a holistic view is achieved
f. To understand that change of plans is more critical when automated technology is part of the operation

From the **collaboration** work following elements was addressed:

a. It is important to create teams for collaboration and cocreation between stakeholders that are involved in a transport system.
b. Collaboration is to find new solutions, new ways of working, and an instrument to be used when conflicts occur.
c. Collaboration is to understand each other's plans, and to inform if something deviates from plan

Continuous learning had following items to address:

a. It is important to understand the technology and to learn its capabilities, limitations and way or working
b. It is important to have a close collaboration between all stakeholders involved, the whole transport system should be understood
c. It is important to create tutorials and to have table-top exercises between the stakeholders such that possible events can be trained for and alternative B can be executed easily
d. It is important to understand the possible events that can occur, the threats and how to build barriers

5 Stakeholder recommendations

The following section present recommendations from the user groups in case A, but can also be addressed to the other use cases in AEGIS; ports and terminals, service operator, technology provider, and research and academia. This represents the partners within the use case A. The recommendations were given after several iterations, based on their own views, interviews, and from workshops with colleagues. The sub chapters present the main categories mentioned within each stakeholder category.

5.1 Recommendations from shipping operators/providers

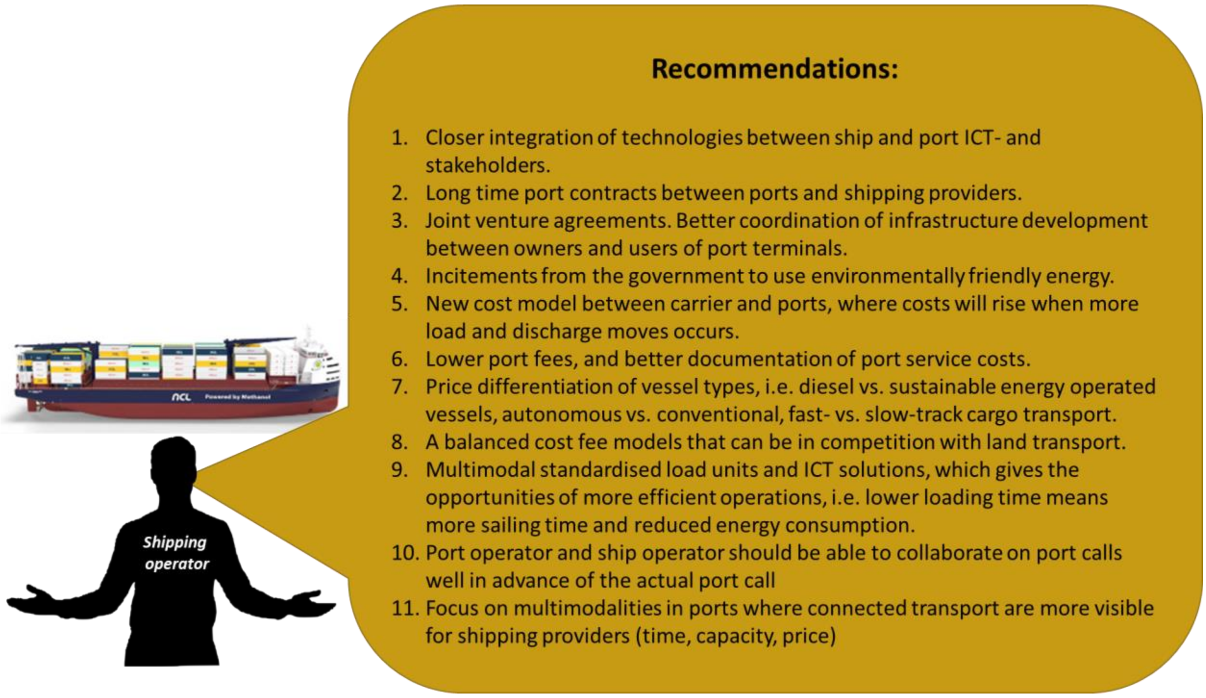

Figure 5: Recommendations from a shipping operators point of view

Figure 5 summarises some of the recommendations coming from the Shipping operator's point of view. One major issue listed by the shipping companies was that the port costs constitute a large portion of the total cost of the operations. Regards to the CAPEX costs it is said that the collaboration between the terminal/ports and the shipping operators can be improved and will be important when investing in new technologies and equipment that has a high investment cost. The investments in vessels and vessel technology should be coordinated with the port infrastructure investments. Shipping operators and shipping providers should have more knowledge on future energy support and availability at the different ports, following their transport chain, to be able to make long term sustainable business decisions. Currently the risk is that the different ports are going in different directions regarding energy provision, it is from a shipping company difficult to decide what types of energy and technology to be selected when they are not aligned with the ports. Shipping providers would appreciate a closer dialogue with providers of autonomous technology/equipment previous to investment in new equipment, vessels and technology. Following phrase was mentioned during one workshop:

> "*There are so many different ICT alternatives out there, which very often are proprietary, and it therefore makes it hard for us to decide the best alternative for the future. We would like*

independent assistance with knowledge on upcoming automation technology to ensure we select the best technology",

The technology on a vessel must work together with the port technology, which is often challenging. A recommendation from a shipping operator's point of view is that the ports and terminals should have a joint venture company, where technology and operations are part of the agreements between them. It was also said that maritime transport should be compensated with the same governmental funding as for other transport modes, such that the different modes are competing on the same premisses. Sustainability should of course be appreciated. The different AEGIS KPIs could be used to validate the governmental funding instruments, to makes it easier for the government to compare equally between the transport modes and give support or provide incitements thereafter (see previous chapter).

A maritime service provider would also like to see better incitements for use of environmentally friendly energy. Currently there are limited "*wins*" for changing fuel types to more sustainable one. Environmentally friendly energy has both a high CAPEX and OPEX cost compared to conventional energy. One possible recommendation is to reward environmental sailings with lower port fees.

The shipping operators also pointed to the opportunity to reduce costs following the AEGIS transport system approach, the deployment of a mother vessels sailing the open seas, while "*daughter vessels*" are feeding the connection hubs with cargo. This means that *daughter* vessels can operate in areas with a small cargo volume, while the *mother* vessels that have a much higher CAPEX cost can be loaded faster and possible have a higher utilisation degree than today since cargo is centralised in a connection or transshipment terminal. The *daughter* will likely have lower operational costs and fees than a *mother*. It was also mentioned in the workshop that a *daughter* vessel has better capacities and flexibility to meet land-based requirements, for example schedules aligned with a land-based transport service system. A mother vessel must follow planned schedules in a higher degree since it has many cargo customers and considerations to follow.

Regarding ICT solutions, standardisation of messages and interfaces is important for flexible systems. Today the systems in use are seldom integrated with other transport modes, such as with rail and truck ICT systems, which might be the next transport mode for the containers. One thought is to strengthen the focus on multimodal transport, where also the ICT systems are more integrated. Better integration could stimulate for *just-in-time* (JIT) arrival instead of a fixed schedule. One example relevant for several ports is that cargo from a vessel is to be transhipped to a train, which means that the vessel's JIT arrival should be aligned with the train's port departure schedule.

Collaboration between the owners, operators, traffic management and those requiring transport is important for success and to build a functional infrastructure. This means collaboration at the different planning levels, from strategic to executional. Strategic planning is very often CAPEX intensive, while executional is more related to use of real-time information for operational purposes. Shipping operators wishes to take part in decisions where port infrastructure investments are decided, to be in a better position to tailor their vessels to serve the port infrastructure, that are related to the operational planning level. This can lead to a more efficient transport, which further can lead to a shorter vessel service stay time in port, and thereby gives more time available for sailing to the next port. More time for sailing gives a better opportunity for a slower speed sailing, leading to less energy consumption. Another issue mentioned was to look for different sailing configurations as example fast- versus slow-track sailing. The different configurations can be priced differently, slow-track is cheaper than fast-track since it require less energy. Storage in terminals should also be included in cargo handling time. It is also important that the terminals should have the containers sorted as close as possible to the vessels loading zones, that allows for more efficiency in terminal operations.

5.2 Recommendations from ports and terminals

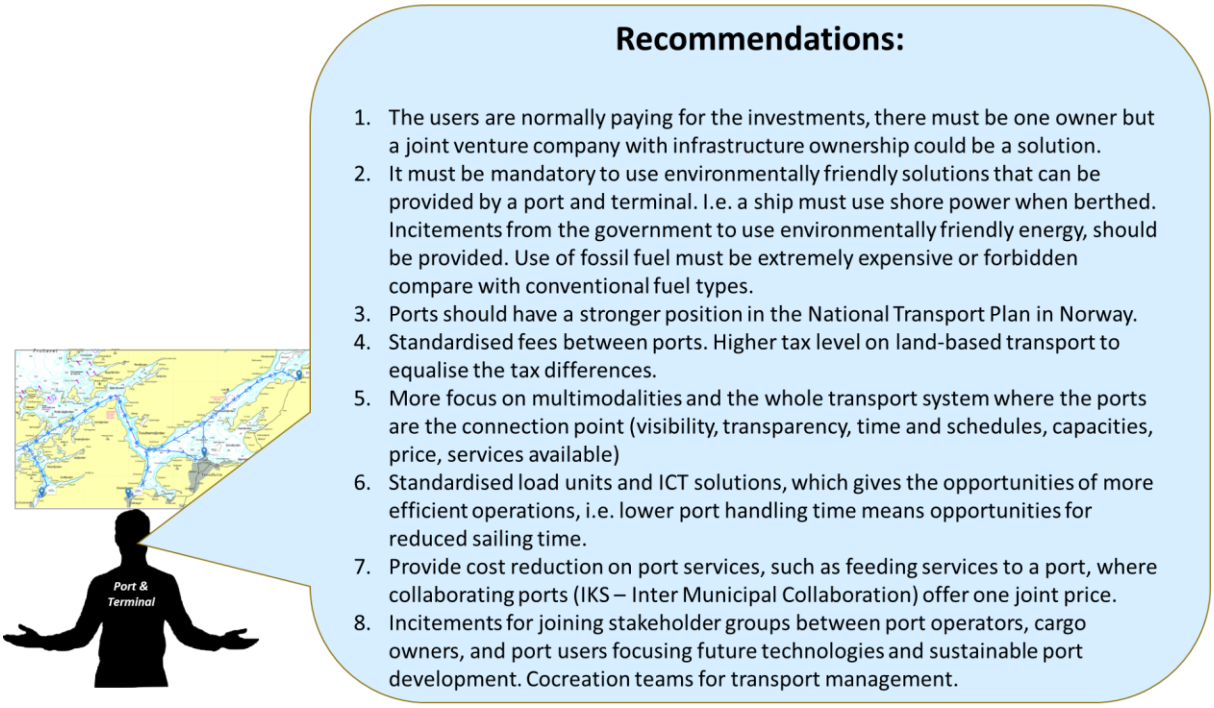

Figure 6: Port and Terminals point of view

Figure 6 points to some findings addressed by the ports and terminals. As for the previous group, a shared investment approach between owners and users of a ports regards investment in equipment and port infrastructure was mentioned as an interesting thought, that also could lead to a lower total investment cost for the ports and terminals. This could be organised as a joint venture company. In this case it is important to have a clear agreement between the stakeholders, with one owner and agreed pricing of services. Long term contracts will give room for predictability and makes it easier to invest in new equipment or technology, for example investing in new cranes or loading equipment. Feeder loop services is also an example of a possible joint service in a limited geographical area. Another possible arena for collaboration is regards sustainable technology and provision of energy in a port or terminal. A port cannot invest in expensive technologies or factories producing new energy without being sure that there are end users. But the danger of joint companies will be that the collaboration result in a monopoly situation, that makes it harder for new customers to start using the ports and facilities.

To give best possible services to the users and community at a port, modern technology and sustainable energy must be offered. The existing fees are used for port management, cargo handling, security purposes and it facilitates further development of the port. If port fees charges to maritime users is too high, this will lead to higher expenses on maritime services. From a national perspective, the ports suffer for lack of public incitements for maritime transport, that could be a mechanism to reduce the port fees for maritime users. The land-based infrastructure is normally paid by governmental funding programs, the maritime sector is more self-served. The role of a port and a terminal is always to offer best services to their users. To change transport corridors from land to sea, to a more sustainable transport corridor, it is important to offer compatible prices with land transport. The end users of the transport are normally selecting the corridor that has lowest price, and best service.

Port fees must be reduced, that is a common statement within the maritime industry, was mentioned in one of the workshops. One reason is the unbalanced competition between the transport modes, another is to allow for more sustainable waterborne transport. But it is also important to understand what you are paying for with the fees. To ensure recommendations are economically viable for all parties involved, it is crucial to target operational improvements that increase throughput in the supply chain. By enhancing operational efficiency, the market can experience cost reductions that can be passed on to clients. In this case shipping companies. Additionally, providing incentives for cost reductions at ports can enable them to lower prices for their clients, fostering a more competitive and cost-effective environment. Environmentally friendly solutions should become a higher focus in pricing of port fees.

During the discussion between the user groups, it was mentioned that from a shipping operators' point of view it was difficult to understand the port fees and the pricing, it should have been more transparent. Often the prices are different from port-to-port. One possible recommendation that was discussed was to stimulate for a more standardised port costs regime between the ports, where the fees are well explained to the users. As long as one port gives better service than another, this can defend a higher price. Another discussion considered whether other transport modes should pay a higher price for terminal use than currently, for example a truck driving into a terminal could be charged when passing the gate-in.

One other important remark for a sustainable port was the way of pricing fossil fuel in comparison to sustainable energy. If fossil fuel is cheaper to use, and there are no other incitements that premise sustainability it will be a challenge to change the use to sustainable energy.

5.3 Recommendations from ICT providers

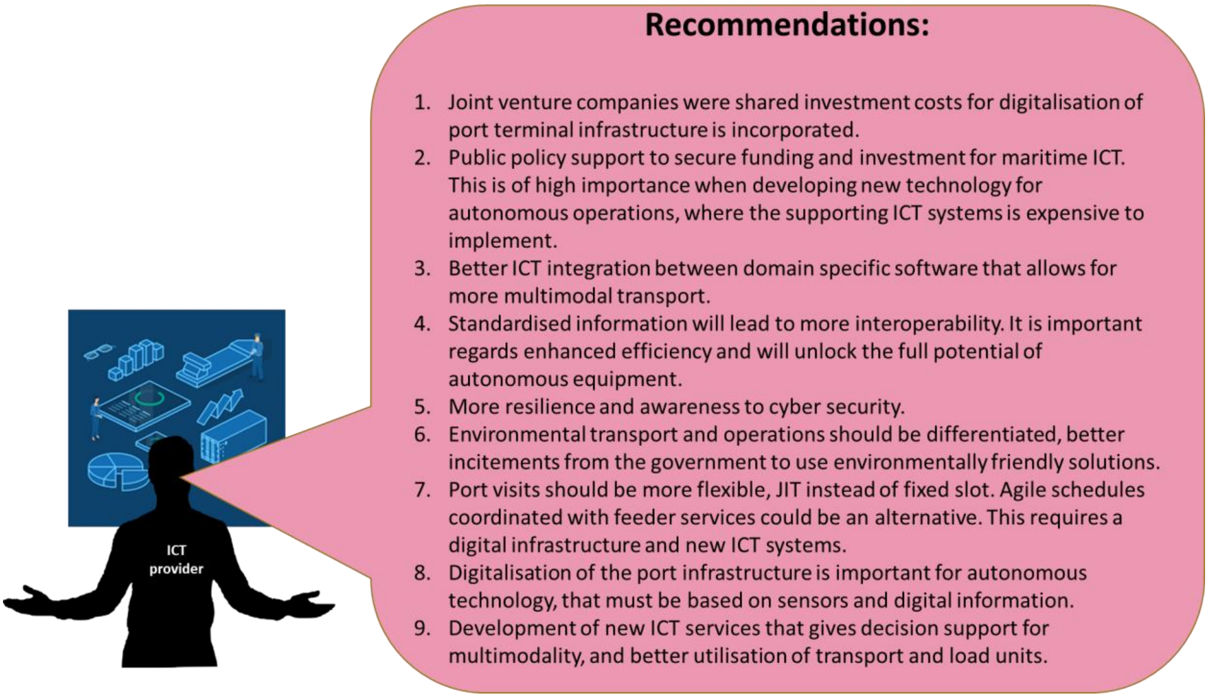

Figure 7: ICT Provider's point of view

From the discussion with the ICT providers, Figure 6 summarises the points that was addressed. The ICT Providers have pointed to shared investment in infrastructure as beneficial to stimulate for more collaboration, including multimodal collaboration, which also have been mentioned by the other stakeholders. The investment (CAPEX) cost is high when developing new software and solutions, which must be covered by new sale and support from an ICT provider. Long term contracts are an incitement for providing better ICT support, since the engineering, training, support, and operation of the ICT system is costly.

Public policy support is necessary to secure funding and investment in autonomous equipment and supporting ICT systems infrastructure in ports, particularly during the critical "*valley of death*" phase of TRL 6 and 7. This support enables the advancement and deployment of transformative autonomous technologies in ports, driving innovation and economic growth. Market incentives and public-private partnerships to support investments is needed to reach TRL 8 and 9. New technology often has a higher cost in the pilotage stage where the technology will be validated. When the technology is ready for commercial sale and the mass market, the market drivers and customer's payment will be the main funding mechanism. Still, it is important to understand the technological operation domain, not only purely focused on the technology individually but also how it should work together with other technologies. For instance, introduction of autonomous technology very often requires electricity and battery capacities, i.e. an autonomous reach stacker, the introduction needs to be seen in connection with the terminals power stations and power supply. Governmental support enables the advancement and deployment of transformative autonomous technologies in ports, driving innovation and economic growth.

In Norway, ports are only briefly included in the National Transport Plan (NTP), which is a governmental strategy plan for investments in transport infrastructure. The maritime transport is in general weakly addressed, as it is mostly focused on land-based infrastructure. One recommendation is to have a stronger focus on the whole transport chain, not only one transport mode. A closer integration with land-based transport will sometimes allow for flexible arrival time and adaptive operation through JIT port calls, it would enable slow steaming and reduced energy consumption and cost.

ICT and digitalisation of the transport system is one of the main enablers for success. A better integration also means a higher chance for slow steaming and increased transport efficiency. To accelerate the adoption of standards in the port and shipping ICT industry, consolidation of European standards, as well as global standards, is essential. Public incentives can drive industry-led capital investments, promoting the development and implementation of standardized solutions. These investments can support the integration and interoperability of ICT systems within ports and shipping, leading to enhanced efficiency, collaboration, and overall performance in the industry.

Regarding the transport logistic chains, it is often seeing an unbalance, a high utilisation degree one way and a much lower in the other direction. A balance between containers and cargo is not always possible, but more transparency will make it easier, where technology plays and important role. This requires possibilities of exchanging data between the ICT systems that could lead to a more efficient transport. The establishment of ICT system standards for information interchange between autonomous equipment such as reach stackers and cranes, and terminal operating systems is crucial for seamless real-time data exchange. These standards ensure compatibility, interoperability, and efficient communication, enabling autonomous equipment to integrate seamlessly with terminal operations. By implementing standardized information interchange protocols, ports can optimize their operations, enhance efficiency, and unlock the full potential of autonomous equipment in the maritime industry.

Another important remark from the ICT providers is that general digitalization of customs clearance procedures would significantly reduce terminal storage time. By adopting digital systems for customs processes, such as electronic documentation and automated data exchange, the efficiency and speed of clearance procedures can be greatly enhanced. This streamlined approach minimizes delays, improves cargo flow, and ultimately reduces the amount of time goods spend in terminal storage, leading to increased operational efficiency and cost savings. Introduction of a single window for maritime purpose, is highly recommended (it exists today but a new version is under development).

ICT system support for JiT port calls involve precise scheduling of vessel arrivals to match cargo availability and port operations. This approach minimizes idle time and waiting periods for ships, optimizing the use of port infrastructure, and reduces congestion. It enhances the efficiency of port operations, leading to faster cargo handling, reduced port turnaround times, and improved overall supply chain performance. The target for a sailing time indicator is not always reduced time, but rather facilitate for a flexible arrival time that is aligned with next transport out of a terminal. ICT system support for JiT port calls and efficient ship to shore communication potentially enables slow steaming. Slow steaming involves reducing vessel speeds, which significantly reduces fuel consumption and greenhouse gas emissions. By operating at lower speeds, ships can achieve better fuel efficiency and contribute to mitigating the environmental impact of maritime transportation.

Shore power plays a crucial role in reduction of emissions of CO_2, NO_x, and SO_x in ports. By providing a clean and alternative power source to ships at berth, land power eliminates the need for vessels to run their auxiliary engines, leading to a substantial reduction in greenhouse gas emissions and air pollutants, promoting a greener and healthier port environment.

Digitalisation of the port infrastructure, make the load units possible to trace, and to allow for autonomous operations will be important. Standardisation is mentioned as an important issue, but ICT systems also provide crucial support for yard optimization in import and export flows. By leveraging advanced technologies, such as real-time data integration and analytics, these systems enable efficient management of yard operations and reduces number of container moves. They facilitate streamlined processes for import flows, from discharge to gate out, and for export flows, from gate in to load, ensuring optimal utilization of yard space, minimizing dwell times, and enhancing overall operational efficiency. ICT systems provide valuable support in reducing haulier turnaround time through interfaces that offer pre-advice capability and container status updates. These systems enable efficient coordination between hauliers and terminals, allowing for streamlined operations and improved communication, ultimately resulting in faster and more effective haulier turnaround times. Higher cargo throughput would enable reducing terminal area per cargo unit, that will be another benefit.

5.4 Recommendations from research and development

The reader is recommended to look into the AEGIS deliverable D2.6 Roadmap for automated waterborne transport [14] for further details on R&D recommendations and challenges.

6 Conclusions and recommendations

This report has identified several important recommendations for an automated short-sea waterborne transport system, and especially those relevant for the proposed transport system in use case A.

The work behind this report started with a review of findings from the other work packages, and then a review of the results from previous work within this work package. Further, interviews and workshops have been conducted to point to recommendations from different perspectives. The main conclusions follow below, where they have been spread on different overall topics.

Mother vessel
The current transport system described in use case A is only operated by NCL mother vessels. NCL has ordered two new 1300 TEU vessels based on the AEGS concept, to be launched in 2024. The vessels will be using green methanol, which will be a new step towards sustainable shipping. Still, the CAPEX costs related to newbuilds are high, which in turn will require more cargo to be transported compared to today. Some observations regarding mother vessel: - In some areas and ports, such as in Trondheimsfjorden the cargo volume is too low to favour the mother vessel operating directly. A transhipment hub with a high throughput of containers will make the mother vessel more efficient, saving time related to longer sailings to ports with very limited cargo volumes. - The sailing time from Hitra to Skogn, and the other ports located in Trondheimsfjorden is too high and will disfavour a weekly roundtrip for a mother vessel to Rotterdam. - The smaller ports' quays are too small to serve bigger vessels like the mother vessels. - Onboard automated and efficient loading and discharging equipment is required. - Provision of new energy such as green methanol should be offered by ports along the coast line of Norway.
R1: Consolidation and more cargo for a mother vessel should be focused. The different cargo owners should work together to optimise maritime transport corridors, and green transport should have lower taxes than conventional.

Daughter vessel solution
The combination of mother and daughter vessels operating in case A is non-existing today. However, NCL has announced that they will order daughter vessels, following the AEGIS concept. The recommended daughter vessel capacity in AEGIS is 100 TEUs and the vessel feeds the transhipment hubs where the mother vessel can pick-up and transport the cargo to Rotterdam. Some observations regarding the daughter vessel: - In some areas and ports, such as in Trondheimsfjorden the cargo volume is too low to favour the mother vessel operating directly, hence a daughter vessel can be applied to feed the cargo to the transhipment hub at Hitra Kysthavn.

- The outcomes of economic studies in the project show that certain mother and daughter vessel constellations can compete with truck transport in the Trondheimsfjorden region, especially if external costs are internalised.
- Smaller terminals in the Trondheimsfjorden region have limited cargo handling equipment available, which implies either use of geared daughters or investments at the terminals.
- A daughter vessel can sail slower than a mother vessel, and thus reduce energy consumption.
- The daughter vessels can feed to/from these hubs and enable smaller ports and terminals to increase their waterborne cargo volumes. The daughter vessels will provide a service which is currently not available because it is too costly and time consuming to visit these terminals with the mother vessels. A mother vessel should ideally visit several such transhipment hubs along the coastline and reduce the number of port calls compared to today's way of business.

R2: Smaller geared daughter vessels are more cost efficient, consumes less energy, and are more flexible in terms of time and outreach compared with a mother vessel. It is therefore recommended to investigate transhipment hubs in different regions in Norway and Europe.

Terminal and port solutions

NCL serves many ports and terminals along the west-coast of Norway and in Rotterdam, where they frequently visit 5-7 terminals before sailing back to Norway. Along the west-coast of Norway they visit up to 10 ports before returning to Rotterdam. The ports are operating differently, where some have invested in new technology while others are more conservative. In Rotterdam the shipping companies are not allowed to use their own vessel cranes, while the picture is opposite in Norway where the vessel cranes are used. Port and terminal handling costs are high, and more transparency on cost details is expected by the shipping companies. It is also somewhat unclear what the future alternative fuel will be. The infrastructure in Norway, the power grid, has a low capacity which is a challenge when introducing electricity in the transport sector.

Some observations regarding the terminal and port solutions:

- It is important to also invest in standard and widely used ICT systems, to ease the digital connectivity that will be required by automation. As part of this there should be a particular focus on cyber security issues.
- It is not a clear understanding on market uptakes of different alternative fuels, and which will be the market winners (examples are batteries, hydrogen, methanol, ammonia, bio, MDO, etc).
- Port fees should also be charged to road transport users, not only to maritime users.
- There will be specific needs related to transhipment terminals to enable mother and daughter vessels constellations. These terminals will be central hubs and must be highly automated and digital to enable the business case.
- To enable the modal shift and a sustainable maritime alternative such as the AEGIS mother and daughter constellation, the ports and terminal will have to invest in automation, new ICT systems and general terminal equipment. These investments are too high to bear by the ports themselves, the number of users is low compared to the large intercontinental ports.

R3: Ports and terminals are key parts in a vital maritime infrastructure. Still, the maritime infrastructure gets no or very limited funding from the National Transport Plan in Norway, at least when comparing with infrastructure investments for road and rail. Hence, it is recommended to include more maritime infrastructure investments support in for example the National Transport Plan for the Norwegian case.

Regulatory bottlenecks

There are two main categories of regulatory hindrances that may be found in the deployment of the proposed new transport system for AEGIS use case A: those associated with the vessel design itself and its ability to navigate along the Norwegian coast, and those associated with the access of the vessels to areas of transhipment at sea and to the port terminals involved in use case A. Another one could be to allow remote terminal operations, for example that an autonomous crane can be remotely monitored and controlled from a site located away from the terminal. This requires also that the terminal ICT systems should be open for remote operation.

Some observations regarding regulatory bottlenecks:

- The regulations must change to realise unmanned vessels.
- It must be investigated how to The ISPS regulations must allow for automated transport.
- Use of a daughter and mother vessels for cargo transport in/out of Norway, related to customs clearance of cargo at transhipment hubs.

R4: The regulatorily stakeholders must collaborate more closely with the industry to foresee the possibilities and hindrances when introducing autonomy. This counts for an early-as-possible approach to make dialog with the providers and users of technology.

The transport system

The current transport system described in use case A are only operated with a mother vessel, the future AEGIS transport system is based on both mother and daughter vessels working together. One major challenge today is to balance the transport, to have enough cargo in both directions. In the use case A studies, it has been investigated whether fish transport, which is a significant export commodity from Norway, could be shifted to maritime from road-based transport. There have been several attempts to offer maritime services, but only a few have succeeded so far. The NCL transport is more balanced with different types of cargos, which makes it more robust. NCL is not serving the smaller ports in the Trondheim region, they have Orkanger as their hub. Hitra Kysthavn is about to be developed, to become a regional transhipment port. Hitra can also be used as a transhipment hub between transport from north of Norway, to the continent. But the growth also requires new customers, and new operators to sail out of Hitra.

To succeed it will be important to not only focus on the vessels, but also the terminals. Future system will be more sustainable, multimodal and digitalised, which means ICT collaboration is one important driver for the future. The studies and calculations have showed that it is possible to move cargo to waterborne and a more sustainable transport, but it has also pointed to the need for collaboration between modes, companies and technologies.

Some observations:

- The CAPEX and OPEX costs for a mother vessel favours the introduction of a smaller and cheaper daughter vessel for serving a transhipment port. - In some areas and ports, such as in the inner Trondheimsfjorden, the cargo volume is too low to favour the mother vessel operating directly. - The sailing time from Hitra to Skogn, and the surrounding ports in the fjord is too high and will disfavour a weekly roundtrip for a mother vessel out of Rotterdam. - The maritime fees are too high, which disfavours maritime transport compared to road. - There is a high willingness in the cargo transport sector to become more sustainable. - Sustainable energy needs infrastructure or areas at a terminal. - It is important that technologies can work together, digitalisation is important for autonomy. - Standardisation of load equipment, procedures, messages, and operational practices are important.
R4: Maritime transport should have new governmental incitements to become more attractive compared to road-based transport. The Norwegian government should stimulate for more maritime transport, as a sustainable alternative to other transport modes. AEGIS recommends a similar arrangement as for the introduction of electric cars in Norway, regarding implementation of autonomous and green transport solutions.

7 References

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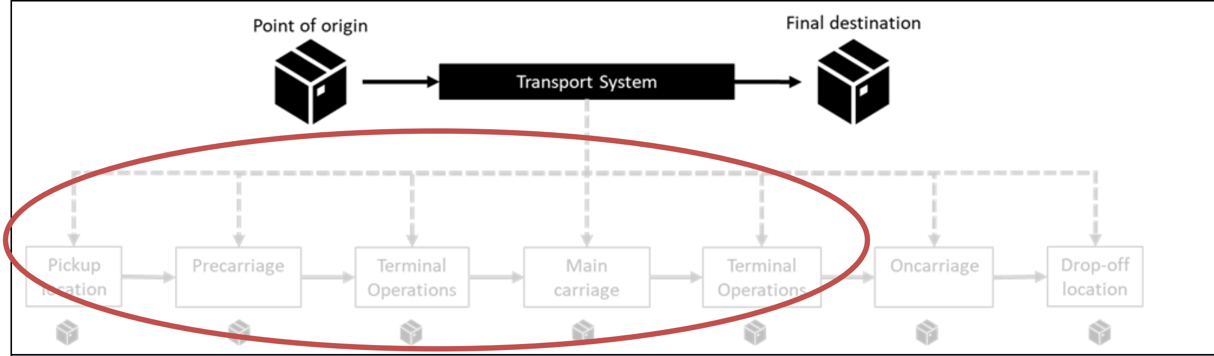
Annex A. Bottlenecks identified in D8.3

A.1 Possible bottlenecks in the transport system

This chapter describes bottlenecks in a typical transport chain involving pickup location, transport from factory to terminal, terminal operation, and main carriage that it many cases will be the longest distance, and further the transport to the end customer or the drop-off location. The background and description below are with background from previous studies, it is also written with input from the use case A studies in AEGIS.

A.1.1 The transport system



Background – The Use Case A Transport System

The transport system described in the figure above is the Use Case A transport scenario Norway – Rotterdam. The transport of goods out of the Trøndelag county in Norway is firstly done by using a daughter vessel solution as a pre-carriage alternative, to bring cargo from the local ports close to the factories in the fjord to the transit terminals Orkanger and Hitra. In AEGIS this is planned to be an autonomous vessel, but this is currently a non-existing solution. The terminal operations are either in Orkanger or in Hitra, where the differences are that Orkanger is an old existing port with established infrastructure while Hitra is under development and can be designed more or less from scratch. The AEGIS case will be to identify possibilities of using autonomous technology in both ports. The transport from Norway to Rotterdam will be done with a mother vessel solution. In our case this will be a vessel operated by NCL. NCL have ordered two new mother vessels based on the AEGIS mother LoLo-designs, that will be operating on green methanol and start sailing in 2024. In Use Case A, the focus has been on the transport in Norway, transit in Norway with destination Rotterdam. Transport out of Rotterdam has not been prioritised.

Use Case A, D8.3, background documents are:

1. D8.1 Cargo volume analysis
2. D8.2 Transport system specification
3. D2.5 Resilience in automated transport systems
4. D5.1 System design specification
5. D5.2 Communication system catalogue

Bottlenecks, independent of transport means

1. Many transport providers involved can lead to a higher cost and longer lead times.
2. Difficult to digitalise the whole transport chain due to complexity.
3. Unclear regulations, difficult for multimodality.

4. Different tax regime for the different transport means types (i.e., maritime transport providers are often paying the terminal taxes, land-based transport is seldom taxed). Expenses and benefits are not balanced between stakeholders. 5. Deviations or disruption of services is harder to handle in an intermodal chain compared to a single transport. 6. Lack of standardized interfaces between systems. Lack of technological interaction possibilities. 7. No agreed standard for secure and trusted data transfer. It will be a higher security risk (cyber) if a high number of ICT systems are involved compared with a low number. 8. Compliance Flow (e.g., Digitalization of Customs Interaction). 9. Trust between parties. Many stakeholders involved is a challenge. 10. Traffic jams along the supply chain could result in transport deviations. 11. Transport of dangerous goods is differently regulated in the different sectors/transport means. 12. Reloading and transhipment of cargo generates a higher possibility for damages and deviations.
Bottlenecks regards maritime services
1. It is said to be much harder to book transport of cargo in an intermodal chain, involving maritime transport, compared to a single transport provided by truck. 2. Today the transport taxes/fees of using terminal services are much higher for maritime users than land based. 3. Difficult to understand the time requirements in the maritime transport chain, as well as the consequences of delays. The transport time from pick-up to drop-off is in many cases longer since the transport requires a modal shift before bringing the cargo to end destination. 4. It is often too much administrative documentation needed when entering terminals/transport hubs. 5. Because of transhipment and terminal activities, the speed of transport makes a maritime service slower compared to only road transport. 6. Maritime services require a skilled crew for cargo handling (qualification and manning, crane manning, loading process). 7. Governmental investment in maritime infrastructure is low prioritised compared with road infrastructure, it is also unfair taxes between road and sea. 8. It is harder to plan for resilience since the cargo volume is higher than for road transport. 9. Terminal activities, transhipment and reloading is expensive. 10. ISPS and regulations at sea makes it more difficult to operate than for land-based services. 11. Balance between in and outbound logistic (volume) must be more balanced compared to road transport. 12. The CAPEX costs are higher on maritime transport than land transport. 13. Pressure on infrastructure is higher since maritime transport needs more space (higher cargo volume) 14. Maritime services are less flexible than land-based services. There are more dependencies in the transport chain.

15. Maritime services have its strength when transporting a high cargo volume over longer distances, compare with truck that is more tailored for a low volume.

Bottlenecks regards introduction of autonomy

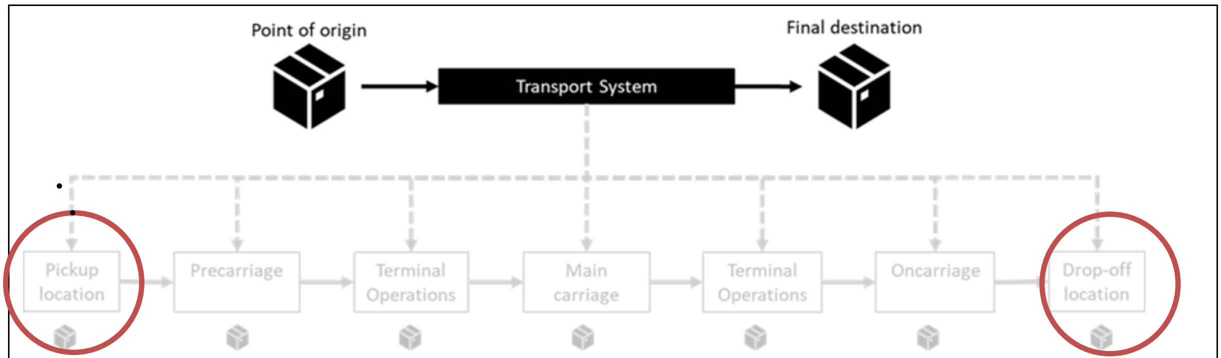
1. To operate autonomous solutions the infrastructure requires a high digitalisation level.
2. Autonomous technology is immature.
3. Operations crossing national borders might require different regulations to be followed.
4. The loading process and required time for cargo handling is not known. In an introduction period manually cargo handling/operations might be more efficient than autonomous cargo handling.
5. Unforeseen events where autonomous technology is involved might be harder to combat than human operated technology.
6. Lack of safety zones and digital infrastructure for autonomous technology, for example crane operation, vessel operation, berthing and mooring operations.
7. Lack of available autonomous technology spare parts for maintenance purposes.
8. Operation of autonomous technology from a ROC (Remote Operation Centre) requires good knowledge of the technology, as well as of the infrastructure the technology should operate in.
9. Investment cost of autonomous technology requires investment in infrastructure.
10. Unclear business models for autonomous operations/technology.
11. Too complicated technology than needs expertise, which is often not physically located close to the operation sites.
12. Collaboration and competition with conventional solutions is unclear.
13. Flexibility of autonomy might be lower compared to human operated technology.
14. The capacity and regulations for autonomous operation might be lower than for manual ones.

Bottlenecks regards terminals and ports

1. Standardization of yard/port technology across terminals are different.
2. There are different procedures and requirements to be followed depending on terminal/port.
3. The different terminals have different standards and rules regards possibilities of integrating with third parts service providers and ICT systems.
4. Most terminals and ports have limited terminal space for cargo storage and operations.
5. Autonomous solutions require safety zones, that often conflicts with conventional operations.
6. Gate capacity is low, traffic jams in terminal areas is a main problem for efficient operations.
7. Financial and organizational regulations of ports are different. Often collaboration with the terminal users is lacking.
8. Expensive infrastructure and port equipment makes it hard to compete with land-based transport.
9. Smaller ports have a low cargo volume, but need an expensive infrastructure to be able to serve autonomous operations/technology.

10. Immature infrastructure in port.
11. Lack of standards (information, equipment, technology, load units).
12. Noise in loading operations makes it difficult to operate 24/7.
13. Many movements on containers in a terminal makes it less efficient, more expensive, and will generate a higher footprint.
14. ISPS and security zones will restrict cargo handling.
15. Lack of resources in terminal (humans, technology, equipment, load units) delays operations.
16. Hard to offer services to all types of vessels and technology, this also out of a CAPEX perspective.
17. Old infrastructure and resources make it hard to optimise, the terminal is not tailored to meet new technology and requirements.
18. Utilisation degree on equipment and resources is too low and generate a high cost on one operation.

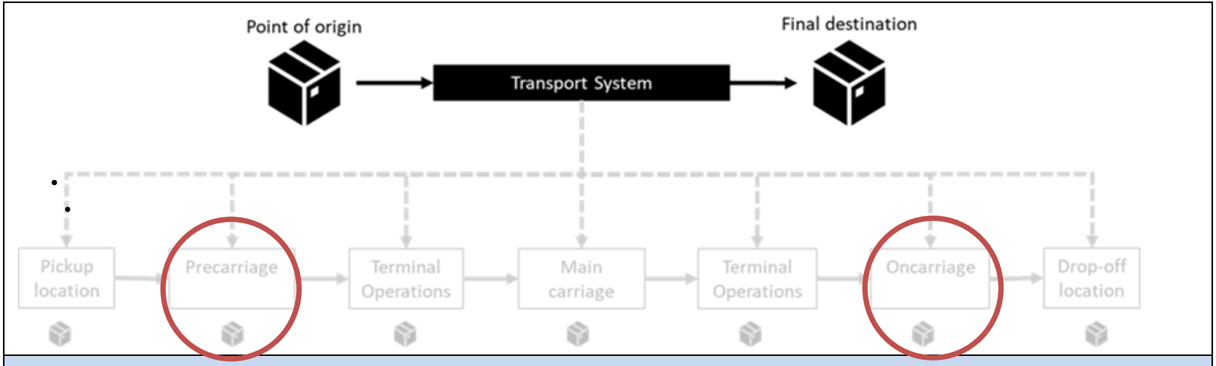
A.1.2 Pickup and drop-off location



Background – Use Case A – Pickup and Drop-off location
Pickup and drop-off locations is often unknown or are changed rapidly from transport to transport. In a fixed point, for example pickup location at a factory, this can be more regulated, and it will be possible to invest in technology (equipment, ICT, resources) such that the operations can go faster, cheaper and be more reliable. In Use Case A the *D8.1 cargo analysis* report has been used to understand some potential transports out of the Trondheimsfjorden region. The salmon transport from a factory at Frøya (an island outside Hitra) has been studied, along with the transport of silica and micro silica from Orkanger. Further the report looked into some general cargo for export out of the region. The study was limited to focus on the transport that have the potential to be carried by a maritime service, where both a daughter and a mother alternative has been elaborated.
Bottlenecks regards maritime services
1. There are no existing precarriage maritime solutions in Trondheimsfjorden. 2. Cranes and loading equipment at the pickup and drop-off locations is not existing, requires new investments. 3. There are many different load unit standards.

4. There are limited possibilities to utilise containers. 5. The infrastructure investments (CAPEX) are significant. 6. Maritime solutions are a better solution when a high number of containers or volume are to be transported as an opposite to one container. 7. Utilisation of a vessel on the return voyage is vital. 8. Transport of empty containers to the production/pick-up location must be done when requested. The period from ordering of a load unit to expected use is short. 9. The opening hours at a pick-up or drop-off location are restricted.
Bottlenecks regards truck services
1. A common problem is knowledge and language problems (international trucking companies) when communicating with land-based service providers. 2. The regulations for Norwegian infrastructure/roads are unclear. For instance, icy water from fish transport is leaked from the truck wagons with fish, resulting in slippery roads, especially in the winter period. 3. Trucks generate road congestion. 4. Trucks generate a higher risk to citizens (accidents, heavy traffic, not familiar drivers on winter roads). 5. Paper and clearance document can be a challenge. 6. Norwegian winter roads are challenging.
Bottlenecks regards autonomous technology
1. Needs new investment in autonomous technology at pick-up and drop-off locations. 2. Unclear procedures and operational management of technology between producer/pick-up/drop-off location. 3. The regulations are some unclear. 4. The investment needs in autonomous technology are high. 5. The knowledge in operating autonomous technology is low. 6. ISPS-zones, clearance paper and administration. 7. Deviation management can be a challenge. 8. There are no allocated safe autonomous areas. 9. The interaction between autonomous technology and a ROC is unclear.

A.1.3 Precarriage and oncarriage



Background – Use Case A – Precarriage and Oncarriage

In Use Case A the focus has been on the pre-carriage service where the daughter vessel is the alternative, operating in the Trondheimsfjorden. The daughter vessel is not in operation today, still it can become a future service to be offered in the region.

Bottlenecks regards maritime services

1. The infrastructure is not ready for an autonomous daughter vessel.
2. The daughter vessel is not in place, but has been draft designed in the AEGIS WP4.
3. The loading and unloading equipment in the smaller pick-up ports is not in place. One alternative studied is to bring the reach stackers on board the daughter vessel and bring it to the remote terminals.
4. The autonomous vessels are planned to have battery as energy source. Some of the terminals must offer the possibility for charging.
5. The loading of cargo from terminal to vessel might be difficult.
6. The ROC to operate remote terminals and daughter is not existing.
7. The solutions will require local service personnel in case of emergencies or damages.
8. The weather can be a challenge regarding a daughter vessel operation, which means disruption in cargo service.

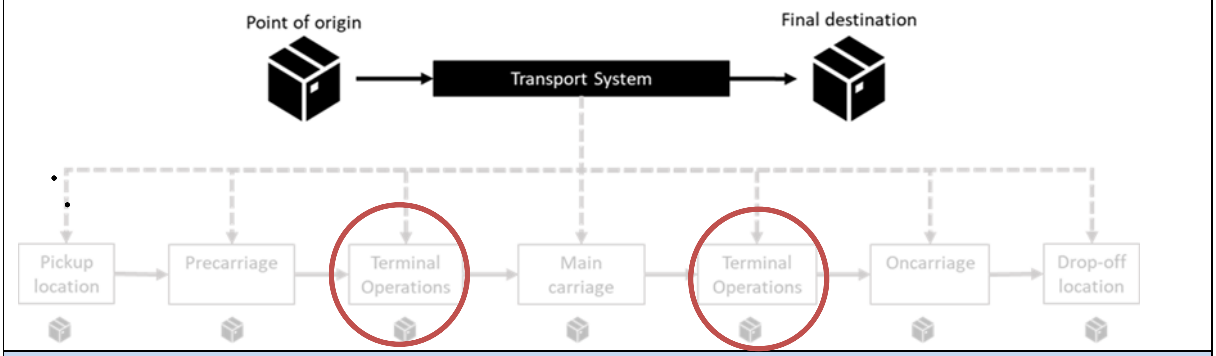
Bottlenecks regards truck services

1. Autonomous land-based operations require regulations and permissions to operate, that are non-existing.
2. Knowledge and language problems when visiting terminals (international trucking companies).
3. Unclear regulations for Norwegian infrastructure/roads.
4. Paper and clearance document.
5. Norwegian winter roads are challenging for truck services.
6. Autonomous truck services are immature.

Bottlenecks regards autonomous technology

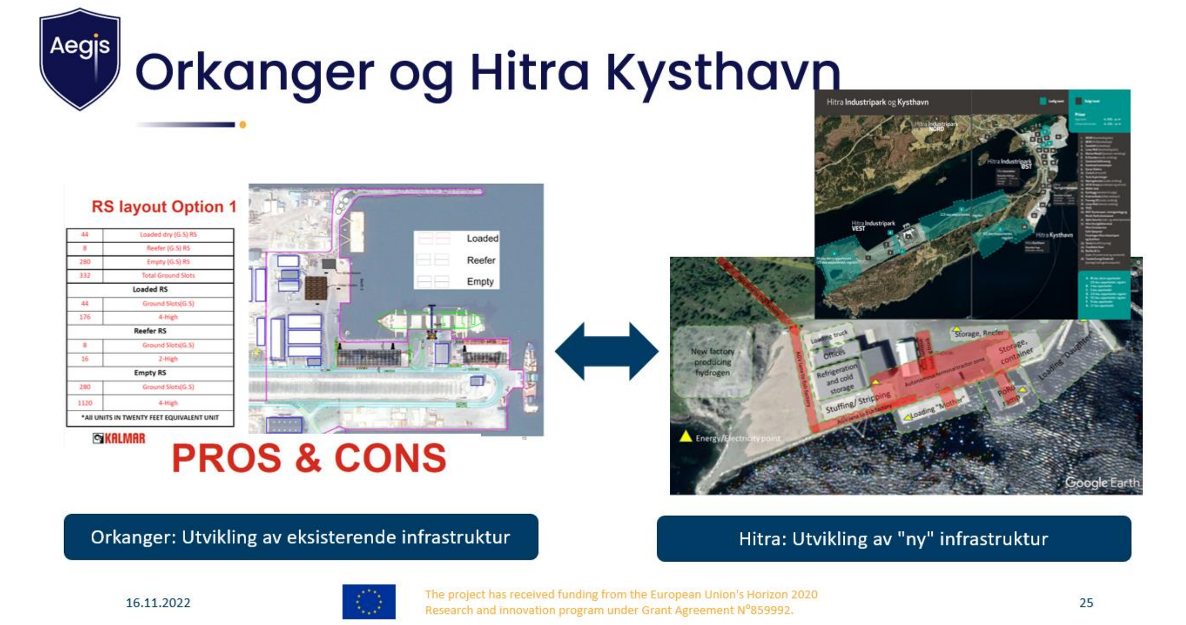
1. Needs new investment in autonomous technology, both for transport means, terminal equipment, operation centres, and for the ICT infrastructure.
2. Difficult to serve ad-hoc locations with no infrastructure in place.
3. Supply of energy to autonomous technology might become difficult.
4. To bring autonomous technology from a vessel to terminal for operation might be challenging.

A.1.4 Terminal operations



Background – Use Case A – Terminal Operations

In our studies the focus has been on the Orkanger and Hitra terminal. Orkanger is an old terminal/port, with existing technology and resources/equipment to be used where the available area for container operation is limited. Hitra is a new terminal that still are under development.



Bottlenecks regards maritime services

1. To incorporate autonomous technology to an old terminal with existing infrastructure will be challenging since normally lack of area for autonomous operations are the case.
2. It might be challenging to offer a direct reloading between a daughter and a mother vessel.
3. Extra services will require new infrastructure, such as a battery charging installation.
4. Today the ICT systems and the digital infrastructure is immature to serve autonomous operations.
5. It takes time to establish a new port, with new technology and with a total new transport corridor.
6. The collaboration with local industry, such as using the terminal for storage of containers, must be planned for to optimise cargo flow.
7. The regulations for use of smart and autonomous technology are unclear.

Bottlenecks regards truck services

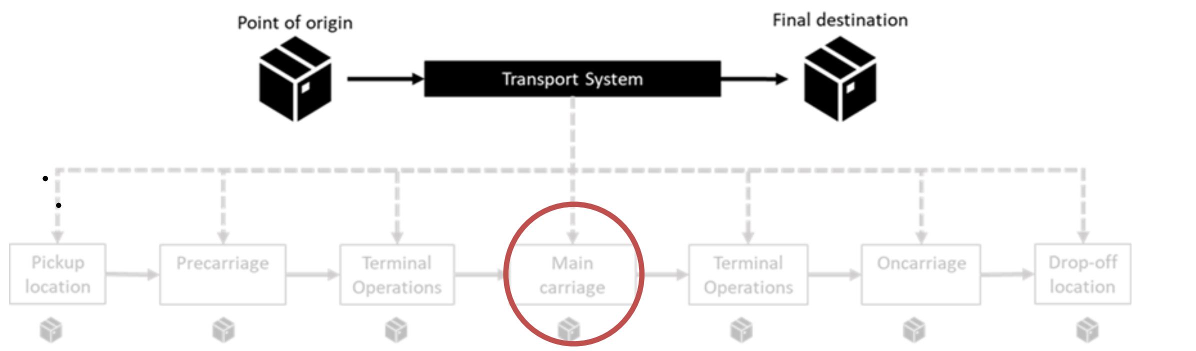
1. Low integration with rest of transport chain, if for instance delays in services this is not always announced to the truck drivers.

2. Unclear procedures to get access to terminal areas. The ICT system used by the trucks is not integrated with terminal systems.
3. Waiting time and lack of information/clearance in/out of terminals.
4. Introduction of autonomous technology in port areas not always harmonises with services provided by truck drivers. An example is that there often are ad-hoc trucks driving into the terminals, that are not familiar with how to be served by an autonomous reach stacker.
5. Trucks are using the public infrastructure in/out of a terminal, which is in many cases congested with heavy traffic.
6. Negative public perception on additional traffic on roads, slow driving, and pollution to environment.

Bottlenecks regards autonomous technology

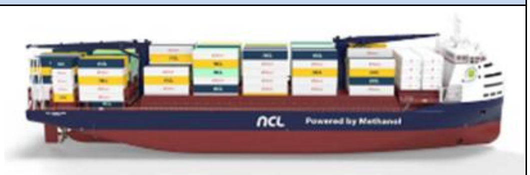
1. Unfamiliarised technology, lack of competence to operate the autonomous technology.
2. Needs safety zones that are not always available.
3. Integration with conventional transport is not always easy.
4. Operation in terminal zones in parallel with other activities might be unwanted.
5. Expensive technology.
6. Port infrastructure is not ready to allow remote or autonomous operations.
7. Deviation and damage management is not planned for.
8. Lack of regulations, procedures and standards for operation of autonomous technology.

A.1.5 Main carriage



Background – Use Case A – Main Carriage

Use Case A has focused the main carriage to be operated by NCL. This will be a transport between Hitra/Orkanger and Rotterdam with a LoLo vessel with the capacity of about 1200 TEU. The new vessel ordered by NCL that will be in operation in 2024 will be sailing on green methanol (upper figure). The vessel is partly designed with input from the AEGIS project (lower figure).



Bottlenecks regards maritime services

1. The CAPEX and OPEX costs of the vessel require a high number of cargo units onboard. The vessel cannot sail long distances to pick-up a low cargo volume. 2. The transport to Rotterdam must change time schedule, mainly because of not available terminals in Rotterdam due to frequent delays related to deep sea transport. 3. The vessel requires high utilisation both directions south- and northbound. 4. Deviation management at terminal. 5. No-show cargo. 6. Unclear regulations and collaboration between terminal workers and crew. 7. No berth availability. 8. Lack of labour. 9. Slow cargo operation. 10. Technical failures such as crane breakdown. 11. Weather restrictions.
Bottlenecks regards truck services
1. Low integration between vessel and truck. 2. Unclear cargo documentation. 3. Waiting time and lack of information/clearance where either truck or vessel are delayed. 4. Deviation management can be challenging. 5. Language problem.
Bottlenecks regards autonomous technology
1. Integration between terminal autonomous technology and vessel technology/workers. 2. Operation in terminal zones where other activities is ongoing. 3. Expensive technology, low knowledge on the technology in use. 4. Change orders, deviation and damage management is challenging. 5. Utilisation of technology, less flexibility.

Annex B. Bottlenecks

The report *D8.3 Bottlenecks and obstacles in use case A* discusses several bottlenecks for case A. Some of these bottlenecks are general and applies for most transport system, but others are more specific to our case. The main objective was to identify factors that make transport users prefer trucks over waterborne. The approach was to first identify some general factors relevant for most transport systems, and then specify factors relevant to the proposed transport system in case A.

The report used three approaches. It describes the main logistic chain of today. In this system, car or trucks are the modes of the transport corridor. There are several reports describing this system, such as the Green Shipping Programme, The Office of the Auditor General of Norway, Menon Economics, Statistics Norway and National Transport Plan as our main sources when studying use case A. The main conclusion from this part was that most of the Norwegian national infrastructure investments are aimed at roads, both to upgrade existing roads, but also to build new roads, bridges, and tunnels. Only 2.7% of the investments are aimed at waterborne transport, which includes both the port and terminal infrastructure as well as the maritime fairway.

Based on this the report discussed bottlenecks which are highly relevant to start-up the mother daughter operation, and to further develop the technology and logistics. The main conclusion is that there are different obstacles in the start-up, than at later stages. Mother - daughter transport systems will also be relevant to other geographical areas and could give a robust alternative to trucks and roads.

Finally, the bottlenecks, sorted along the use case A route was specified.

Main categories of obstacles identified was:

1. Present transport system
2. Bottlenecks associated with vessels and ship route
3. Bottlenecks associated with terminals and equipment
4. Technological bottlenecks
5. Commercial bottlenecks
6. Regulatory bottlenecks

Of these bottlenecks the first one is associated with the present infrastructure and the willingness to invest in roads, bridges, and tunnels. This is the main bottleneck to overcome if this, or any other alternative to present use of trucks are to be challenged. The next three bottlenecks are linked directly to use case A. The discussion regarding the next two will also apply to other cases where new technology or logistic solution needs investment from one or several partners. The last category consists of a variety of obstacles difficult to place in one of the other categories, but still important to our case.

Present transport system

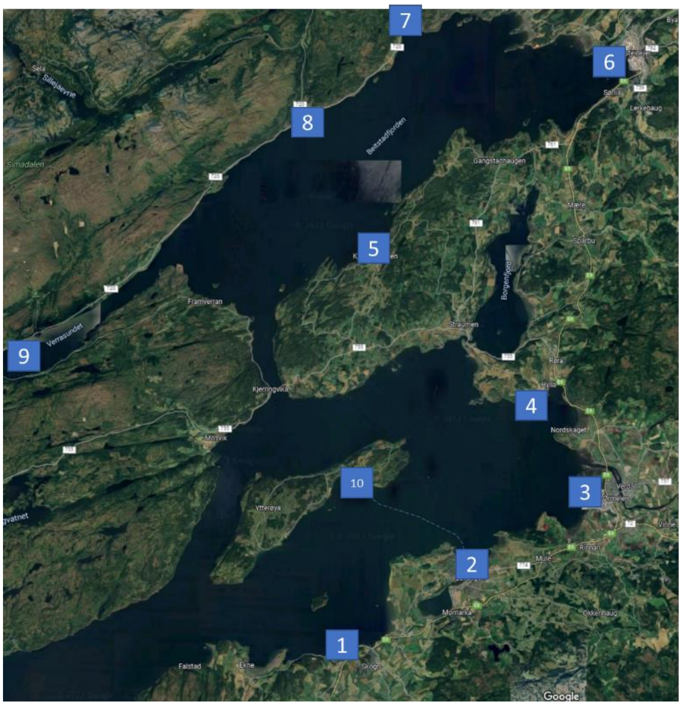
When planning for a new transport system it is important to understand the existing transport system and why it is organised as it is. As described in previous deliveries, the commodities are mainly transported from central part of Europe to hubs in the eastern part of Norway as logistic hubs. In this system roads and trucks are the preferred transport methods. The further distribution is mainly distributed from these central transport hubs by truck. This transport system has existed for years. In the report *Logistics 2030* it is claimed that the present logistics and infrastructure for cargo into Norway is developed on the premisses of road transport. The existing transport system, by using trucks and roads, is therefore the main obstacle to all proposals for alternative transport methods.

From the work within the use case following was issued as important elements on a successful maritime transport system:

1. Modernise ICT systems to allow collaboration for all partners involved in the transport system.
2. Facilitate competitive cost conditions compared to existing transport solutions.
3. The use of established warehouses in eastern part of Norway, that are central nodes for distribution of cargo to rest of Norway, might be a challenge when new maritime solutions to the west coast of Norway are to be offered. New corridors must be disseminated as a sustainable and cost-effective solution compared with existing.
4. Costs and flexibility in ports is important for successes, the ports must be a service provider to the operators, that offer services that makes the maritime transport corridor competitive with the road alternative.
5. Lead time and punctuality on maritime transport is seen as a barrier. It is important to address the benefits and not only focuses the challenges.
6. Collaboration and integration between the transport modes should be prioritised. The cargo seldom stops in a port, it will need further transport out of the port area.

Bottlenecks associated with vessels and ship route

The daughter vessels operating in use case A are designed to be uncrewed, and sail with a low speed to be as environmentally sustainable as possible. One challenge in the region is that the power supply capacity in smaller ports is limited, which makes it hard to offer a battery as energy solution for the daughter vessels. Another challenge is that most of the ports to be served has limited, if any, manning, and access to cargo handling equipment is limited. The weather picture in the Trondheimsfjorden can be ruff, with high waves and where the terminals are not very protected from wind and waves. Next figure shows a study presenting some available ports in the region, that could be served by a daughter vessel. Still, it is likely that a daughter vessel only serves a few ports, not all mentioned in the figure. The figures below with available ports in the Trondheimsfjorden region is copied from Frode Halvorsen, Fremtidens Innovasjon/Ocean Autonomy Cluster.

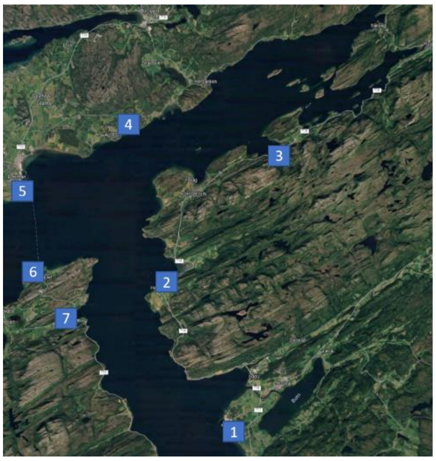


Smaller ports in the inner Trondheimsfjord

1. Fibrotangen
2: Levanger
3: Verdal
4: Verdalskalk – Røra
5: Kjerknesvågen *
6: Steinkjer*
7: Malm
8: Follafoss
9: Verrabotn
10: Ytterøy

1: Leksvik
2: Vanvikan
3: Rørvik
4: Småland
5: Tautra
6: Langstein
7: Skatval
8: Stjørdal
9: Muruvik
10: Hommelvik
11: Trondheim
12: Flakk

1: Statsbygd
2: Lensvik a + b
3: Orkanger
4: Buvika



1: Kvithylla
2: Hasselvika
3: Frengen
4: Ottersbo
5: Brekstad
6: Agdenes
7: Selva

1: Beian
2: Garten
3: Uthaug
4: Bjugn
5: Storfosna
6: Kråkvåg
7: Leksa
8: Valset
8: Værnes

1: Jøsnøya
2: Laksåvika
3: Singsholmen
4: Kvenvær
5: Kjærringvåg
6: Ulvøya
7: Fillan
8: Hestvika
9: Hammarvika
10: Nordhammervika
11: Sistranda
12: Ervik
13: Vikasundet
14: Norddyrøya
15: Kverva
16: Titran
17: Flatval

Bottlenecks associated with terminals and equipment

There are several terminals involved in use case A: Rotterdam, Hitra Kysthavn, Orkanger, Trondheim, Skogn and Holla. Also, smaller ports in the Trondheimsfjorden have been studied as feeder ports to Hitra. Of these terminals AEGIS have mainly address Hitra Kysthavn, Orkanger and Trondheim. These three terminals are good examples on the differences there are between the types of terminals, small to medium sized in Norway.

The terminal at Hitra Kysthavn is currently under development, and as such is considered a strategic location for the future of maritime transport in the region. The port of Orkanger is where most containers pass today. From the use case study, it argues that there is a need to modernise this terminal with new infrastructure and ICT systems. The port in Trondheim has a lower container volume but this is increasing. Trondheim is Norway's third largest city, and the port area is under pressure because of residential development plans. Industry terminals close to houses will lead to a higher pressure on the port because of noise and closed public areas etc.

Another dilemma is the development of Hitra Kysthavn. The port infrastructure needs costly investments to allow for high automation and autonomy. One example is the availability of electricity to allow terminal equipment to be operated on battery. The area capacity today is limited, it will require high investments to provide enough capacity to serve all users. The terminal must also support energy to the mother vessel, that for example NCL will be methanol. Hydrogen is also considered as energy where a new factory close to the terminal is under consideration.

Technological bottlenecks

The daughter vessel will transport a smaller set of containers, e.g., 60 or 100 TEU dependent on vessel design, from Hitra Kysthavn and to various locations inside Trondheimsfjorden and opposite direction. The work performed throughout the AEGIS project is built on a foundation of addressing key environmental concerns from the EU and local authorities. The technology proposed in the project facilitates for a future where maritime transport can do more and reach further than before. The most important feature of use case A is not the level of autonomy, but the use of mother and daughter vessel in combination with terminal operations. One could also have an autonomous daughter ship and manual operations in the port.

In an autonomous system, a robust and comprehensive ICT solution is a key factor to ensure safe, secure, predictable, efficient, and cost-effective operations. Standards and protocols are necessary for success, such as ISO 28005 and the EMSWe[3]. Another concern is related to trust between parties, in particular when it comes to willingness and risk related to data-sharing. In use case A, there are multiple stakeholders involved and it is not feasible to assume that all parties will use the same ICT system. Therefore, it is critical that systems that are in use can exchange data. This in turn requires standards for how and when data should be transmitted and overall standardization of system integration. High degree of data-sharing is needed to facilitate just-in-time operations. An autonomous system requires high quality real-time data with a much higher level of granularity than manual systems, not only data from the vessel but also digital data at the terminal to control the container moves and to protect safety and security. E.g., a ship's position at quay must be continuously calibrated and shared among all involved systems to facilitate efficient autonomous loading/discharging. In an autonomous system, ICT security is crucial for safe operations and public trust.

Commercial bottlenecks

Waterborne transport does not have the same public funding incitements than for land-based transport in Norway. This means that waterborne transport users must pay a higher tax of using the infrastructure such as fairways and the terminals, that are often free of charge for land-based transport.

Regards the foreseen use case investments, the transport system needs large investments before a fully autonomous system can be offered. This is investments in mother and daughter ship, and terminal infrastructure and equipment used for loading and unloading. Terminal infrastructure investment is especially important at Hitra Kysthavn since this is a new terminal where equipment and infrastructure around the terminal must be considered for. The studies performed welcomed a private-public partnership model, where the industry and port owners could have a closer collaboration, maybe in a joint company structure model. One challenge of today is if one of the involved companies does not prioritize the necessary investments this would be a serious obstacle to the whole transport system. Previous projects and studies have pointed to the danger of investing in too expensive technology and infrastructure, that makes the port taxes high and thereby not that attractive for the users that at the end must pay for the investments. Successes regard moving more cargo to waterborne solutions requires a closer collaboration within a transport system, to avoid wrong investments.

Regulatory bottlenecks

There are two main categories of regulatory hindrances that may be found in the deployment of the proposed new transport system for AEGIS use case A: those associated with the vessel design itself and its ability to navigate along the Norwegian coast, and those associated with the access of the vessels to areas of transhipment at sea and to the port terminals involved in use case A. Another one could be to allow remote terminal operations, for example that an autonomous crane can be remotely monitored and controlled from a site located away from the terminal. This requires also that the terminal ICT systems should be open for remote operation.

Energy sources for shipping propulsion may be subject to regulatory hindrances due to environmental policy associated with maritime transport, this also counts for autonomous technology. Regulatory

[3] https://www.emsa.europa.eu/emsw.html

hindrances associated with access to port terminals may relate either to the terminal itself or to the goods carried by the vessel (assuming the vessel is capable of berthing in existing infrastructure). Port terminal development generally depends on municipal permitting due to zoning laws. The regulations when the cargo is coming unmanned to a terminal is not in place and needs studies. It is necessary to consider security regulations, namely the port facility security as defined in the ISPS code as it is applicable to larger ports and terminals and may raise challenges to local terminals, that is the case for the use case. The digitalization of both the ship's certificates, the communication with the remote-control centre, as well as the communication interface with AGVs at the terminal may all raise issues with data protection that are highly regulated within the EU's General Data Protection Regulation (GDPR).

Policy support for the implementation of AEGIS use case A is necessary to overcome these regulatory hindrances. While some of the highlighted hindrances are specific to the locations involved, they would generally also exist in other geographical contexts. Regulatory bottlenecks cover all laws that may be relevant for use case A. For the ports involved the ISPS-code is one such example, the Ports and Waterways Act is another one. Also, health, safety and environment are important at all places where people are involved. These are important subjects, but regulatory questions are not critical bottlenecks. The proposed transport system consists of stakeholders already familiar with shipping, cargo handling, and port operations. The feasibility of this use-case must thus consider the regulatory framework applicable at different levels: The municipality, the region, the state and the international, namely the efforts conducted at the European Union level to standardise rules applicable to transport systems. All of this is needed for the use case A.

AEGIS use case A has pointed to lack of governmental incentives, financing and a comprehensive plan for the waterborne transport system, as the largest bottleneck for any transport system which may challenge the existing way of business.

R4: It is recommended to perform further studies on the combination of mother/daughter vessel solutions. The case in Trondheimsfjorden can easily be adopted to other regions, not only in Norway, but also Europe. Since the main support from most of the Norwegian national infrastructure investments are aimed at the road sector, it is important to continue working with the promotion of sustainable waterborne alternatives. It is also important that the work is coordinated between the different stakeholders involved. AEGIS recommends that the Norwegian Research Council continue prioritising maritime transport, at the same time it is important that the introduction of new technology and autonomy must be aligned between the service providers, technology developers, research and the regulatory stakeholders.

- The Parliament in Norway has set a target that 30% of all transport longer than 300 km on roads should be moved to waterborne transport by 2030. Investments should stimulate for this to happen.
- Few measures have been implemented to strengthen the competitiveness of waterborne