FIRST – Fire strategies for unmanned island ferries

Appendix 1 – Background Study

DBI BRAND OG SIKRING

FORCE TECHNOLOGY

MOLSLINJEN

JJOHANNESSON APS

Content

1 Appendix Introduction

1.1 Scope

The scope of this appendix is to function as a background study regarding the current trends in - and state of - autonomous maritime vessels and hereby explore the readiness for autonomous ferries in Denmark. Specifically, the appendix provides a brief introduction to the concept of autonomy, a review of the current laws, regulations, and guidelines, a short presentation of key developers as well as viewpoints and insights from the Danish Maritime Authority.

The overall project is based on an actual ferry design provided by Molslinjen (Formerly Rederiet Færgen). This design is Sønderho II, the replacement ferry for Sønderho, currently in service between Esbjerg and Fanø in Jutland. However, this appendix will seek to establish a broader focus on the readiness for autonomous ferries in Danish waters.

1.2 Acronyms

BV	Bureau Veritas
CCTV	Closed Circuit Television
EU	European Union
GPS	Global Positioning System
IMO	International Maritime Organisation
RCM	Risk Control Measure
RCO	Risk Control Options
SCC	Shore Control Centre
SOLAS	International Convention for the Safety of Life at Sea
STCW	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers
LR	Lloyds Register
MSC	The Maritime Safety Committee of IMO
MASS	Maritime Autonomous Surface Ships
UMS	Unmanned Marine System

2 General definitions and concepts

When addressing the concept of autonomous vessels it is key to note that there are several definitions of what an autonomous ship is. Among others, these definitions are available in autonomous vessel guidelines from class societies [1], [2] & [3]. The overall definition is often accompanied by a more detailed definition, of what functions an autonomous ship is able to take over from the crew. To give an idea of which directions some definitions point in, two quotes to exemplify this are included below.

"Autonomous ship: ship having the same capabilities as those of a smart ship[1] *and including autonomous systems capable of making decisions and performing actions with or without human in the loop. An autonomous ship may be manned with a reduced crew or unmanned with or without supervision.* [1]*"*

Bureau Veritas's (BV) definition of an autonomous ship, is as stated above

The ship's control system computes consequences and risks. The control system makes independent decisions and determines its actions. Operators at shore are only included in decisions, if the system fails or is confused enough to ask for human assistance in decision-making. If this occurs, the autonomy levels changes to a lower level…." [4][2]

The above quote is Rambøll and CORE's over all definition of what an autonomous ship is. The definition is not that different from BV's. One key difference is however that the autonomous system must be able to compute risks and consequences of different choices.

Below some of the commonly used terms, when dealing with autonomy, will be presented and variations hereof will be discussed briefly.

2.1 Autonomy levels

To give a more nuanced picture of these definitions it seems beneficial to present a couple of autonomy level examples from well-known class societies. See Lloyds Register's (LR) definition in Table 1 and Bureau Veritas's definition in
Table 2.

Table 1: General autonomy levels as defined by LR [3]

[1] *Smart ship: generic term to define a connected ship, capable of collecting data from sensors and having the capacity to process a large amount of data in order to assist the crew during the decision making process. Compared to a conventional ship, a smart ship may be manned with reduced crew or totally unmanned with a remote control.* [1]

[2] Original text in Danish: *Skibets styresystem beregner konsekvenser og risici. Styresystemet træffer selv afgørelser og afgør sine handlinger. Operatør i land inddrages kun i beslutninger, hvis systemet fejler eller er i vildrede og anmoder om menneskelig beslutningstagen. Hvis dette sker, skifter autonominiveauet til R eller RU afhængig af, om skibet er bemandet eller ej.*

AL0	Manual: No autonomous function. All action and decision-making performed manually (n.b. systems may have level of autonomy, with Human in/ on the loop.), i.e. human controls all actions.
AL1	On-board Decision Support: All actions taken by human Operator, but decision support tool can present options or otherwise influence the actions chosen. Data is provided by systems on board.
AL2	On & Off-board Decision Support: All actions taken by human Operator, but decision support tool can present options or otherwise influence the actions chosen. Data may be provided by systems on or off-board.
AL3	Active' Human in the loop: Decisions and actions are performed with human supervision. Data may be provided by systems on or off-board.
AL4	Human on the loop, Operator/ Supervisory: Decisions and actions are performed autonomously with human supervision. High impact decisions are implemented in a way to give human Operators the opportunity to intercede and over-ride.
AL5	Fully autonomous: Rarely supervised operation where decisions are entirely made and actioned by the system.
AL6	Fully autonomous: Unsupervised operation where decisions are entirely made and actioned by the system during the mission.

The autonomy levels presented in Table 1 range from AL0 to AL6, where AL0 describe the level of autonomy present on current ships and AL6 describe a fully autonomous ship. The intermediate levels consider ships in which the crew/master has progressively fewer parts of the operation to handle entirely manually.

Table 2: Navigational autonomy levels as defined by Bureau Veritas [1]

Ship category		Level of autonomy	Manned	Method of control	Authority to make decisions	Actions initiated by
Conventional	0	Human operated	Yes	Automated or manual operations are under human control	Human	Human
Smart	1	Human directed	Yes/No	Decision support Human makes decisions and actions	Human	Human
Autonomous	2	Human delegated	Yes/No	Human must confirm decisions	Human	System
	3	Human supervised	Yes/No	System is not expecting confirmation Human is always informed of the decisions and actions	Software	System
	4	Fully autonomous	No	System is not expecting confirmation Human is informed only in case of emergency	Software	System

The BV autonomy level description seen in Table 2 is to some degree more specific in its definitions of autonomy levels than LR. Further, the category "Smart Ship[3]" is part of the steps towards fully autonomous ships. A large portion of existing ships may to some extend already be characterised as smart ships. Decision support systems that advice on potential ship motions in adverse conditions, speed-trim fuel optimisation, anti-collision systems and structural monitoring are already present on parts of the world fleet.

An important notion to consider is that from a helicopter view, the definitions in Table 1 & Table 2 can apply to the entire ship and operation, but may also apply to specific parts of the ship and operation. Consequently, autonomy can be understood in the popular term of un-maned voyage, but much more plausible in the near future, autonomous marine vessels will mean autonomous decision-making or navigation in some use-cases and under certain operational conditions. Therefore it should be considered that an autonomous vessel can and most likely will be crewed, at least in the near future. From the interview with the Danish Maritime Authority, seen in section 5, the latter will most likely apply to initial autonomous ship designs. The Sønderho II ferry project will most likely aim towards LR's autonomy level AL3 or AL4 or BV's autonomy level 2 and 3.

[3] Smart ship: generic term to define a connected ship, capable of collecting data from sensors and having the capacity to process a large amount of data in order to assist the crew during the decision making process. Compared to a conventional ship, a smart ship may be manned with reduced crew or totally unmanned with a remote control [1]

2.2 Manning – a wider definition

In a traditional sense, the "manning" required to operate a ship would include the ship's crew and a supporting organisation on land, i.e. designated person ashore. Minimum manning requirements are set by the flag state with reference to SOLAS[4] and STCW[5]. To determine the minimum safe manning several factors like size, mooring arrangements and level of ship automation must be taken into account [5].
Considering autonomous ships, where in some cases the end goal is to eliminate the necessity of a permanent on-ship crew. Guidelines in most cases stipulate the requirement of having a shore control centre (SCC). BV considers the SCC an extension of the ship. Within the current scope/prospect, autonomous ships will not go entirely crewless, as autonomous ships will have designated personal on shore to handle tasks too "complex" for the system to handle. Regarding the educational and training requirements for shore control manning, it is currently unknown, but in the early states they most likely will not differ much from current standards.

[4] SOLAS - International Convention for the Safety of Life at Sea
[5] STCW - International Convention on Standards of Training, Certification and Watchkeeping for Seafarers

3 Laws, Rules, and Guidelines

Currently there are no international rules specifically governing autonomous ships or vessels. First time the issue was addressed in the IMO was on the 99th Maritime Safety Committee (MSC) session in May 2018[6]. During this session, work was officially initiated on Maritime Autonomous Surface Ships (MASS). On the next session, i.e. the 100th MSC session, it was decided that an IT-tool for development of autonomous ships should be created [5]. A scoping exercise for how the issue should be addressed in IMO is underway. However, it is a very complex and long process and most likely regulation will have to happen on multiple levels as several chapters will be affected. Consequently, there is currently no set of rules to follow in order to ensure compliance towards IMO when designing an autonomous vessel.

In Denmark, autonomous ships have been part of a clear political strategy defined in 2017. The Ministry of Industry, Business, and Financial Affairs drive this strategy. To help the industry along the previous minister has stipulated the importance of adapting legislation to allow autonomous ships[7]. As of now, there is not a set of national rules that describe what is necessary to get an autonomous ship approved.

Class societies have however been developing guidelines that describe what they consider best practice when engineering autonomous maritime solutions. These are quite concerned with topics like redundancy, risk assessments, and latency in communication.

Below section will be dealing in more detail with what regulations actually apply to autonomous ships and what practical procedural steps are necessary to get an autonomous ship approved. The point of reference will be the Sønderho II project and therefore limited considerations are given to ships for international operations.

3.1 Danish regulations

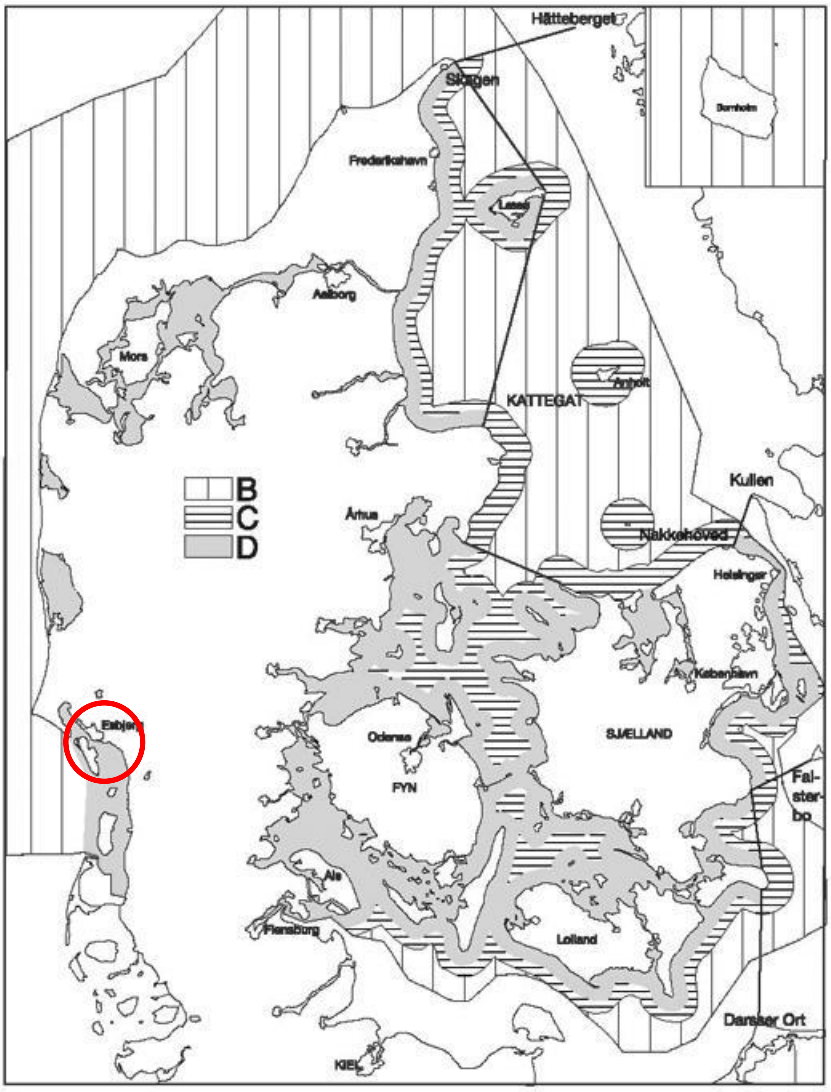
Passenger ships operating solely in Danish territorial waters will have to abide by the Danish Maritime Authority's (DMA) Declaration D [6], [7], [8], [9] & [10]. The declarations are updated regularly to keep up with developments in international regulations from EU and the IMO. As of such, a great deal of Declaration D is rules that are implemented to create a harmonization between all countries in EU. Further, it is an implementation of IMO founded rules into Danish law. In general, there are very few specifically Danish rules in these declarations and great efforts are put into removing these. Currently there are no specific rules for autonomous ships.

3.1.1 Area of operation

The Sønderho II ferry will only operate in the waters between Fanø and Esbjerg. Danish domestic waters are split into three types of areas, i.e. B, C and D areas. Areas denoted 'A' do exist, but is not present on DMA's map of area characterization, as seen in Figur 1

[6] News article about IMO discussing autonomous ships, from the Maritime Executive: "IMO Takes First Steps to Address Autonomous Ships" Link

[7] News article about improving legislation on autonomous ships: "Regeringen vil bane vej for skibe uden kaptajn" Link



Figur 1: Domestic sea areas in Denmark, denoted B, C and D

The sea area between Esbjerg and Fanø is characterised as a D area. Such areas provide limited environmental challenges, i.e. low wave heights and short distances to an area of refugee. For exact definition see below, excerpt from Declaration D:

”Class D comprises passenger ships for domestic travels in sea areas where the likelihood of having a significant wave height greater than 1.5 m is less than 10 %, calculated on basis of all year around operation or over a specific part of the year for operation in said part of the year; the ships can at no time be more than 6 nautical miles away from a port of refugee or 3 nautical miles away from the coastline, where shipwrecked can be brought to shore at mean water level.” [6]

Areas denoted C, B and A denote progressively harsher environmental condition, see Declaration D for specifics. Because of the light environmental conditions in areas denoted D, requirements for radio equipment, means of communication and redundancy in said communication means are significantly reduced.

3.2 International regulations

Passenger ships only performing domestic travels will, as previously mentioned, not have to abide rules stated in international rules stated in SOLAS and similar. However quite a significant amount of the Danish declaration D refers to rules created in IMO. As an example, the interior materials must be tested and approved according to the IMO's FTP-code, the SOLAS's load-line convention must be followed and damage condition stability. As previously mentioned, there are no international or IMO rules specific for autonomous ships

3.3 Guidelines from class societies

In anticipation of autonomous ship designs, class societies have formalised guidelines that describe necessary steps or principles to follow in order to get such designs approved.
The guidelines deal with issues like navigation, structural integrity, and most of the all how to ensure safe operation when certain processes are "automated". Below sections will present how LR, BV and DNV-GL have formalised this into guidelines.

3.3.1 Lloyds Register (LR)

In February 2017 LR published the document "ShipRight - LR Code for Unmanned Marine Systems" [3] to describe best practise in developing Unmanned Marine System (UMS). Essentially the code deals with the subjects presented in Table 3. For each subject it does this by:

- Presenting the scope, i.e. what is covered on the given subject
- Outlines the goal, i.e. what should be achieved through the functional objectives and performance requirements
- Defines functional objectives, in relation to maintenance and safety
- Describes performance requirements, i.e. what parameters must designed towards

The information in Table 3 is limited to the subject that in some way deals fire.

Table 3: Summary of LR ShipRight document

Subject	Summary
Structure	The overall goal is to ensure that the ship's structure is designed, constructed and maintained to a degree that ensures safe operation in all reasonably foreseeable operating conditions. This mean that the ship's structure must be able to carry and respond to all foreseen loads in a predictable safe manner and meet requirements for watertight, weathertight, and fire integrity. The performance requirements dictate that consideration shall be given towards the probability of the occurrence of a load and combinations of loads that are outside of the reasonably foreseeable operation scheme. Essentially meaning that safety margins must be implemented. This must be considered in relation to ballast, cargo, and similar, but also fire. To exemplify hydrostatic and global loads may change significantly if water is used for extinguishing a fire in a room and this room is partially filled with water. Such cases should be thought of in advance of the construction and used as design input. Structural parts may experience reduced properties in the event of a fire, i.e. reduced structural carrying capacity and similar. The guideline describes that this must be taken into consideration when designing the ship. This is not different from other ship design standards and may likely be solved via insulation and similar.
Stability	The overall goal is to ensure sufficient buoyancy, stability, watertight, and weathertight integrity. Like in the case of structural considerations, the stability of a ship may be significantly affected by a fire and subsequent extinguishing procedures. Because of such scenarios, there is a functional objective for reserve buoyancy and adequate stability.

Control system	**Scope:** onboard and remote control of navigation, propulsion, and manoevering. Also systems for transmission of data **Goal:** level of integrity sufficient safe and maintainable operation **Funtional obj:** Enable operation in all reasonably foreseeable conditions Operate in a predictable manner Meet requirements for watertight, weathertight, and fire integrity minimise risk of fire Crew must have adequate access, information, and instructions for safe operation **Performance req.:** -Actually a requirement to use sensors, systems and eq. to operator autonomous control system of potential hazards and op state -Control ambient condition -Designed with consideration towards human system interface -Sensor data shall be logged -Automatically initiation of corrective measures -Minimise risk to people, environment, or assets -Visual and audio alarm if energy source fails -Software failures shall never escalate, hinder mitigation or recovery from a hazardous situation
Electrical systems	
Navigation systems	
Propulsion and manoeuvring	
Fire	Goal: detect and extinguish a fire with a level of sufficient Functional: -Constructed to minimise the risk of initiating a fire -Constructed to detect, contain, and extinguish fire Performance req.: -Effect and proportionate means of extinguishing -Should consider risk of ignition, fire growth potential, and operational importance -May not pressurise rooms, endanger stability -Status of extinguishing must be displayed to operator -Extinguishing must be designed with
Auxiliary systems	

Reasonably Foreseeable Operating Conditions: Conditions in which the UMS can be reasonably foreseen to operate in an intact, degraded, aged and/or damaged state. They are normally defined in the ConOps.

The naval architect Johannes Johannesson has informed the project group that the ship will be classed by LR and will be given the notation: ✠100 A1 Passenger, ✠LMC[8], UMS[9], ICC[10], Battery Operation.

3.3.2 Bureau Veritas (BV)

Bureau Veritas has developed a guideline for autonomous shipping, "Guidelines for Autonomous Shipping Guidance Note NI 641 DT R00 E" [1]. The guideline is split into four themes:

- General

Presents the scope and methodology of the document. Further, general definitions and concepts like shore control centres are introduced.

- Risk and technology assessment

The whole section introduces the concept of risk and provides some of basis for doing hazard identification in relation to navigation, voyage and emergency. This leads on to more quantitative ways of assessing and analysing risk.

- Guidelines for functionality of autonomous systems

These guidelines are very specific in relation to communication, weather routing, lookout and situational awareness. For communication there are specific bandwidth that are recommend for different sort of communication. Similar requirements are in place for situational awareness and the other subjects.

- Guidelines for reliability of autonomous systems

The guideline covers subjects like redundancy, cyber security and software quality assurance.

[8] LMC: Propelling and essential auxiliary machinery constructed, installed and tested under LR's Special Survey and in accordance with LR's Rules and Regulations

[9] UMS: Ship can be operated with the machinery spaces unattended & control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or equivalent

[10] ICC: Integrated computer control

4 Technical Solutions

The first and to date only full-scale test of an autonomous ship was concluded on the 3rd of December 2018, in Finland. The test was conducted on an inland ferry called Falco, on route between Pargas and Nagu south of Turku. Similar projects are underway elsewhere in the world, however, Scandinavia is amongst those currently pushing a lot of development within autonomous vessels. The below section serves to provide the reader with an idea of companies who are currently developing systems that can be implemented on ships to make them autonomous.

4.1 Suppliers

There are currently several suppliers and developers of automation solutions for ships worldwide. The whole concept of automating processes on ships is not new and maritime autonomy has been discussed in the IMO as early as 1964. As previously mentioned, automating a process does not necessarily make it autonomous. Whether a solution can be characterised as autonomous is a question of definition.

4.1.1 Kongsberg

Kongsberg is one of the market leaders in autonomous maritime technology.
Kongsberg are involved in 3 high-profile autonomous vessel projects called Yara Birkeland, Hrönn and, Odin. Yara Birkeland is probably the most well-known project and will be elaborated below, while Hrönn and Odin perhaps less familiar to the public.
Hrönn is supposed to be a light offshore service vessel platform that may serve offshore fish farms, offshore energy or perform hydrographic surveys.

The purpose of YARA Birkeland[11] is to transport containerised cargo (fertilisers) between Herøya, Brevik and Larvik in Norway. The aim is remove 40.000 truck transport journeys, between these destinations. The ship will, when built, be able to carry 120 TEU and have length of 79.5 m. To navigate and have additional environmental awareness, compared to ordinary ships, the ship is fitted with LIDAR, cameras and IR-Cameras.
Currently a model of the ship is being tested at SINTEF Ocean in Trondheim. The ship will operate with crew in the first two years and subsequently move to un-manned operation.

Furthermore, Kongsberg and Wilhelmsen have created a joint venture shipping company called massterly to establish infrastructure and services to design and operate autonomous vessels.

4.1.2 Rolls-Royce (RR)

Rolls-Royce invests heavily in developing autonomous vessels and automation solutions for operating ships. One of the project that RR has taken part in is "Project SVAN - Safer Vessel with Autonomous Navigation".
One of the results of Project SVAN is seen in Figure 2: Falco - perhaps the first autonomous full scale ferryFigure 2, namely the FinFerries ferry called Falco, which was retrofitted with several systems to allow for autonomous operation.

[11] https://www.km.kongsberg.com/ks/web/nokbg0240.nsf/AllWeb/4B8113B707A50A4FC125811D00407045?OpenDocument

Figure 2: Falco - perhaps the first autonomous full scale ferry

https://yle.fi/uutiset/osasto/news/autonomous_ferry_makes_first_demonstration_voyage_in_finland/10537448

4.1.3 Wärtsilä

For the Norwegian ferry operator Norled, Wärtsilä has delivered an automatic docking system that enables the ferry Folgefonn to dock without human interaction. This system was successfully tested in April 2018. Such system should be thought of more as a pre-programmed docking procedure and not as an autonomous system[12]. The system was however further developed to allow fully automatic dock-to-dock navigation[13] by push of a button. Positional information is acquired via GNSS (GPS and similar) and a Wärtsilä system called CyScan. CyScan is essentially distance measuring system, able measure the distance between a moving vessel and a stationary reference point. This is typically employed in ships with dynamic positioning, to verify position via fixed reference points. On Folgefonn it is being tested as a secondary means for determining the ship's position during voyage[14]. None of the articles describing Folgefonn mention systems implemented to avoid collision or handle other processes automatically or autonomously. Meaning the master of the vessel is still an integral part of the operation, considering collision avoidance, fire safety and much more.

[12]https://www.wartsila.com/twentyfour7/innovation/look-ma-no-hands-auto-docking-ferry-successfully-tested-in-norway
[13] https://www.maritime-executive.com/article/waertsilae-conducts-autonomous-ferry-voyage-and-docking
[14]https://www.wartsila.com/media/news/28-11-2018-wartsila-achieves-notable-advances-in-automated-shipping-with-latest-successful-tests-2332144

5 Insights from the Danish Maritime Authority

The following section outlines insights from the Danish Maritime Authority (DMA) regarding the future of autonomous ferries in Danish waters. The insights are based on information and discussions from a meeting and dialogues between DBI and the DMA during the project period.
Specifically, the discussions were rooted in the concrete project of Sønderho II, including the current GA and the use-scenarios available to DBI at the time of the meeting (for more detail on these, see the concluding report). In addition to the concrete and specific insights gathered for the Sønderho II project, the discussions took a more general approach to evaluate the current and future state of autonomous vessels in Denmark including the DMA's viewpoints and process of approval. In order to make the insights as widely useable as possible, it is this general approach that the will be the primary focus of this section.

5.1 A general notion of support

On an overall level, the official statement from the DMA is one of support for the development and use of new autonomous (passenger) vessel in Danish waters. This co-aligns with the political decision, as mentioned earlier, regarding the *Blue Denmark* becoming a test hub for new maritime technologies, including autonomous vessels.
However, while the support for new technologies and innovation is strong, the approach from the Danish authorities is not to provide new guidelines or rules to support or address these specifically, but rather work within the existing laws and regulations e.g. ISM code and Notice D. This will in all likelihood be the status until the IMO releases rules specific for autonomy, which is realistically not within a ten-year period. Therefore, every vessel will be approached the same in the approval process regardless of the technology used – thus leaving it to the ship-owner to document equivalent operation and safety.

5.2 Key points

A key point from the discussions was that according to the DMA, the technology for autonomous seafaring is overall, ready and able to a satisfactory level. Not disregarding that much technological development is still needed to realize the full potential for autonomous vessels, but rather emphasizing that the current state is actually in most ways sufficient to operate safely. This notion is particularly interesting as much of the discussions regarding autonomous seafaring still takes a technological approach and focus.

This strong focus and emphasis on technology development and description proved to be a concern from the DMA's side, as a focus on use-scenarios that can then lead to risk-scenarios and ultimately risk control options is preferred. A satisfactory description of use-scenarios is a vital component in achieving approval for future autonomous ferries in Denmark. As presented by the DMA, as much as 80% of the approval can be achieved before the ship and technology design is even begun, as long as the use-cases and risk scenarios are in place to a satisfactory level.

As a consequence of this heavy emphasis on use-scenarios, the approval process is greatly dependent on specific parameters concerning the route in question. Therefore, decisions regarding operational parameters, technology and design should all be based on these parameters.

During the discussions, the DMA did point to one issue in the current state of autonomy focused technology development, primarily focused on navigation and collision avoidance. The problem, as seen by the DMA, is the ability to re-create "good seamanship" and decision-making concerning navigation through programming. The point being that navigation and decision-making is an experienced based dynamic process often supported by communication between vessels and internally on the bridge among the crew with no clear-cut defined rules. The nature of this process and the lack of defined rules makes it – according to the DMA - very difficult to re-create a solid autonomous process to handle navigation decision-making.

If a given vessel is designed, for the "safe return to port" principle, it is necessary to prove and document safety and redundancy. Specifically, the vessel must be able to return safely to port, regardless location and severity of a fire. For the specific design of Sønderho II, the concrete recommendation would be to have redundant battery rooms, propulsion (ideally one azimuth thruster in each end) and navigational equipment. It should be noted however, that a secondary bridge does not need to be a physical replica of the main bridge, but can be a mobile control device that the master can use remotely from anywhere on board the vessel.

A key point to note for future ship-owners who venture into the world of autonomous seafaring is that to obtain approval for any vessel, regardless of the technology used, equivalent safety must be documented according to the existing rules. This can be mitigated through 1) alternative design, or 2) operational changes. Alternative design is to prove and document that the design is *as safe, or safer* as a traditional vessel with full crew. Alternatively, operational changes can be made to mitigate concrete use-cases and thereby enable use of autonomy for specific roles or in specific use-cases.

5.3 Manning

Regarding the topic of manning, the dialogue with the DMA covered several discussion points with insights relevant for the future of autonomous ferries in Danish waters.
Regardless of a given use-case and autonomy level for a given vessel, there must always be a designated responsible master. This means that if the vessel operates under full autonomy, a shore-based control must be ready and available to take control of the ship and be legally responsible for safe navigation. A designated person ashore will not be sufficient in case of a vessel operating under full autonomy.
The DMA was however, positive about the concept of stewards on board autonomous vessels. A similar concept is currently implemented in the Copenhagen Metro. The stewards does not control the train, but is present to assist passengers in case of any trouble or emergencies. This could be taken further on maritime vessels letting stewards be responsible for assisting in case of emergencies or evacuation, but on a daily basis function as regular service crew, handling amenities like selling coffee or food and the like.

Concerning the minimum requirement for personal on board a passenger ferry, this will depend heavily on the use-scenarios for the given vessel. There are currently small ferries operating in Danish waters with only one crewmember – however, the key to approving such a low amount of crew is down to a heavy restriction on amount of passengers. This restriction must naturally be taken into account when considering the business case for autonomous passenger ferries. Whether these rules will change with the development of autonomy is currently unclear – but for now, each case will be assessed individually based on use-case and risk scenarios.

5.4 Super users

The DMA had a positive notion towards the concept of super users. An exact definition of the term was no discussed during the dialogue. However, the concept is that certain users who either frequently uses the vessel or has special roles on board (e.g. an ambulance driver) receives special training for a specific use-case, which in turn can alter the operability of the vessel. This would e.g. enable ambulance drivers to utilize a small ferry to transport the ambulance without full manning on board.

In the concrete case of the Sønderho II, when the vessel transports the ambulance, the driver and assistant must be trained super users, so they can be responsible for their own safety and the safety of the patient.

This concept would also be relevant for *ferries on demand* where commuters can call the ferry when needed, and the vessel operates under unmanned under full autonomy.

6 Referencer

[1] Bureau Veritas, »Guidelines for Autonomous Shipping - Guidance Note NI 641 DT R00 E,« Bureau Veritas, Paris, 2017.

[2] DNV GL A/S, »Class guideline - DNVGL-CG-0264 - Autonomous and remotely operated ships,« DNV GL AS, Oslo, 2018.

[3] Lloyd's Register, »ShipRight Design and Construction - Additional Design Procedures - LR Code for Unmanned Marine Systems,« Lloyd's Register Group Limited 2017, London, 2017.

[4] Ramboll, CORE Advokatfirma, »ANALYSE AF REGULERINGSMÆSSIGE BARRIERER FOR ANVENDELSE AF AUTONOME SKIBE AFSLUTTENDE RAPPORT,« Søfartsstyrelsen, Valby, 2017.

[5] Danish Maritime Authority, »Hovedpunkter fra MSC 100 3.-7. december 2018,« Danish Maritime Authority, London, 2018.

[6] *BEK nr 556 - Bekendtgørelse om Meddelelser fra Søfartsstyrelsen D, teknisk forskrift for skibes bygning og udstyr m.v., passagerskibe i national fart,* 2011.

[7] *BEK nr 922 - Bekendtgørelse om ændring af bekendtgørelse om Meddelelser fraSøfartsstyrelsen D, teknisk forskrift for skibes bygning og udstyr m.v.,passagerskibe i national fart,* 2013.

[8] *BEK nr 645 - Bekendtgørelse om ændring af bekendtgørelse om Meddelelser fraSøfartsstyrelsen D, teknisk forskrift for skibes bygning og udstyr m.v.,passagerskibe i national fart,* 2014.

[9] *BEK nr 1352 - Bekendtgørelse om ændring af bekendtgørelse om Meddelelser fraSøfartsstyrelsen D, teknisk forskrift for skibes bygning og udstyr m.v.,passagerskibe i national fart,* 2016.

[10] *BEK nr 516 - Bekendtgørelse om ændring af bekendtgørelse om Meddelelser fraSøfartsstyrelsen D, teknisk forskrift for skibes bygning og udstyr m.v.,passagerskibe i national fart,* 2017.

[11] M. Blanke, M. Henriques og J. Bang, »En foranalyse om autonome skibe,« DTU Elektro, Danish Maritime Authority, Kgs. Lyngby, Valby, 2016.

[12] Maritime UK, »Maritime Autonomous Surface Ships UK Code of Practice - Maritime Autonomous Surface Ships up to 24 metres in length,« MARITIME UK, London, 2018.

[13] HSBA Hamburg School of Business Administration , »Seafarers and digital disruption - The effect of autonomous ships on the work at sea, the role of seafarers and the shipping industry,« International Chamber of Shipping, Hamburg/London, 2018.

[14] *BEK nr 968 - Bekendtgørelse om ændring af bekendtgørelse om Meddelelser fraSøfartsstyrelsen D, teknisk forskrift for skibes bygning og udstyr m.v.,passagerskibe i national fart,* 2012.

[15] CORE Advokatfirma & Cefor, »Maritime autonomous surface ships - Zooming in on civil liability and insurance,« Danish Maritime Authority, Århus, Oslo, Valby, 2018.