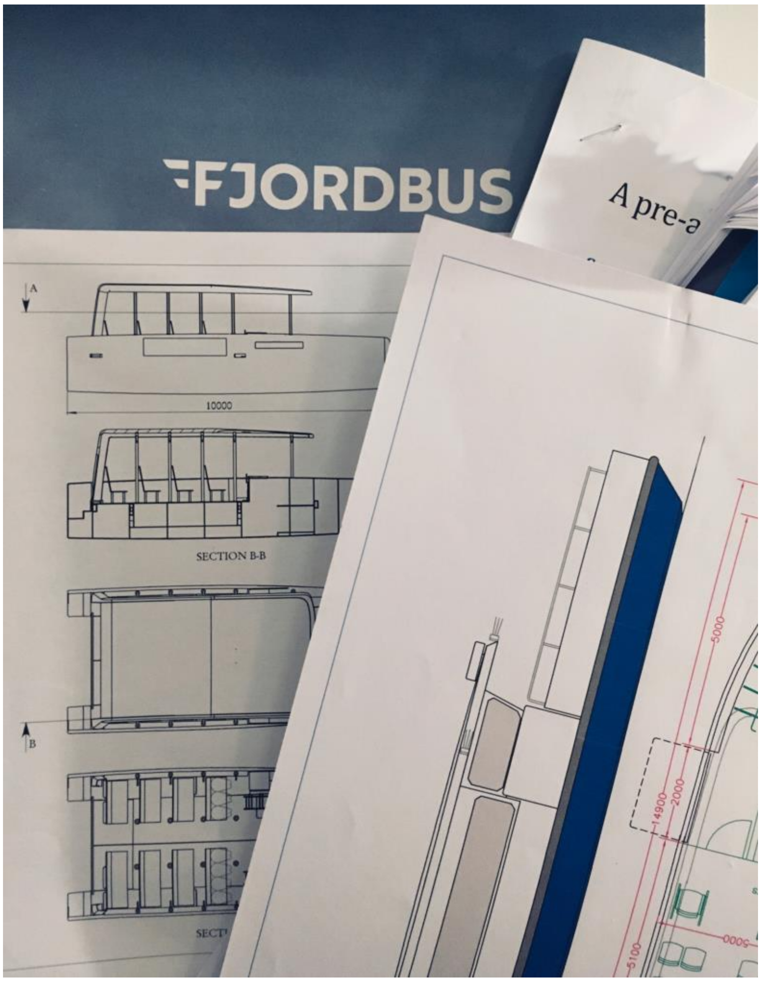

Delegation, Practices and Trust:

A case study about the development of safety for maritime autonomous transport

ABSTRACT

This thesis analyses through the case study of the Fjordbus in Aalborg Denmark, how the development of safety for autonomous passenger ships is a local social practice. By analysing core-concepts from Social Construction of Technology, Actor-Network Theory and Social Practice, I characterise safety through the interconnections of technology, institutional frameworks, and user's involvement in the context of Aalborg. The findings shown that the development of safety depends on delegating to the autonomous navigation technologies the roles of a conventional crew, that defines the efficiency of the technology and the trust that the passengers will stablish with the transport. This interplay is what integrates safety as part of the daily transport practices for the potential passengers of autonomous transport.

Camilo Andrés Perdomo Luengas

Techno-Anthropology

Department of Planning
MSc Master of Science in Techno-Anthropology

AALBORG UNIVERSITY

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Supervisor:
Lars Bo Henriksen

Camilo Perdomo Luengas
Camilo Andrés Perdomo Luengas - 20181717

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By signing this document, each member of the group confirms participation on equal terms in the process of writing the project. Thus, each member of the group is responsible for the all contents in the project.

I dedicate this small work

To those I knew along the way...
Also to those I won't be seeing again,

And to those I want to see once more...

My gratitude, admiration and utmost respect.

Index

Introduction

One of the most common situations a person faces daily is to decide how to move in a city. If the person does not know its destination, the first step would be to find it by using a digital mapping service, a GPS device, or for the most adventurous ones, a physical map or asking for directions to other people. The second step is to find a suitable mode of transport to reach the destination. The selection of the mode of transport depends on the options available to the person. For example, he/she could take a bus, ride a bicycle, drive a car, or simply walk. This choice is based on factors such as accessibility to any of these means of transports, personal preferences, and at least a basic understanding of how to use them.

The accessibility to a means of transport could be related to the population's income (Guzman et al. 2017) and having a driver's license. Personal preferences could be associated to past experiences, such as risk perception while travelling (Roche et al. 2013), while knowledge could be related to understanding how to ride a bicycle or how to drive a car. The combination of each of these factors becomes a transport practice, an embedded decision-making process of routines, meanings, and understandings that any person faces in its daily life to choose how to move around.

A transport practice is not only a micro-social relationship, but it is also related to a historical process of technological transformation in a global context. According to the expert on transport studies Collin Polley:
"Human mobility, and the infrastructures and technologies that facilitate it, are central to all societies, places and time periods. They have been a constant feature within a changing global economic, societal, cultural and environmental landscape" (Pooley 2016, 1-2).

The type of relationship between human mobility, transport infrastructures, and technologies is neither that human need for mobility creates technologies, nor that technological innovation generates social changes. Pooley (2016) claims that "[...]despite technological innovations that produce new modes of travel and communication, old and well-established means of moving from place to place persist and, in some instances, remain dominant" (Pooley 2016, 2).

The historian David Edgerton (2008) supports the notion that technologies contribute to the development of societies. "(…) Technologies appear, disappear, reappear and mix throughout time" (Edgerton, 2008 xii). He illustrates this point by claiming that since the 1960s more bicycles have been produced than cars globally, that the guillotine made a return in the 1940s, and that cable TV declined in the 1950s but returned in the 1980s (Edgerton xii, 2008).

The interplay of well-established transport technologies, transport innovations, and transport practices constructs scenarios of political and legal discussions, technical development, and stakeholders' interests. In the case of transport technologies in urban contexts, we find well-stablished technologies like bicycles, automobiles, and buses. These technologies rely on an acceptable infrastructure and are regulated and managed by public and private institutions. Recently, some of these transport technologies have modified their relationship with the user offering new transport services in cities, such as the possibility to rent them instead of owning them[1].

Regarding transport innovations, several technologies have the potential to modify people's transport practices, institutional and legal frameworks related to urban mobility, and the technological development of transport. Autonomous driving technologies are a case in point. The case study analysed in this thesis delves into an

[1]The scooter operator Voi offers a renting service via smartphone in several European countries (Voi n.d.a).
The company GoMore allows private owners to rent their cars and people without a car to rent one. (GoMore n.d.a).
The company Donkey Republic rents its own bicycles across Europe by using a smartphone (Donkey Republic n.d.a).

autonomous passenger vessel that will be offered as a public transport option in the city of Aalborg, Denmark - the Fjordbus.

Problem Analysis

The socio-technical context of the Fjordbus

In the city of Aalborg, Denmark, several organisations have been working on the design of an autonomous passenger ferry (Fjordbus) to connect two urban areas separated by the sea. The primary purpose of the Fjordbus is to become a public transport solution to connect the population of Aalborg and Nørresundby. The Fjordbus will transport around 25 people and it will carry onboard objects such as baby carriages, bicycles, and wheelchairs (Perdomo 2020)[2].

The proposed initial route will sail between *Musikhuset* in Aalborg and *Fjordspladsen* in the *Stigsborg Havnefront* area.

Illustration 1: Planned route for the Fjordbus. May 20th, 2020 (Google Maps)

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[2] An extended summary of the article *A Socio-Technical User Based Perspective for Urban Transport Solutions - The Fjordbus Case* was published as part of the articles and presentations for the event *Trafikdage*, which was cancelled due to Covid-19.
This working paper analyses how the potential users of the Fjordbus imagine the future of urban transport with the Fjordbus as part of it. We also identify basic aspects of the daily transport practices of the inhabitants of Aalborg and Nørresundby.
See appendix #1.

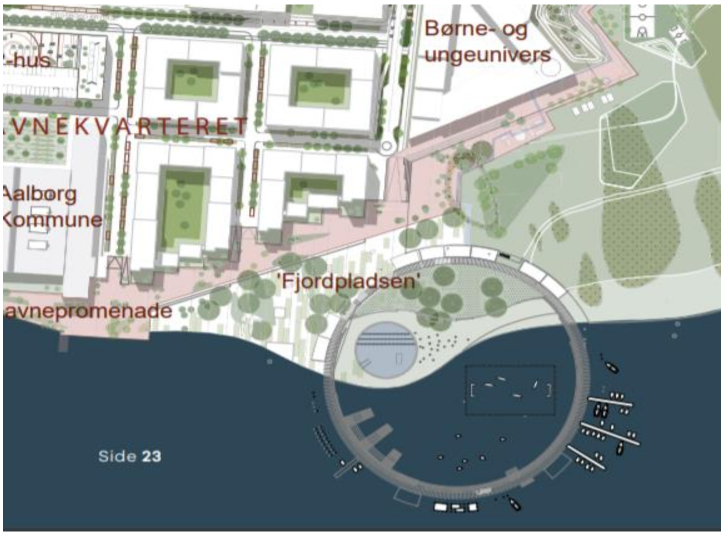

Illustration 2: Planned design of the new harbour area Fjordpladsen in Stigsborg. September 13th, 2020 (D|K2 bygherrerådgivning et al. 2020, 23).

The Fjordbus is being developed by the *Center for Logistik og Samarbejde* (CLS) and is partly sponsored by the Port of Aalborg, Aalborg Kommune and the national organisation ShippingLab Project. CLS is an organisation created by the Port of Aalborg in 2014 that seeks to *[…] "promote bridge building between university-based research and the business environments in our sphere of interest, to create practice-based development and research"* (CLS n.d.a). As far as the Fjordbus project is concerned, CLS has been assembling the necessary technical and institutional stakeholders to materialise an autonomous passenger ship that will use an electric engine and will be integrated into the public transport network of Aalborg and Nørresundby.

As for the financing of the project, it is necessary to explain the role and involvement of the three major economic supporters of the project, namely the Port of Aalborg, the Shipping Lab, and most recently Aalborg Kommune.

The Port of Aalborg has been involved in this project to partially finance the first stage of development of the Fjordbus and entrust CLS the negotiations with the stakeholders (CLS 2020, 14). As for ShippingLab, it is first of all necessary to explain that they are a (...) "non-profit innovation and project collaboration for the partners in the Blue Denmark.[3] [Their] vision is that Denmark will be the driver of the smart shipping of the future" (ShippingLab n.d.a).

ShippingLab pursues the long-term aim of securing Denmark's position at the forefront of the global shipping market. Its short-term objective is to materialise technological innovations in three areas, namely digital ship operations, autonomy, and decarbonization. The goal of ShippingLab and its partners is to *[...] "create Denmark's first autonomous, environmentally friendly ship"* (ShippingLab n.d.a). They have integrated the Fjordbus into their network of projects and have partially financed the first stage of development of the project alongside the Port of Aalborg (CLS 2020).

ShippingLab (n.d.a) has set four major goals in relation the Fjordbus project:

1. Testing of full autonomous functionalities package in completely unmanned ferry
2. Requirements, detailed design, interface documents, installation
3. Sea tests to support fast prototyping with stepwise refinement
4. Final validation and demonstration of autonomous harbour bus

The timeframe for the completion of these goals was established as a four-year development plan[4], from 2019 to 2022. During 2019 and 2020, the testing of the autonomous navigation systems has taken place on a manned ship at the Limfjord in Aalborg and several events have been held by CLS in order to assemble and align the

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[3] Blue Denmark is a conglomerate of organisations and institutions related directly and indirectly to the Danish shipping industry and internationally (DMA n.d.a).
[4] **See appendix #3, The Fjordbus Brochure. As of the time of writing the thesis, a detailed development plan is being designed.**

necessary stakeholders to construct a prototype of the Fjordbus. Throughout 2020, CLS has applied to several organisations related to the maritime industry in Denmark to get funding for the construction of the prototype, whose budget is around 5 million kr.[5] In parallel with the application process, it was possible to contact Aalborg Kommune and present them with the project to be included in the 2021 city budget. After several discussions and meetings, on September 24th, 2020 it was decided that the Fjordbus will received 5 million kr. in funding from the Kommune[6] (Qureshi 2020).

As seen above, the funding during the first stage of development has been obtained from different sources, each with their own interests, concerns and agendas. The execution of the next stages related to the construction of the prototype and all the electronic equipment required, the land infrastructure to monitor and operate the vessel, and the legal requirements to transport people imply that new organisations will be part of the project and new associations will emerge in Aalborg.

The involvement of CLS in the project design and my role as a techno-anthropology intern for CLS gave me the opportunity to understand their approach to the development of this technological innovation from an insider's perspective. In my 9th semester internship report *How to develop an autonomous passenger ship?* (2020), I concluded that the type of project development approach CLS has adopted is based on constant social and technical negotiations occurring in three scenarios.

The first one is the legal scenario in which *Søfartsstyrelsen* - the Danish Maritime Authority (DMA) - has been facilitating the Fjordbus development by solving stakeholders' enquires about regulations and authorising a test area at the Limfjord for a test vessel. The second scenario revolves arounds access to technical research

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[5] None of the organisations decided to grant the funding.
[6] The involvement of Aalborg Kommune in the project is not yet clear due to their late enrolment in the project.

and knowledge on autonomous navigation through Danmarks Tekniske Universitet (DTU), which has conducted several tests of their navigation system at the Limfjord.

Illustration 3: Test session of the navigation system at the Limfjord. June 24th, 2020 (Personal Photo)

The third scenario relates to citizens' acceptance of the Fjordbus. In November 2019, a survey was conducted by CLS and advertised in a digital newspaper to gather empirical information from the inhabitants of Aalborg and Nørresundby about their transport preferences to commute, go shopping, or engage in leisure activities[7]. In one section of the survey, it was asked whether people would like to see the Fjordbus as part of the public transport system. 87% of the respondents agree with the statement[8]. The survey results have been used to legitimate the social acceptance of the project in public events and in the applications for funding.

The interplay of these three negotiation scenarios constitutes a network of technical, legal, and social actors whose participation is defining how the Fjordbus could materialise in Aalborg in the coming years.

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[7] Hentze, N. November 16, 2019. "Alternativ Limfjordsforbindelse: Fjordbussen skal forbinde Nørresundby og Aalborg". Migogaalborg. Accessed December 20, 2019.
[8] See appendix #2, Analysis of the survey results about transport practices and perceptions for the Fjordbus in Aalborg and Nørresunby

The close work with CLS and the Fjordbus stakeholders and the analysis of the development of the project from within the organisations revealed a common topic that caught my attention as a techno-anthropologist, namely the concern for the safety of the autonomous passenger vessel.

In everyday life, safety appears to be a topic relegated to manuals, regulations, procedures, and protocols. However, these types of documentation are the result of the interactions of local and international organisations, definitions on technological innovation, and institutional approaches to safety.

I argue that the interactions among these elements shape the concept of safety as a social construction hinged on technological innovation, regulatory approaches, and users' participation. The outcome of these interactions creates a network of human and non-human actors that shows how the development of safety for autonomous vessels can be understood as a social practice framed in local contexts and dependent on the following factors: technical resources and knowledge; institutional mediation among the shipping industry stakeholders; and the future users and workers that will interact with the autonomous ships.

The purpose of defining safety as a network and as a social practice is to comprehend that it plays a central role in shaping how autonomous technologies could benefit human transport, the future of the labour market, and the relationship between humans and technology. From a techno-anthropological perspective, analysing safety as a social practice and as an actor network shows that, despite the complexities of the technical discussions and the local and international regulations in the maritime industry, the development of safety for autonomous vessels is a cultural process mediated by social acceptance, uncertainty, and local stakeholders.

The case study of the Fjordbus demonstrates that discussions about safety are not exclusively related to assuring that passengers can travel without major concerns.

They also allow to shape a development path that takes into consideration the benefits and risks that this technology brings to society. In order to frame the thesis research question, it is important to start by presenting the topic of the analysis – safety - and the ways in which it materialises within well-stablished transport technologies.

The boundaries of safety in practice and safety integration into transport technologies

The Oxford Dictionary of English (2010) defines *safety* as "the condition of being protected from or unlikely to cause danger, risk, or injury", while *safe* is defined as "protected from or not exposed to danger or risk; not likely to be harmed or lost" (Oxford Dictionary 2010). These two definitions have the problem of being absolutes,
which means that they entail an environment or situation absolutely free of danger.

According to the safety engineer Fred Manuele (2013), a definition of safety should recognise that safety is relative as nothing is completely safe under all conditions. Secondly, it should be considered that safety is "(…) a judgment of the acceptability of risk. A thing is safe if its risks are judged to be acceptable" (Lowrance, W. 1976. *Of Acceptable Risk: Science and the Determination of Safety* [cited by Manuele 2013, 29]).

As Manuele claims (2013), the ontology of safety is that it is linked to a certain degree of risk since it is impossible to create and environment or situation absolutely free of danger. Therefore, a moral layer is added to the abovementioned definition by stating that, in a reality where risks are possible, it is necessary to make a judgment of risk acceptability.

Lowerence (1976), as quoted by Manuele (2013), underlines that on a macro-scale the decision-making process of making a judgment of acceptable risks involves politicians, bureaucrats (experts), and/or scientists. Nevertheless, their role is solely to provide the "results of their studies [to] establish the probability of undesirable events occurring under given circumstances and the severity of their outcomes. Whether that probability and severity is acceptable or not is a societal judgment" (Lowrance, W. 1976. *Of Acceptable Risk: Science and the Determination of Safety* [cited by Manuele 2013, 30]).

A judgement of acceptable risks is therefore a socio-technical process in which science, politicians and experts provide empirical knowledge on the probability and severity of an environment or situation. Ultimately, however, it is society that decides whether the probability and severity is acceptable. In our daily life, we make constant judgments of acceptable risks. Manuele (2013) concludes that "determining whether a thing, an activity, or an environment is safe requires making a judgmental decision. People are risk takers. They make countless decisions to participate in activities for which they judge the risks to be acceptable (driving an auto, skiing, boating, etc.)" (Manuele 2013, 29).

All of these judgments are part of our daily transport practices and are related to our individual preferences, access to means of transport, and understanding of how to use them. It is possible to claim that safety is part of our daily transport practices and decision-making processes and we accept the risks of using a means of transport.

The following example aims at highlighting how safety is intertwined with urban transport and our daily lives and how it is implemented in the local context.

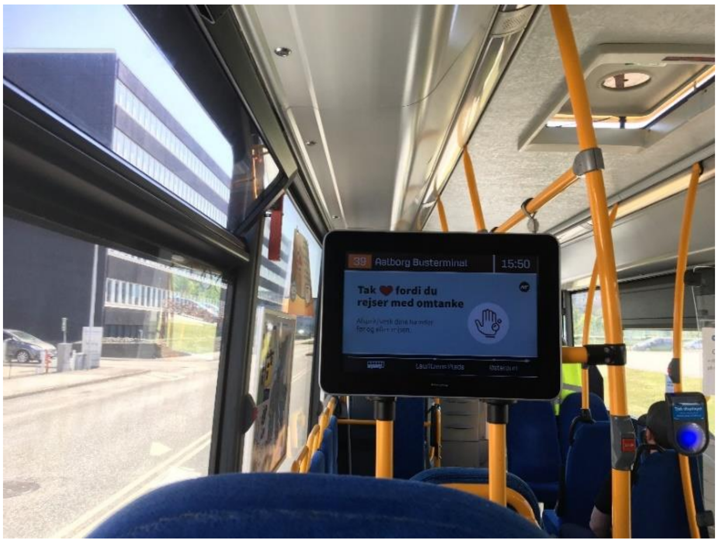

Illustration 4: The interior of a public bus in Aalborg. May 20th, 2020.

Based on the image above, how many objects related to safety can a bus user interact with?[9] A small-sized red hammer (1) is placed next to the window (top left corner) to help break the glass from the inside of the bus in case of emergency. The yellow tubes (2) are designed to facilitate the mobility inside the bus, so passengers can grab them while the bus is on the move. Seats allow passengers to travel comfortably and without any concern about sudden movements in case the bus brakes. The stop button (3) announces when someone needs the bus to stop at a designated location to the bus driver and the other passengers. The card reader (4) (blue circle to the left) allows passengers to be charged for their journey and helps the bus driver ensure that passengers are paying for the journey. Finally, (5) the removable panel on the ceiling serves as an emergency exit in case the bus overturns.

Regarding the screen at the centre of the picture (6), it provides the following information: the bus stops, the number of the bus, the final destination, the time, and

[9] Total of objects related to safety in the picture: six.
Total of objects in the bus: nine.

the weather. It also shows advertisements and information from the bus company. In the picture above, the screen is displaying information related to COVID-19 by thanking passengers for travelling considerately and reminding them to wash their hands before and after each journey.

Besides the six devices related to safety, there are three additional devices that do not appear in the picture but are worth mentioning. Two cameras are placed at the entrance and back of the bus. The third device is a button placed on the back door that can be pushed to open it. Finally, the middle door is equipped with an electric ramp that helps people carrying strollers or wheelchairs access the bus.

Due to COVID-19 in 2020, the Danish government introduced three restrictions to regulate the interactions between bus driver and users. The first restriction forced passengers to get on the bus using the back door instead of the front one. This aimed at minimising the contact between the bus driver and the passengers. The second restriction forbade bus drivers from receiving cash from passengers[10]. The third one came into force on August 22nd making it mandatory to wear a facemask while travelling on buses (The Danish Ministry of Transport and Housing 2020).

Each of the described devices, which are focused on safety on board of the bus, are part of the social practice of using a public bus in Aalborg in 2020. The placing of these objects within the bus results from a process of discussion, testing, legislation, and integration that has been naturalised by its users. The changes that COVID-19 has introduced into the interactions between bus drivers, users, and the space within the bus show that safety is a malleable concept capable of modifying transport practices, technology, and regulations.

[10] During the summer, the first restriction was lifted, and passengers are now allowed to get on the bus using the middle door. However, the banning on receiving cash is still in place.

Problem Statement

The Fjordbus could be considered as a constellation of social, technical, and legal factors that are closely intertwined to develop a technological innovation in the Danish context. A common element in this constellation is safety, which is a transversal theme for technological innovation, regulatory frameworks, and users' involvement for the development of autonomous transport vessels.

Under this scenario, this thesis breaks down safety as a network of technological innovation, legal and regulatory frameworks, and users' involvement. This network shows that safety is a major force for technical innovation, that it depends on a regulatory local culture, and that it has the potential to shape the future of human-technology relation in terms of urban transport and the labour market.

Therefore, the research question that guides this thesis is as follows:
What characterises the development of safety for autonomous passenger ships and how is it being constructed as a local social practice?

Methods

Framing heterogenous actors explaining decisions: The Fjordbus case study

The Fjordbus is a project that was conceived by the minds of two individuals who are neither related to maritime organisations that work with autonomous vessels, nor belong to an educational institution that researches in this field. However, they possess enough social capital to convince the Board of Directors of the Port of Aalborg to support the project in 2017 and participate in its development through CLS, which took the lead in June 2020[11].

A few weeks after I started my internship at CLS in September 2019, I realised that the project was facing three major challenges. The fist one was that this technological innovation project was on the verge of being abandoned for financial reasons. The second challenge was that, despite the appeal of an autonomous ferry for Aalborg, the Kommune was not participating in its initial stages. It is worth reminding that its participation was only sealed in September 2020. The third challenge was understanding that CLS was doing everything they could to find the economic resources, the technical stakeholders, and the support of maritime institutions to ensure the materializarion of the Fjordbus.

As a techno-anthropologist intern with a background in sociology, I contributed to the project by designing, implementing and analysing a survey about the social acceptance of the Fjordbus in Aalborg and Nørresundby. For CLS, the creation of empirical material relying uniquely on quantitative data was more important than conducting ethnographic work about the transport routines of its potential users, as suggested by Pink (2019), or proposing a cultural mapping (Strang 2010) of the public transport of Aalborg in relation to specific social groups (students,

[11] These observations were recorded as fieldnotes during my internship in 2019.

immigrants, elders, people with special needs, etc etc.).

Nevertheless, in the last year I had access to meetings, events and documents related to the project. This allowed me to directly observe and participate in the development of the project. As part of the analysis conducted for my 9th semester report, I came to the conclusion that the potential success of the Fjordbus depends on three factors: the support of legal and institutional organisations like the Danish Maritime Authority (DMA); the access and support of DTU and ShippingLab, and the approval of the project from the citizens of Aalborg and Nørresunby.

The type of knowledge that I have produced about the Fjordbus project is a case study. According to Flyvbjerg's analysis (2006) on the epistemological relevance of the case study, one can claim that it is a type of context-dependent knowledge. My assumptions about the development of the concept of safety as a social construction are the result of my interactions at CLS, with the stakeholders, the review of documentation about autonomous ships, my fieldnotes, and the interviews conducted for this research. One of the purposes of analysing safety as a social construction is to open an ontological discussion in techno-anthropology to reposition safety as a key component in the study of human-technology relations.

The technical features of autonomous navigation, the legal aspects of unmanned sailing, and the potential users' role of autonomous ships are fields of knowledge with their own debates and experts. As mentioned in the Problem Analysis, safety can be understood as the combination of technological innovation, legal and regulatory frameworks, and users' involvement. In order to make sense of these heterogenous factors, it is necessary to analyse different types of documentation and experts' perspectives related to the maritime industry, maritime law, and autonomous transport.

This thesis adopts the methodological approach of data triangulation to analyse what characterises the development of safety for autonomous vessels and to understand how safety can be considered a local social practice.

"Triangulation includes researchers taking different perspectives on an issue under study or more generally in answering research questions. These perspectives can be substantiated by using several methods and/or in several theoretical approaches. Both are or should be linked. Furthermore, it refers to combining different sorts of data against the background of the theoretical perspectives that are applied to the data" (Flick 2007, 41).

Defining the empirical material

The analysis conducted for this research is based on four empirical sources. The primary sources are institutional reports on autonomous navigation. The second source of material relies on semi-structured interviews with experts on maritime law, shipping technologies, consultant organisations specialised on maritime affairs and autonomous transport. The opportunity to contact most of the participants arose from the social capital gained during my internship at CLS. The third source of material relies on books and articles on autonomous navigation, safety and technology, while the fieldnotes that I took during my internship and meetings from September 2019 to July 2020 constitute the fourth source of material.

It is worth noting that by 'experts', I am adopting the definition given by Collins and Evans (2007), who state that: (...) "expertise is the real and substantive possession of groups of experts and that individuals acquire real and substantive expertise through their membership of those groups. Acquiring expertise is, therefore, a social process—a matter of socialization into the practices of an expert group—and expertise can be lost if time is spent away from the group". (2-3).

Therefore, the experts that I contacted and interviewed are people who belong to an organisation or institution related to the maritime industry, autonomous transport, and maritime law.

Methods

Participant observation

As mentioned above, my participation in the Fjordbus project granted me access to documentation related to the project, relevant events and the knowledge of the stakeholders that joined the project. This type of participation on the part of the researcher is defined as participant observation and consists in "(...) a method in which a researcher takes part in the daily activities, rituals, interactions, and events of a group of people as one of the means of learning both the explicit and tacit aspects of their life routines and culture" (Musante 2014, 238).

Semi-structured interviews

Due to the fact that the development of the technology was still in its early stages, the interviews with the experts only revolved around three main topics: technological innovation of autonomous transport, institutional and legal frameworks for autonomous navigation safety, and the user's role in the development of safety for autonomous navigation.

I interviewed six experts in fields such as autonomous transport, maritime industry, and maritime research. The interviews were conducted online due to the pandemic and were all transcribed and categorised[12].

The interviews were conducted applying the semi-structured method, which allows to design the interview as "(...) a sequence of themes to be covered, as well as some prepared questions. Yet at the same time there is openness to changes of sequence and question forms in order to follow up the answers given and the stories told by the interviewees" (Kvale 2007, 65).

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[12] **See appendix C for the interview questionnaires.**

Categorisation

As defined in the Problem Analysis, safety involves the act of assessing the potential risks involved in a given situation. All the discussions about safety presented in the analysis of the Fjordbus case study will refer to regulations and laws that encompass the development of autonomous navigation technologies and the possible risks for its potential users.

As a result of the analysis of the empirical material, I propose the following three categories to help define the development of safety for autonomous passenger ships: (1) Technological innovation; (2) Institutions and regulations, and (3) the users of autonomous transport.

The construction of safety as a local social practice is the result of the interaction of these three categories and emerges from the combination of technological perspectives on the development of autonomous transport, institutional frameworks, and the roles that the users of the autonomous transport will play. I argue that the development of safety for autonomous navigation heavily depends on the following factors: cultural aspects related to trust in institutions and technologies; uncertainty related to how autonomous transport technologies will unfold in society; and the slow technological delegation process between human roles and autonomous technologies.

Theory

The formulation of the research question is hinged on three assumptions about human-technology relations. The first assumption is that this relationship is an on-going process of interactions. The other two assumptions posit that there are human and non-human groups that can equally influence each other and that the actions preformed by technologies and human beings shape reality, in this case safety.

Each assumption relies on a theoretical framework that supports it. My primary objective in this section is to provide an overview of these theories through case studies relevant to this thesis. My secondary objective is to formulate the categories that will be used for the analysis of the empirical material.

Social Construction of Technology (SCOT): It is not all about the brightest minds or an apple falling into ones' head

As mentioned in the Problem Analysis, the Fjordbus is a technological innovation whose realisation depends on finding technical stakeholders, obtaining funding, gaining political support, and being social acceped by the citizens of Aalborg and Nørresundby. However, this is only one of the possible visions of the project's development. From the perspective of the UN Sustainable Development Goals, for instance, the Fjordbus is contributing to achieve goal number 11 by helping create a sustainable city and a more inclusive society thanks to a new transport solution (UN n.d).

One could also claim that the Fjordbus is the materialisation of the efforts of the *Center for Logistik og Samarbejde* (CLS), which has facilitated its creation by acting as a bridge and combining the efforts of Danmarks Tekniske Universitet (DTU), the Danish Maritime authority, Logimatic (engine), and Tuco (ship model).
These claims about the Fjordbus development adopt an institutional and

organisational stance according to which the Fjordbus is perceived as a passive component dependent on political agendas or management decisions.
However, in techno-anthropology and other social sciences, several researchers have devoted their efforts to analysing the history of technological artefacts and have proposed alterative views that position technological artifacts on the same ontological level as policy, regulations, and culture.

The Social Construction of Technology (SCOT) is among the theoretical frameworks that identify technology as a force of social change. "Constructivism is the study of how scientists and technologists build socially situated knowledges and things. Such studies can even show how scientists build good representations of the material world, in a perfectly ordinary sense" (Sismondo 2010 ,71).

Scholars who have worked with SCOT propose concepts that are flexible enough to study technology under the premise that society is a seamless web. "The analyst should not assume a priori different scientific, technical, social, cultural, and economic factors "(Bijker 1995, 15). One of the most prominent case studies that employs SCOT is the history of safety in relation to the modern bicycle (Bijker 1995). Instead of following linear and determinist arguments about the so-called evolution of a model, the modern bicycle model is argued to be the result of the inclusion and exclusion of social groups that have determined the outcome of the design process and the ultimate success of the model. In the case of the bicycle, the social groups that played a crucial role were men, women, children, elders, bicycle manufacturers, engineers and others (Valderrama 2004).

As seen above, the concept of social group is a central component of the SCOT approach. Relevant social groups are the embodiment of particular interpretations: "all members of a certain social group share the same set of meanings, attached to a specific artefact" (Bijker et al. 2012, 23). Another concept worth mentioning is *interpretative flexibility.* "By [*interpretative flexibility*] we mean not only that there is flexibility in how people think of or interpret artifacts but also that there is flexibility in how artifacts are designed” (Bijker et al. 2012, 34). As it will be shown in the analysis, there are several ongoing projects that are researching and developing their own autonomous navigation technologies for projects such as cargo ships, modular design vessels, and public transport. The stages of technological closure and stabilisation -which mark the end of any controversy that relevant social groups might have in relation to an artefact - can be achieved through the use of rhetorical strategies and advertisement, which was a driving force for the development of the modern bicycle model.

Lastly, another key concept proposed by SCOT is *technological frame*. “A technological frame structures the interactions among the actors of a relevant social group. Thus, it is not an individual's characteristic, nor a characteristic of systems or institutions; technological frames are located between actors, not in actors or above actors. A technological frame is built up when interaction "around" an artifact begins” (Bijker 1995, 123).

This thesis seeks to characterise the development of safety for autonomous passenger ships by analysing the Fjordbus as a socio-technical construction emerging from the interaction of different social groups, technologies, fields of knowledge, and culture. The analysis section is based on this concept. The development of safety for autonomous passenger ships is hinged on three types of interactions that make up the technological frame. The first type of interactions are technical ones and involve the social groups specialised in autonomous technologies. The second type revolves around legal and regulatory interactions of experts in the maritime context and autonomous transport, while the third type comprises of users’ interactions with the development of safety.

Bijker (1995) claims that the “[t]echnological frame is a theoretical concept: it is used by the analyst to order data and to facilitate the interpretation of the interactions within a relevant social group. Like other concepts such as "culture" or "form-of-life," technological frame will be most effectively used when the analyst focuses on situations of instability, controversy, and change” (124).

A case study worth mentioning that applies the technological frame and relates to safety is the study of the Challenger shuttle explosion in 1986. Collins and Pinch (2002) sought to determine who was to blame for the explosion of the Challenger shuttle. By applying a socio-technical model to the analysis, they were able to identify that the explosion was the result of (...) “long-running disagreements [among the stakeholders] and uncertainties about the joint but the engineering consensus by the time of the teleconference was that it was an acceptable risk” (55).

The joint or O-ring was a component of the fuel tanks that helped isolate and control the pressure of the fuel. Despite several testings, designs and launches, there were still some doubts about the functionality of the joint for the final launching. Cancelling the launching due to some unproven doubts, however, was out of the question. “Without hindsight to help them the engineers were simply doing the best expert job possible in an uncertain world. We are reminded that a risk-free technology is impossible and that assessing the working of a technology and the risks attached to it are always inescapable matters of human judgement” (Collins and Pinch 2002, 55).

As it appears from this case study, the fieldwork and literature review about technology and safety performed for this research, the notion of uncertain is recurring. As with the Challenger case, uncertainty surrounds the social groups and the technology they interact with. As mentioned above, the role of technology in the interactions among social groups is not passive and technology itself is not an object determined by the subject. Therefore, it is essential to bring up concepts from other theoretical backgrounds that highlight the ways in which technology and social groups can influence each others’ decisions.

Actor-Network Theory: An ontological map whereby human-technology constructs realities

The Actor-Network Theory (ANT) problematises the division humans-nature and separates the knowledge and practices of engineers and scientists from those of philosophers, anthropologists, and sociologists. According to Latour (2005), the main tasks of sociology and other social sciences should be to trace the connections of human and non-human actors that shape the social context.

ANT has developed a broad set of concepts and discussions. For this thesis, I am going to highlight three features that contribute to answer the second half of the research question on how safety is constructed as a local social practice. The first feature is that ANT equally distributes agency among human actors and non-human actors (e.g. technology, concepts, regulations, nature, etc, etc.) (Law, 1992:383).

Once ANT grants human and non-human actors agency, it is necessary to define what human actors share with non-human actors. Latour (1992) analyses the technical development of automated doors to reflect on how humans have delegated the role of opening and closing doors - a task previously performed manually - to a mechanism. "We have been able to delegate to nonhumans not only force as we have known it for centuries but also values, duties, and ethics". (Latour 1992, 157).

We humans expect technology to follow certain behaviours and to perform as we think it should. By doing so, we are creating expectations, which means it can performed well or bad and that it must perform as we wish when we need it. This notion is crucial for the analysis of autonomous transport because, from this perspective, we (human actors) are delegating the values, ethics and duties normally assigned to a captain and the crew, a bus driver, or a pilot to a rather complex set of technologies.

This socio-technical process is shaped by different actors: the technology that enables autonomous transport; the sets of local and international regulations and laws that frame how autonomous technology transport must perform; and the dimension of the users, which encompasses the human roles that autonomous technology is replacing and the technology users in charge of operating these technologies. As Sismondo (2009) claims, "(...) users contribute to technological change, not just by adapting objects to their local needs, but also by feeding back into the design and production processes" (99). In the Fjordbus case, this will be analysed for the third analytical type of interactions among the users of autonomous transport.

The third feature of ANT that I will apply during the analysis is the concept of assemblage. Müller (2015) reviews some of the core notions of ANT, more specifically the concept of assemblage, to claim that it "(...) is a mode of ordering heterogeneous entities so that they work together for a certain time" (Müller 2015, 38). According to Müller (2015), the notion of ordering implies that it is feasible to identify hierarchies among the human and non-human actors within networks.
In summary, this implies that an assemblage of actors can include both human and non-human elements, whose associations are temporal and that can create hierarchies.

The organisation of heterogenous actors in a network enables the characterisation process of the development of safety, which helps answer the first part of the research question. However, in order to answer the second part, it is necessary to incorporate how the human and non-human actors involved in the network for the development of safety give meaning to safety within the technological frame of autonomous transport. For this reason, I will explore below how Practice Theory could help understand how safety encompasses human values and technology.

Practice Theory

Reckwitz (2002) defines practices as "(...) a routinized type of behaviour which consists of several elements, interconnected to one other: forms of bodily activities, forms of mental activities, 'things' and their use, a background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge" (249). These interconnected forms of body-mind-things-knowledge-emotions are not an exclusively human prerogative. These social practices are performed by human and non-humans actors and their scope ranges from micro-social interactions such as boarding a public bus in Aalborg to macro-social practices that shape institutions, regulations, technologies, and politics, as with the case of safety for autonomous navigation.

In another techno-anthropology master's thesis about autonomous ships, Moraiti (2018) explains:
"Through the investigation a conclusion of different realities enacted upon the autonomous ships unveiled. The actual problems resulting to a long term process until the stabilization of the technology are the lack of prescriptive regulations for autonomous ships, a reassuring proof to the potential users that the technology can guarantee their safety, as well as a mutual understanding and clear definition of autonomous ships" (Moraiti 2018, 49).

I argue against considering the development of technology and human-technology interactions as a process of technical and legal stabilisation that generates trust in the potential users. I claim that the development of safety is a driving force for the technical, legal and human factors that are developing autonomous transport. Furthermore, the way safety is being developed depends on the inner social practices of the technical stakeholders, the institutional culture, and the potential users' understandings and expectations on autonomous navigation.
All these three forces - technology, institutions, and humans - are intertwined and shaped in a local context that provides them with an understanding of safety.

Analysis: Characterising the development of safety for autonomous passenger

The characterisation process of the development of safety for the Fjordbus is presented from the perspective of three main factors: (1) The technological innovation, (2) The Legal and Regulatory framework, and (3) The users of autonomous transport.

The purpose of the analysis is to break down how some experts related to the maritime and autonomous transport context define safety and how the development of safety for autonomous technology is a constructed concept that is defined by the interactions of local stakeholders, institutions, technical resources, and the potential users of the autonomous technology.

The technological innovation factors

Understating autonomous technology: let something else do the job by delegating human tasks to an autonomous system - one of the dreams of Western Civilisations

The mere notion of machines operating without any human control whatsoever can be traced back to Greek Mythology, more specifically to the technological invention called automaton. Automatons [...] "were animate, metal statues of animal, men and monsters crafted by the divine smith Hephaistos (Hephaestus) and the Athenian craftsman Daidalos (Daedalus). The best of them could think and feel like men" (Atsma 2017). The range of their functions was wide, from a mechanical eagle for torture (the eagle that tortured Prometheus as punishment for giving the fire to humans without the Gods consent) to Golden Maidens that helped Hephaistos with his household (Atsma 2017).

Taking a long leap in the history of humankind, the participation and role of machines in the production of goods had a major turning point during the 17^{th} and 18^{th} century. The Industrial Revolution initiated a transformation in the relationships between human groups, the economic system, and the technology that contributed to establishing the economic system.

About this transformation process, in The Capital Karl Marx (2015) analysed the implications carried by the technical development of machines for the people who worked in factories during the Industrial Revolution.

"In the first place, in the form of machinery, the implements of labour become automatic, things moving and working independent of the workman. They are thenceforth an industrial *perpetuum mobile*, that would go on producing forever, did it not meet with certain natural obstructions in the weak bodies and the strong wills of its human attendants. The automaton, as capital, and because it is capital, is endowed, in the person of the capitalist, with intelligence and will; it is therefore animated by the longing to reduce to a minimum the resistance offered by that repellent yet elastic natural barrier, man" (Marx [1887] (2015), ch.15, sec. 3, sub-sec. B)[13]

The ability of machines to produce autonomously without the constant input of the weak bodies of men and women allowed to increase the production and brought about different types of human-technology relations. For instance, one of the consequences of the relationship between technology, the economic system and society has had since the 19^{th} century is massive damages to the planet in terms of industrial pollution due to Co2 emissions from factories (Uekoetter 2009).

[13] I recommend the reading of The Capital [1887] (2015) Volume 1 by Karl Marx to delve into the consequences of the early interactions between production means and the consolidation of the proletariat and bourgeois social classes.

This type of relationship has used technical innovations as a means to solidify political and economic power. Perhaps one of the most notorious examples of this type of relationship with technology occurred in the 20th century with the atomic bomb (Pellegrino 2015).

However, in other spheres of society such as education, public health, communication and mobility, this relationship has contributed to globally increase the average human life expectancy (Roser et al. 2013). It has also facilitated the electrification, supply, and distribution of water to human settlements, which has in turn improved human wellbeing and public health. It has also lead to the development of appliances and digital technologies that have benefited education and human mobility (National Academy of Engineering 2020)[14].

The field of Science and Technology Studies (STS) has analysed and reflected on the active role that technology has played as a force of change in society. In this regard, Feenberg (1991) points out that "(...) the real issue is not technology or progress *per se* but the variety of possible technologies and paths of progress among which we must choose" (3).

The aforementioned outcomes of human-technology relations are only a few examples of the complexities of their development and the social and technical contexts in which they are embedded. Nevertheless, as Feenberg (1991) claims, the paths towards progress that technology embarks on are influenced by factors that are not only technical, but also a materialisation of the moral values of the societies we live in.

[14] The consequences of technological development since the Industrial Revolution is without a doubt a matter of further discussion, research, and reflection. I recommend the book The Age of Revolution: Europe 1789–1848 by Eric Hobsbawm.

The analysis and intervention on the choices we (society) make in shaping a path towards progress are core competencies of techno-anthropology. The inquiries into how humans are shaping the relationship with well-stablished technology and new technology, such as autonomous technology, are relevant to discuss and shape a path towards progress that benefits human societies and the environment.

Winner (1986) reflects that society usually intervenes actively over a technology once its side effects or secondary consequences start to emerge: "(...) it seems characteristic of our culture's involvement with technology that we are seldom inclined to examine, discuss, or judge pending innovations with broad, keen awareness of what those changes mean. In the technical realm we repeatedly enter into a series of social contracts, the terms of which are revealed only after the signing" (9).

The case of the autonomous passenger ferry (Fjordbus) provides an opportunity to contribute to a path towards progress that can benefit society and to start setting a discussion scenario in the Danish context to understand the drivers and barriers of the development of autonomous navigation. The idea of an automaton - a machine in which we humans delegate part or the totality of the tasks related to work, transport, leisure activities, household, etc. - implies making decicions over different development paths. Ever since the Industrial Revolution analysed by Marx (2015), our societies have already gone through two other Industrial Revolutions and we are now on the verge of a Fourth Industrial Revolution that considers autonomous technologies as a force of change.

The socio-technical context of the Fjordbus within the Fourth Industrial Revolution

Klaus Schwab, founder and Executive Chairman of the World Economic Forum, defines the industrial revolutions as follows: "The First Industrial Revolution used water and steam power to mechanize production. The Second used electric power to create mass production. The Third used electronics and information technology to automate production. Now a Fourth Industrial Revolution is building on the Third, the digital revolution that has been occurring since the middle of the last century. It is characterized by a fusion of technologies that is blurring the lines between the physical, digital, and biological spheres" (Schwab 2016).

It is worth remembering what Edgerton (2008) mentioned about the appearance, disappearance, and reappearance of technologies throughout history. Even in the 21st century, while autonomous transport technologies are a reality, there are places like India where a camel, a yak, or an elephant are an option for transport due to geographical conditions, culture and human relationship with nature (Menon 2014). The Fourth Industrial Revolution started during the third one, therefore the combination of technologies, development paths, and ideas are intertwined. According to Schwab, the Fourth Industrial Revolution "(...) will fundamentally alter the way we live, work, and relate to one another. In its scale, scope, and complexity, the transformation will be unlike anything humankind has experienced before. We do not yet know just how it will unfold, but one thing is clear: the response to it must be integrated and comprehensive, involving all stakeholders of the global polity, from the public and private sectors to academia and civil society" (2016).

The Fourth Industrial Revolution, as it is portrayed, promises changes in our daily lives, but it is unknown how these changes will unfold. A promise of change mostly based on the belief that technology carries those changes by itself is called technological determinism. Sismondo (2009) claims that approaches as the ones proposed by Marx [[1887](2015) or Winner (1986) are examples of technological determinism. For the social division proposed by Marx, the class that owns the technology to produce goods is the class that controls the economy. In Winner's (1986) case, the approach is more gradual, so the role of technology will depend on the particularities of the political and social context (Sismondo 2009, 97).

As for the case study being investigated, the Fjordbus has been advertised as an emission-free and autonomous vessel that will sail in Aalborg from 2022 (CLS 2020, 3). It will help to promote tourism and solve traffic problems for the new urban area in Stigsborg.

Alongside the Fjordbus, the company Holo has been testing an autonomous bus in Aalborg Øst. According to one of the company directors, the importance of developing autonomous transport solutions has three main benefits:

"There is the environmental angle, in terms of making a public transport more efficient and making peoples transportation more efficient in general and making it electrified. Then there is the cost perspective, we usually have this number in our heads, that 70-80% of operating a bus line in Denmark is the driver. So, if we make it autonomous, we can really make some progress in many ways. Generally, try to launch a service that is as inexpensive as public transportation, but has a service level that is more comparable to a taxi over time " (Bering Interview).

Environment, efficiency, and costs - these are the factors that shape the benefits of autonomous transport solutions in urban areas. By using an electric engine, the vehicle is not producing Co2, thus not polluting air. Efficiency refers to the fact that the bus has the potential of providing a better service than public buses. As explained in the quote above, the delegation of the driver role to an autonomous technology allows to achieve cost efficiency.

The following statement captures the essence of safety in relation to an autonomous vehicle.

"We have to be, at least, as safe as a vehicle that are currently on the street, that is also as we evaluated, especially in Denmark where there is a system that we have to compare on like a mini-bus" (Bering Interview).

The premise on which safety is predicated is that autonomous transport must be as safe as conventional transports. The delegation of the roles and functions of a driver or a captain are translated into a set of technologies that will carry out ethical responsibilities of transporting people. In this regard, it is important to introduce the approach of the International Maritime Organisation (IMO) to autonomous navigation development.

IMO have worked on a four-degree scale to assess the technical development of autonomous ships.

"Degree one: Ship with automated processes and decision support. Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated and at times be unsupervised, but with seafarers on board ready to take control.

• Degree two: Remotely controlled ship with seafarers on board. The ship is controlled and operated from another location. Seafarers are available on board to take control and to operate the shipboard systems and functions.
• Degree three: Remotely controlled ship without seafarers on board. The ship is controlled and operated from another location. There are no seafarers on board.
• Degree four: Fully autonomous ship. The operating system of the ship is able to make decisions and determine actions by itself" (WMU 2019,14).
As it can be perceived from the IMO scale, the development of autonomous ships works as a guideline more than a strict manual that a stakeholder should comply with. Nevertheless, the development of this technology goes at a slow pace and the total delegation of roles to machines will take time[15]. "There is still gaps on what we can improve and the capabilities of the vehicle's, we still have a safety drive in the vehicle. Of course, we are collecting data to show on an operational way that we are safe, that we operate within the rules" (Autonomous Transport expert).

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[15] The IMO autonomy scale is based on the Society of Automotive Engineers scale for on-road autonomous scale that, instead of four levels, has six. (WMU 2019,14)

Technical capabilities refer to the development of hardware and software that can quickly process the surroundings of the vehicle to make the travelling experience similar to travel in a convectional vehicle in terms of safety and travelling.

"In our industry, everyone is working towards this goal of technical safety, and there is two ways to achieve that, there are two factors. One is the capabilities of the technology and there is the complexity of where you are driving. So, if the complexity of the road is low, it is possible to take the safety driver out, if there are no pedestrians, bicycles or cars. But we can control the environment, so we can reduce the complexity of the environment. We expect that cities will reduce car traffic and speed limits and will narrow the roads. So that will make it easier for us to operate." (Bering Interview).

The capabilities of autonomous technology and the complexities of the terrain where the vehicles travel are two factors whose interactions with local transport policies can determine the success of a transport, as the quote above suggests.

What makes the Fjordbus an autonomous vessel?

Two technical features are responsible for making the Fjordbus an autonomous ship, namely a battery-powered engine and the navigation system.
The electric engine, developed by the company Logimatic, is powered by a battery system and does not generate CO2 emissions, making it environmentally sustainable and cost-effective in terms of saving costs related to fuel consumption and maintenance. The implementation of an electric engine in a vessel requires developing the necessary infrastructure to make it possible to recharge the battery system at the fjord. Additionally, it will be required to comply with regulations and to the design of the vessel in terms of the weight distribution of the engine and to

develop the interfaces to communicate with the autonomous navigation system.[16]

The second technical feature is the autonomous navigation system, whose goal is to be as safe and reliable as a ship operated by humans. Danmarks Tekniske Universitet (DTU) is the institution on charge of developing the autonomous navigation system for the Fjordbus. They have researched about their technical approach to develop the navigation system, as well as tested it in Aalborg and Fyn. For DTU, one of the most prominent challenges for the navigation system is the interactions of the vessel with the surroundings:

"Safe navigation requires very high confidence in object detectability. Objects that are temporarily or permanently invisible on radar, and do not transmit AIS [Automatic Identification System] messages, need particular attention. Vision is an obvious choice to detect such objects, similar to the role of human outlook. It is essential to have robust and reliable methods for detection available that do not miss any objects that could constitute a navigational risk" (Schöller et al. 2019,1).[17]

The detection of objects through devices has clear limitations. Therefore, further developments are required before delegating the human task of detecting objects to an automated system. In order to accomplish this, DTU is using a system of cameras that detect light in different settings.[18]

The navigation system depends on two technologies, namely the navigation camera

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[16] Unfortunately, I was not able to gather written content about Logimatic electric engine for the Fjordbus. However, they have been participating in most of the project's meetings and other events related to the Fjordbus.

[17] Frederik Schöller, Martin Plenge-Feidenhans, Jonathan Stets, Mogens Blanke."Object Detection Performance for Marine Autonomous Crafts using Ensemble Models" (unpublished manuscript, October 11 2019), Article draft for the International Journal of Control, Automation and Systems.

[18] A very concise definition of light is a type of energy "[...] to which the human eye is sensitive and on which our visual awareness of the universe and its contents relies". The human eye is sensible to certain types of light from a wide range of the light spectrum. This implies the existence of types of light that the human eye is uncapable of percieving, such as infrared light (Law & Rennie 2015).

system and the software that processes the images and videos recorded by the cameras.

The first technology is a set of cameras that can capture three types of images for the detection of objects at sea. There are three types of light that the cameras can capture. Near-infrared (NIR) and long-wavelength infrared (LWIR) images capture light on a spectrum and at distances that are impossible to perceive for the human eye. The third type of images captures colour images that fall within the visible range and can therefore be detected by the human eye (Stets et al. 2019, 2).

Illustration 5. The three distinct types of cameras installed in water protection cases. From left to right: NIR, visible range, LWIR, NIR and visible range (Stets et al. 2019, 4).

The cameras have been tested under different light conditions to gather data and compare the capabilities of each camera. Stets and others (2019) compared and analysed the three types of images in two different light conditions.

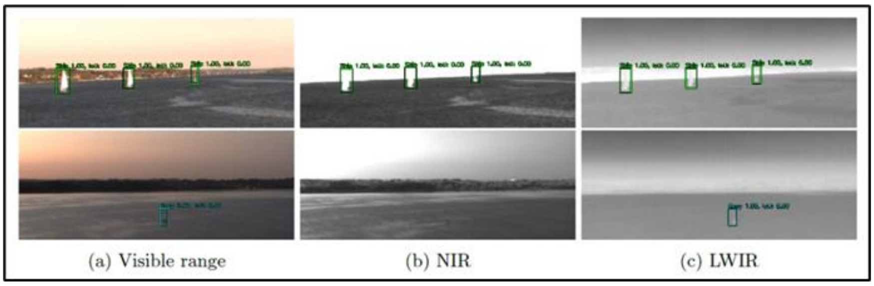

Illustration 6. Pictures taken by the camera system at noon (first row) and after sunset (second row) (Stets et al. 2019, 7).

The first row includes pictures taken at noon. They show that the Visible Range images (within the human eye light spectrum) and NIR images are better compared to the LWIR. The second row includes pictures taken 30 minutes after sunset. They show that the LWIR images have superior image quality than the visual and NIR images (Stets et al. 2019, 7).

Regarding safety as part of the design of hardware within the maritime industry, one of the experts said: "In maritime systems when we talked about technology, we distinguish have the Safety Integrity Level (SIL). It is a system to define safety requirements for control systems, sensors, and all sorts of technical aspects. For example, if I have a propulsion engine, a gear box, and a propeller. There are certain safety requirements for the systems to be operating" (Abildsten Interview)".

This quote shows that the design and construction of hardware highly depends on specific regulations. One can claim that safety influences the design and construction of systems from the start. Therefore, the cameras system that are being tested are being designed to be safe.

The second technology required for the autonomous navigation of the Fjordbus is a machine learning system called RetinaNet Convolutional Neural Network (CNN). In a nutshell, machine learning (...) "is based on algorithmic programmes that recognize patterns themselves based on statistical relationships" (WMO 2019, 10). The amount of pictures taken by each camera is enormous, generating high quantities of information that needs to be processed to make the ship aware of its surroundings. The CNN is a type of machine learning designed for navigation using the cameras system to detect and classify objects into images and videos. This system organises the images at higher speed and has a better performance than other types of CNN systems (Steds, et al. 2019, 2).

Illustration 7. Cameras system before being mounting in Faaborg. July 2020 (Tuco Marine ApS 2020).

As mentioned above, DTU has been researching and testing the cameras system and the Retina RetinaNet Convolutional Neural Network for the project. However, there are other approaches to autonomous navigation that are worth mentioning to exemplify other possible technical paths. In 2016, the Finnish government conducted a cross-disciplinary research named Advanced Autonomous Waterborne Applications (AAWA) Initiative, whose aim was "(...) to produce the specification and preliminary designs for the next generation of advanced ship solutions" (AAWA, 2016. 5). Regarding the technical approach to an autonomous navigation system, they also used a cameras system because:

“They are cheap (with some exceptions), small in size and durable, and can provide very high spatial resolution with colour information for object identification. True night-vision is possible with thermal IR images and a pair of cameras can be used in a stereoscopic configuration for (limited) 3D sensing. Due to the huge range of both commercial and niche applications, camera technology is still constantly improving. The large existing knowledge-base on visual analysis algorithms provides many potential solutions also for marine Situational Awareness”[19] (AAWA, 2016, 23).

[19] The incorporation of economic factors to justify the use of cameras was an argument that I could not find neither in the Danish documentation analysis nor during the fieldwork.

This section has shown that the autonomous navigation system of the Fjordbus comprises of both the camera navigation system and the machine learning system. As shown above, this system is being tested and the approach adopted by DTU is just one of the possible development paths for the navigation system. One of the most critical aspects of the development of digital technologies for autonomous navigation is the cyber-security of these systems. In this regard, the following quote illustrates the technological frame of maritime autonomous navigation technologies:

"I do not think to invent new digital technologies. We already have a lot of security methods we can apply. It is a move forward towards what we are used to do in the maritime context. But if you take a look at what has been happening in the military, the State, IT security. There are a lot of requirements coming on and there is a lot protection against hackers. The shipping business is lagging behind on implementing IT security. Because a ship was to be considered a closed environment, so nobody could enter it. But nowadays we know it can be done. Even if you do not have internet access people could jump with a piece of tech or an employee who was sacked and is against the organisation, he could do harmful things before leaving the ship. There is a lot of IT security aspects that we have to implement " (Abildsten Interview).

Apparently, the implementation of IT security technologies in the maritime context faces more human and regulatory challenges than technical ones. The task to integrate technologies through regulations and with the support of the people within the maritime industry may be complicated, as it will be discussed in the next section of the analysis, devoted to the institutional and regulatory interactions that construct safety.

The Legal and Regulatory framework

As mentioned in the previous section, the International Maritime Organization (IMO) proposed a four-degree scale to assess the autonomy that a ship can achieve. This institution is an agency created by the United Nations and pursues the mission of "(...) creat[ing] a regulatory framework for the shipping industry that is fair and effective, universally adopted and universally implemented" (IMO n.d.a). As part of the process of creating regulations, they are also implicitly creating definitions that ultimately determine what is legal or illegal and what is required for a ship to be considered autonomous or not.

However, for the development of autonomous navigation, "(...) there is not much institutional development. What is happening is the development of concepts such as the one you are working with at the Limfjord. In Norway they have some pilots, also in the UK. So, what we have are projects that are being developed mostly by private entities, sometimes with funding from public agencies to support them. And the arrangements that exist with respect on how to govern the implementation of this solutions. I think they are not in place mostly, because autonomous navigation still not well regulated by the IMO, and because is not clear what the rules are about autonomous vessels, it is not possible for these pilots to go to the market" (Coehlo Interview).

Throughout my experience with the Fjordbus at CLS, I noticed this absence as well. As a techno-anthropologist, I was interested in getting an understating of the regulations concerning the potential passengers of autonomous vessels. However, there was no detailed information about any sort of regulation on this matter. What most of the experts and my own inquiries about this matter made clear is that the level of safety of an autonomous vessel must be equal to that of a manned vessel.

In the scenario being investigated, "(...) so far I would say the institutions are not developing because that would be the last moment. Right now, what is being developed is the technology, the financial support and the feasibly on the technical and economical" (Coehlo Interview).

This also implies that the development of regulations, laws and further institutional frameworks will be the result of those autonomous navigation projects that manage to be successfully designed and implemented. In this regard, projects like the Fjordbus contribute to at least setting the discussion about developing an autonomous maritime public transport solution and to localise the discussion in the Danish context. The importance of developing local solutions is a way to push and facilitate discussions on how to implement regulations and laws to enable autonomous navigation at a national and regional level.

"The IMO is responsible for regulating ships and they are developing protocols already. But they are an international organisation, and their work is rather slow. Then you have regional arrangements and local arrangements, that narrow down the scope of those general norms" (Coelho Interview).

How could safety for an autonomous maritime passenger vessel be developed?

As mentioned in the first part of the analysis, the IMO (2018) proposed a four-degree scale to assess autonomy for Maritime Autonomous Surface Ships[20] (MASS). From this scale, I have been able to identify two major findings about their approach to the development of safety for autonomous ships. The first one is that the roles performed by the crew onboard will gradually be replaced by autonomous

[20] The IMO has a list of 11 types of ships such as passenger ships, fishing vessel, general cargo ships and others. The Maritime Autonomous Surface Ships as concept encompasses most of the types of ships. (IMO n.d.a.)

technology. At the same time, new roles for seafarers and new professions will be created outside the ship. Even though the fourth degree states that the ship will be able to make decisions by itself, it will still require human supervision in case of an emergency or situation that goes beyond the capabilities of the navigation system.

This transitional process not only depends on the development of local cases and financial negotiations to allow for the materialisation of autonomous vessel projects, but also on solving inner discussions about current safety regulations for ships. One of the major collections of regulations is the International Regulations for Preventing Collisions at Sea (COLREG) (IMO 2017 (convention from 1972)). Blanke, Hernandes and Bang (2017) found that compliance of these regulations with the current system of algorithms is difficult because "[...] COLREG is situation-specific and even open for interpretation in some areas. The need for algorithms has been known for a long time (Munk, 1989) and numerous studies have been conducted. Alternative algorithms have also been proposed "[...] but the solution to the COLREG algorithm problem is still only at the level of research" (Blanke et al. 2017, 4[21]).

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[21] The report by Banke et al (2017) cited the following references regarding studies about compliance of COLGREG regulations with algorithms.

Lazarowska, A., 2017. A new deterministic approach in a decision support system for ship's trajectory plan-ning. *Expert Systems with Applications,* volume 71, pp. 469-478.

Grinyak, V., 2016. Fuzzy collision avoidance system for ships. Journal of Computer and Systems Sciences International, 55(2), pp. 249-259.

Munk, T., 1989. Damage prevention and control – Obvious areas for marine expert systems. Lyngby, s.n.

Johansen, T.A., Cristofaro, A. & Perez, T., 2016. Ship Collision Avoidance Using Scenario-Based Model Pre-dictive Control. IFAC-PapersOnLine, volume 49, pp. 14-21.

It is possible to claim that one day an autonomous ship will be able to fully comply with the COLREG and decide the best course of action. For the time being, the role of seafarers and professions with knowledge on maritime transport, regulations, and safety will remain crucial. Knowledge and experience on technical aspects of autonomous navigation systems and the ability to take critical decisions when required will also continue to be valuable skills. With time, however, the current tasks performed by the ship crew will be reassigned and new tasks and knowledge will be added to their jobs, thus adding new roles to the profession of seafarer.

The World Maritime University (2019) has identified two technological trends that represent this transition within the shipping industry. The first trend entails the design and development of autonomous ships. This is the case of Yara Birkeland autonomous ship, "(...) which is designed to operate autonomously, with or without a crew on board" (WMU 2019, 14).

The second trend is the digitalisation of existing cargo ships. The process of digitalisation is related to "[...] increased computerization of systems, possible fuel shifts and increased monitoring of engine and navigational systems" (World Maritime University 2019, 15). One could claim that the digitalisation of

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Zhang, R. & Furusho, M., 2016. Constructing a decision-support system for safe ship-navigation using a Bayesian network. In: Lecture Notes in Computer Science (including subseries Lecture Notes in Artifi-cial Intelligence and Lecture Notes in Bioinformatics). s.l.: s.n., pp. 616-628.

Naeem, W., Henrique, S.C. & Hu, L., 2016. A Reactive COLREGs-Compliant Navigation Strategy for Autonomous Maritime Navigation. IFAC-PapersOnLine, 49(23), pp. 207-213.

conventional ships is focused on assisting onboard crew tasks related to the maintenance, navigation and monitoring of the ship. The process of digitalisation is not destroying or replacing human roles, but is supporting them with information that will supposedly improve the performance of the ship and tasks of the crew.

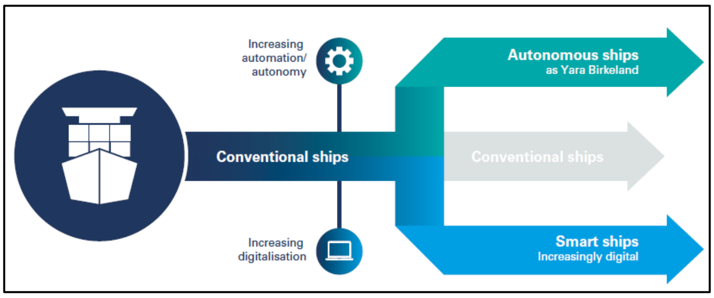

Illustration 8. Bifurcation in development of ships (From World Maritime University 2019)

Regarding the Fjordbus, it will be controlled remotely, while at the same time having a person onboard who will be able to operate the vessel, if necessary, and interact with the passengers. Currently, the autonomous bus in Aalborg Øst relies on a facilitator who performs similar tasks.[22] The Fjordbus will be a combination of the two technological trends mentioned by the WMU (2019), namely a vessel designed for autonomous operation equipped with numerous digitalised systems that will assist and support remote operations.

The technological transition approach also applies to the development of autonomous safety.

"(...) Let's take this analogy with elevators. Back in the old days, there is used to be a person when you entered the elevator and basically handle the elevator. And then, there was a shift towards automated elevators and safety associated with that was a concern of the owner of the elevator that have to assure that people getting into the elevator and using it were not being affected So, in the end there was a safety

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[22] **The role of this person on board has not yet been defined. However, the Fjordbus stakeholders and the DMA agree that this person is essential.**

concern attached to the technology that was being developed. And I believe with autonomous vessels it will be the same. It will not be a copy-paste of the regulations of manned vessels to autonomous, but an understating on how to create a protocol and then the owners, the operator, all the stakeholders that may be involved in the process will negotiate safety protocols to ensure that liability issues when those protocols are broken are clear. Otherwise, there would not be encouragement for companies to invest in that technology if the rules are not clear" (Coehlo Interview).

This analogy allows to identify three stages of the technological development of elevators. The first stage entailed the presence of an operator, the second one marked the technical shift from an operator to delegating the responsibility of assuring the efficiency and safety of the elevator to the owner of the elevator. The third stage occurred when automated elevators became a technology in everyday life.

In the case of autonomous passenger ships, the transition between the second and third stage is critical and will probably take years to consolidate local and regional safety protocols, liability concerns and to develop a legal framework for autonomous vessels.

As showed in this section and until this point, the development of safety regulations involves technology and institutions. As explained below, however, it also requires culture. In the case of safety, culture can be defined as the perception about risks that seems to be a social construction of meanings, routines, knowledge, and emotions.

While conducting fieldwork for this thesis, I came across the concept of precautionary approach, which one of the experts contextualised as:

“The precautionary approach was developed for environmental regulations is relatively new, like 50's or 60 and it came from a regulatory culture. It depends on the society. Some nations are more let's do it and other about preparing, avoiding trouble. I think each country address to this matter according to their regulatory traditions and their own national seek, about how to deal with technology". You see a big bag between continental Europe VS. UK-US approaches. The UK-US approaches are much more like implementing the technology and then fixing it. Europe goes after and tries to learn from their mistakes, so they delay on the implementation of a lot of technology because of the precaution. That means often the regulatory developments stands from experiences that are not happening within the context of the countries that are not implementing them (Coehlo Interview).

In the European context, the precautionary approach is dominant and offers the advantage of analysing others experiences. At the same time, however, it is missing out on the development of local experiences. In the European context, "there is an overall regulatory framework to avoid that the technologies are implemented without safety being considered. You have the European Maritime Safety Agency (EMSA). The EU has an agency on maritime safety, this concern for safety is embedded in the approach of the EU to the maritime industry. They are quite keen ensuring the EU has its own strictly standards for navigation and safety. Also, for historical reasons. The EU has this maritime safety gene very well developed and that is why they taken more precautions than other countries" (Coehlo Interview).

According to the quote above, institutions like EMSA solidify the EU precautionary approach to safety, in comparison to the US-UK approach of learning-by-doing. Both approaches are technological development paths that entail different ethical and political discussions. In the case of autonomous maritime technologies, these discussions can revolve around the progressive replacement of workers in the maritime shipping industry or the integration of autonomous transport in urban areas, like the Fjordbus in relation to guaranteing the safety of passengers.

The next sub-section delves into how safety could be understood as a social practice through the Danish technological frame.

The following testimony from one of the representatives of the autonomous transport company that operates in Aalborg illustrates the inner dynamics of how safety is structured and how different the Danish model is in assessing safety compared to other countries.

“The system in Denmark is different than anywhere else. Denmark is the only place where we do not communicate with the authorities most of the time. When we need to get an approval, we communicate with third parties, safety assessors, Engineering companies. We sent them information about our organisation, and project. And they make a safety assessment of our project.

Then we send a report to the authorities. And the authorities more or less put a stamp on it, at the very end of the process. That process has taken three years for Aalborg! There are no guidelines from the authorities. They do not know what they are supposed to be asking, they do not know about the safety level we are aiming for. It is extremely complicated to do it in Denmark. But this is not because the authorities do not want it. It is because of the law and how it was made back in the day. I think the Danish Road Authority is super frustrated for this process as well. We have talked to them and they are aware of the situation"(Coehlo Interview).

He continues: “In Denmark we go by the rules, we document everything before we start driving, instead of describing it as we go along, and learning together. Norway is a good example [of trying a different approach]. They do not have set rules to operate an autonomous vehicle. They have a framework for it, which is what allow us to operate right now. But they are interested in learning and see what we are actually doing, and then shaping the rules that reflect reality. Should we spend most of our time discussing burning pools of oil at the roof of the bus? Maybe, there are more interesting subjects to discuss. It is important to discuss actual risks than theoretical risks" (Coehlo Interview).

In the experience of this company, the communication process with the authorities is unidirectional, has intermediaries and is not producing practical knowledge on safety risks. On the contrary, in Norway the process is bidirectional, direct and the knowledge that has been produced is related to the on-field experiences of the technologies in that specific context. One could claim that the development of safety is an empirical process that requires open institutional support to facilitate communication and to create guidelines for the development of safety that stakeholders can comply with.

The Users of Autonomous Transport

During this research the topic about the users of autonomous ships has been mentioned throughout two social groups. The crew of the ships, whose role is being delegated to the autonomous navigation technologies opening discussions on how the work market and the education should be aligned to the development of an education that combines knowledge, on IT and sailing in order to guide, monitor or take control of an autonomous ships if necessary. The second group are the potential users of autonomous transport in urban contexts.
In this section both groups are analysed to identify how safety is constructed for them.

The crew on board the ship: Can a whole crew be digitalised?

"How do you handle passengers on an autonomous ship? If you look at the present rules, the crew has to do a lot of things, not only during normal operation, but also when something extraordinary happens. A passenger falling overboard or having an accident. How do you handle that on an autonomous ship? So, that is in itself a very huge case, the passenger handling case according to the rules. It has to be some modifications to the rules, or it has to be some additional rules to autonomous ships." (Møller Interview).

During the Problem analysis it was described how many devices are related to the safety for passengers on board a public bus in Aalborg. It was mentioned that these devices and its use have been routinised by the passengers. In this process people learnt what each one of the devices can do and why are they located in certain places. They learn when they should be used or if the passengers are uncapable of using them the bus driver could use them.

In an autonomous passenger ship that will serve as public transport the creation of safety practices will be a process of developing devices that could be activated by the passengers, by the device itself, and or by the person who will be monitoring the ship. It will also require introducing the regulations to society and to work alongside the authorities, the transitional crew, and the users on pedagogical strategies related to the use of safety devices as well to the handling of extraordinary situations. Still, all the questions mentioned on the last quote do not have a straight answer either in the Danish context or at EU context.

The introduction process of autonomous transport solutions will also require preparing other organisations and institutions to guarantee the safety of the personnel on board and the passengers. “So, if there is a vessel and you see with the camera that someone is on board, and is damaging or sitting there. How could you respond? You cannot send a police car to the water. You need to develop the capabilities of maritime police. You need to develop a whole range of associate solutions and capabilities to answer the new problems that emerge. And sometimes situations are not even detected. The human mind always surprised the regulator. That is why there is always a reactive element to what is happening on terms of the governs of technology.” (Coelho Interview).

In the aforementioned example the police would need to comprehend aspects related to the autonomous vessel, its digital security and the capabilities of the ship i order to intervene successfully if their presence is required.
it is worth to mention a reflection about the welfare of the crew and the obstacles that the implementation of autonomous navigation technologies could bring and could also help to nuance.

“If you read some damage reports from the Danish Commission for Damages of Ships. Then you will see there a lot of variety of reasons for accidents. And some of these are very human... [For example] a common conclusion that I have read is that the crew should be better trained or educated. When you read that 20 or 30 times you think is that the real reason? Or is it an easy explanation? They have also made studies about what happen to people when they are stressed or busy on the ship bridge? These factors could be real causes for the accidents. And you may consider that factors as these could be mitigated by autonomous technologies. I think there will be a balance between safety risks that are coming with the autonomous technologies, but there may be other risks that may be minimised” (Møller Interview).

The occupational safety and health of the on-board crew may be a cause for accidents that supposedly the implementation of autonomous technology navigation could help to reduce by delegating its functions and roles on board. However, as the quoted mentioned it may be also a way to marginalise this sort of problems related to the mental health of the crew. On this regard it is also relevant to consider the wellbeing of the crew and seafarers in general. Mannov (2015) conducted an anthropological work on several merchant ships to research on how piracy and how this social phenomenon affects the lives of the seafarers and their relatives.

Apparently the digitalisation of the roles and functions of the crew requires the development of technology from within the autonomous vessel, the development of the institutions and organisation that would interact with the ship in order to provide and effective such as police, fire departments, ambulances, etc. Simultaneously its is require introducing and teaching alongside authorities and the crew to the population the safety devices the autonomous passengers ship will have on board.

The potential users of autonomous transport: the trust of not even care (at least in the Danish context)

When asked to one of the CEO’S of the autonomous transport company about how they perceived the users, he replied: "There is overall two approaches on how people experience the vehicle. Either you see it as a bus and then you do not really care. You just go in there and do not think it is autonomous. A lot of people are like that because there is a guy in the bus. Then you have more technical or curious people who asks question about the sensors and the setup. When thinks are working people do not noticed as much. When it breaks down, it becomes very clear". (Bering Interview).

Indifference and curiosity could summary a typification of the autonomous buses from the point of view of the CEO. As long as the technology is working people will not notice it. The indifference should not be considered a trivial matter. People use the bus because they know the bus will take them to their destination under certain conditions. The passenger delegate in the transport that responsibility, as well as the passenger has made a risk assessment about their safety on board and has decided that boarding the bus is an acceptable risk. As mentioned in the Problem Analysis, the process of selecting form of transport implies knowledge, emotions, meanings and a context. Therefore, this indifference is related to those factors that will be presented in this part.

"The Danish society has some sort of maritime consciousness. A lot of people have boats, people are used to go to the sea, they are familiar with navigation, they are familiar with taking a vessel. Specially here in Aalborg is very difficult for you not to see a ship, a barge, a canoe every day. And that is an important element to build the trust about this.

The challenge here would be to build on that layer of awareness for worst case scenarios and create trust and create a visualisation of how those worst-case scenarios situations would be address. So, when presenting this project to society, I don´t think that people would be hesitant about engaging with it and using it. But the level of trust that is required with them to deal with an event where normality is broken, the threshold is higher". (Coelho Interview).

The so-called maritime consciousness could be defined as a maritime culture that

encompasses knowledge, relation to things, emotions, and activities. In other words maritime practices that are part of the Danish history and are enrooted to its population. These maritime practices are a distinctive of the Danish population, which means that for the implementation of autonomous ships the citizens will be more aware of any technical or logistic failure.
The knowledge on the maritime context in a society whose transport means works well set initial challenges for the implementation of an innovative transport solution.

"People here are quite time-aware if they got delay, they got annoyed. If they got annoyed, they stop trusting. So, there needs to be this efficiency image. On the positive side, people here are used to navigating on vessels, they like innovative solutions, but they do not like to see their trust broken, and they like to see what precautions are being taken". (Coelho Interview).

The anthropologist Sarah Pink and others (2018) proposed for the her studies on the relationship between a person and the development of autonomous cars is based on contingent circumstances that breaks the approach of a well-defined technological development path. " (...) we understand future automated worlds – not as predictable future scenarios not as predictable future scenarios where new technological innovations will change what people do – but as contingent circumstances where users will draw on and engage the affordances of emerging and as yet unknowable technologies in order to improvise to accomplish mundane goals as they move through everyday environments." (Pink et. al. 2018, 616).

The development of safety may be considered a contingent circumstance for the construction of a technological innovation as the Fjordbus. And it has been shown during this thesis it depends on the context where it is being defined. It depends on the technological frame in the European and Danish maritime context that has set scenarios for different stakeholders, and institutions to start testing and discussing autonomous transport solutions.

Discussion and Conclusions

The development of safety for autonomous navigation ships is the result of the interactions of local and international organisations, definitions on technological innovation, and institutional approaches to safety.

I have argued that the interactions among these factors shape the concept of safety as a social construction of technological innovation, regulatory approaches, and users' involvement.

The outcome of these interactions form a network of human and non-human actors that shows that the development of safety for autonomous vessels could be understood as a social practice framed in local contexts, that depends on technical resources and knowledge; institutional mediation among the shipping industry stakeholders; and the future users and workers that will interact with the autonomous ships.

To the question What characterises the development of safety for autonomous passenger ships and how is it being constructed as a local social practice?

The purpose of defining safety as a network and as a social practice is to comprehend that it has a central role on shaping how autonomous technologies could benefit human transport, the future of a labour market and the relationship between humans and technology. For techno-anthropology analysing safety as a social practice and as an actor network shows that, despite the complexities of the technical discussions, and the local and international regulations in the maritime industry, the development of safety for autonomous vessels is a cultural process mediated by social acceptance, uncertainty, and local stakeholders.

Within the technological frame of autonomous transport in Aalborg it has been shown that safety interconnects technological innovation, institutions, and users. For the technological innovation it was shown that the delegation process to navigation technologies is gradual and it is current success depends on the scenarios (complexities) where the autonomous technologies are tested.

On the institutional and regulatory interactions it was shown that despite the institutional support and concerns on developing safety autonomous transport solutions, there are regional and local issues that needs to be addressed and solved with the purpose of create legal framework for autonomous navigation in urban areas. Finally, the users of autonomous ships, defined as the crew that will assist its operation and that will be monitoring the autonomous ships, will face major changes in their role within the ship, that will demand develop new skills. As for the users in the Danish context their relationship with the sea will be critical to reaffirm their trust in a transport solution as the Fjordbus.

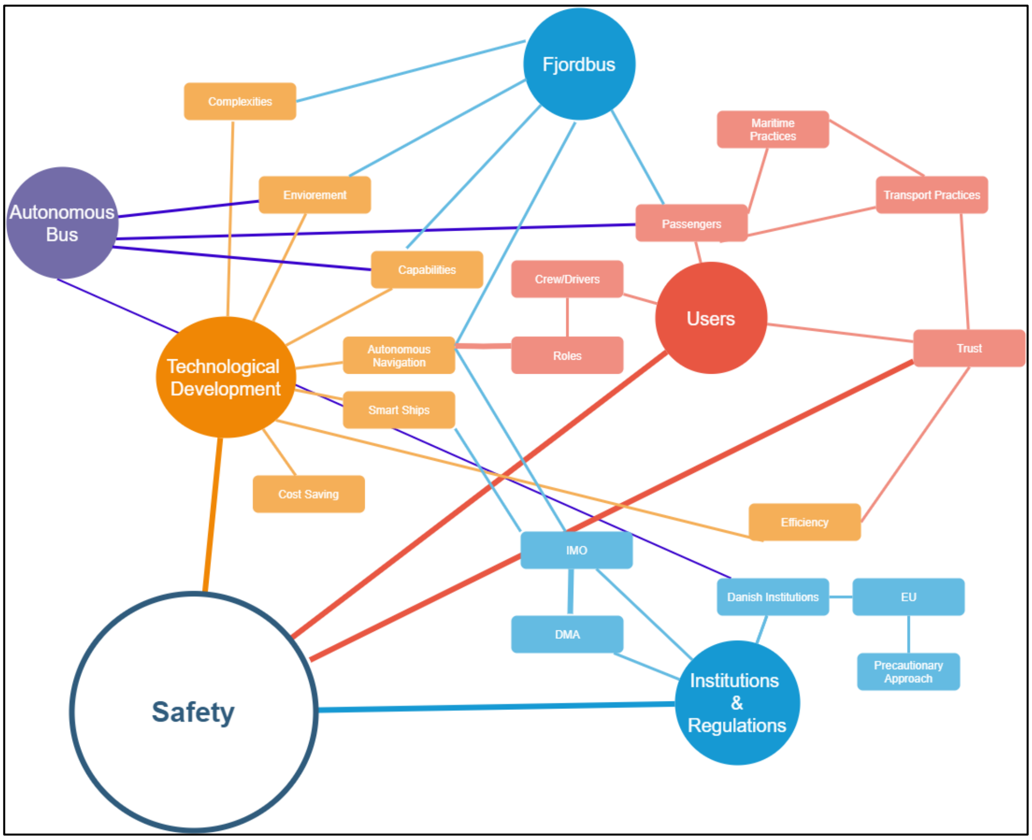

Illustration 9: Safety Interactions Network

Safety is being constructed as a local social practice by five major actors. The technological development; the institutions and regulations; the users; the Fjordbus, and the autonomous bus.

The network shoes that the development of safety is associated to the local context where it is being unfolded. A crucial component that assemblages the passengers and the technological development is the trust on the capabilities of the transport technology, its efficiency on performing as expected, and its integration as a practice of transport, this means the process of integrating the knowledge, sensations, the routines and a meaning towards what using an autonomous transport means for the daily life of people in Aalborg.

On the technological interactions, the concept of delegation to the autonomous navigation technologies the roles and tasks of the crew members is a long-term task, and it will be gradual. As it has been presented there many uncertainties to regarding what can happen on the autonomous transport surroundings, as well as what can happen inside the transport. There is need to keep developing the navigation systems, the integration to institutions like the police department, fire department and emergency services.

For these reasons the presence of on board crew will be essential during the first stage to serve as intermediary among these issues and solve them without hovel disturbing the traveling experience.

Autonomous technology as part of the Fourth Industrial Revolution will play a role in modifying several types of human-technology relations. For instance, in the Fjordbus case the creation of new sets of knowledge that combined knowledge on seafaring and knowledge on digital technologies. It will also create new hybrid labour skills that combined knowledge on digital technologies and knowledge on maritime infrastructure, regulations, transport or logistics. Simultaneously, the workers who does not possess digital skills or knowledge will need to update their skills or could be displaced of their works for lack of competences. The social responsibility of educational institutions to create or readjust academic curriculums that considers this hybridity, to the governments to assess if autonomous technology will solve more problems that it could potentially create, and to assure that the labour market avoids to use autonomous technologies as a mean to deteriorate human work conditions and tasks.

Finally, the interactions and approach this thesis has tried to highlight the importance of integrate qualitative methods to the study of urban transport.
From an anthropological view it is possible to position the researcher in a meso-perspective to understand how knowledge about the values, meanings and practices

are shaped; while support institutions and stakeholders in apply this local knowledge on a successful manner to facilities the introduction and integration of autonomous technology in urban contexts. I think by getting this knowledge a integration process may be highly successful and applied to the safety case it may facilitate to mitigate any major catastrophe in the contingent circumstances in which we as society create a better and safe future.

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