Didrik Kindem Sæther

Leisure Vessel Communication With Autonomous Vessels

A Design study in the Context of Leisure vessel comunication and Navigation in regards to Autonomous Vessels

Master's thesis in Interaction Design
Supervisor: Frode Volden
January 2021

Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Architecture and Design
Department of Design

NTNU
Kunnskap for ei betre verd

Didrik Kindem Sæther

Leisure Vessel Communication With Autonomous Vessels

A Design study in the Context of Leisure vessel comunication and Navigation in regards to Autonomous Vessels

Master's thesis in Interaction Design
Supervisor: Frode Volden
January 2021

Norwegian University of Science and Technology
Faculty of Architecture and Design
Department of Design

NTNU
Norwegian University of
Science and Technology

Preface

This this thesis sets out to help make a solution for leisure vessels to feel safe around autonomous vessels. Use of literature and studies done by others with experience in the field was used to create a solution that aims to help the work along. The work was done by an Interaction design student from NTNU Gjøvik and the assignment was inspired by an assignment suggestion by the faculty of the Institute of design at NTNU.

Being a second-year master student in Interaction design. The writer of this thesis has gathered a lot of experience with design and prototyping. The knowledge obtained through studies and knowledge from having spent a lot of time at sea makes this thesis especially relevant to the writer. Having the ability to work with and design something for a user to make a task as carefree as possible for them is a great inspiration behind the work.

Acknowledgement

I would like to thank my supervisor, Associate professor Frode Volden at NTNU. for help and guidance during this thesis. I would also like to give a special thanks to Thomas Porathe at NTNU for helping to inspire me at the beginning of the project.

I would also like to thank my dad for being there for me and giving me pointers on the prototype. I am sorry I was not able to implement his idea of a way to order food to the boat. Maybe next time. I would also like to thank my mom for constant support. As well as my classmates at the Masterspace at Mustad for not chucking me out a window when I got too annoying. And also for the company and good times. Could not have asked for a better group of people.

D.K.S

Abstract

Autonomous vessels are getting closer and closer to becoming a reality on the seas. But while a lot of work is being done on how they will work and how they will communicate with each other and with other large vessels. there is a group that they share the water with them. This group is the leisure vessels and while larger vessels are being taught and eased into the change. The operators of leisure vessel are not. which is in turn creating a lot of worry and confusion on their part. By creating a way for them to communicate with the autonomous vessels and help them see their intentions. It might help them coexist better. This thesis sets out to help by answering the question "**How can smaller vessels communicate with and know the intentions of autonomous ships?".** this thesis sets out to create a prototype for an application that can help the operators of leisure vessels contact and communicate with autonomous vessels. As well as navigate in a way where they do not have to fear getting in their way and creating unwanted situations.

Scenarios were made based on literature on the subject as well as personas based on information on the users. This was used to create a prototype for a phone application that would help the user see autonomous ships on a map, track them, contact them. As well as set up navigation that would warn them off situations that might arise and help them prevent them from happening. The result of the thesis is a prototype that is ready to be tested with potential users and hopefully can help finalize a solution that can help ease users into the change of autonomous vessels.

The proposed solution needs testing in the field and in a simulator where the user can get the feeling of navigating around actual autonomous vessels. the result does however show that a solution to the research question is possible. but it can only be finalized trough more testing.

Sammendrag

Autonome fartøy nærmer seg mer og mer å bli en realitet på sjøen. Men mens det jobbes mye med hvordan de vil fungere og hvordan de vil kommunisere med hverandre og med andre store fartøy. det er en gruppe som de deler sjøen med dem. Denne gruppen er fritidsfartøyene, og mens større fartøy lærer om autonome fartøy og går inn i endringen steg for steg. Så er operatørene av fritidsfartøy satt på bar bakke. som igjen skaper mye bekymring og forvirring fra deres side. Ved å skape en måte for dem å kommunisere med de autonome fartøyene og hjelpe dem å se deres intensjoner. Kan det hjelpe dem å eksistere bedre med hverandre. Denne oppgaven har til hensikt å hjelpe ved å svare på spørsmålet "Hvordan kan mindre fartøy kommunisere med og kjenne intensjonene til autonome skip?". denne oppgaven har som mål å lage en prototype for et program som kan hjelpe operatørene av fritidsfartøyer med å kontakte og kommunisere med autonome fartøyer. I tillegg til å navigere på en måte der de ikke trenger å frykte å komme i veien og skape uønskede situasjoner.

Scenarier ble laget basert på litteratur om emnet, samt personas basert på informasjon om brukerne. Dette ble brukt til å lage en prototype for en telefonapplikasjon som ville hjelpe brukeren å se autonome skip på et kart, spore dem, kontakte dem. I tillegg til å sette opp navigering som vil advare dem om situasjoner som kan oppstå og hjelpe dem med å forhindre at de skjer. Resultatet av oppgaven er en prototype som er klar til å bli testet med potensielle brukere og forhåpentligvis kan bidra til å fullføre en løsning som kan hjelpe brukere til skifte autonome fartøy.

Den foreslåtte løsningen trenger testing i felt og i en simulator der brukeren kan få følelsen av å navigere rundt faktiske autonome fartøyer. resultatet viser imidlertid at en løsning på forskningsspørsmålet er mulig. men det kan bare fullføres gjennom flere tester.

Table of contents

List of Figures

1. Introduction

The first ships are traced back to 4000 BC (Vance, J. Albert, E. Davies, J. others. 2020) in Norway the first ships that could go on the ocean have been tracked back to 2400 BC (Melheim. 2015) there have been ships roaming the planet for 6000 years. But we are now going into a new frontier. As autonomous ships are becoming a reality in the not-so-distant future. These ships are unmanned and autonomously controlled vessels. Which means they do not have a crew onboard. Seeing how 80% of maritime accidents are caused by human failure (Rothblum, A.M. 2002). One can see how this might be a good thing. In today's plans for autonomous vessels there are still a human overseeing the ship from a remote location. But their job is just to react if for some reason something goes wrong. Docking and undocking from ports and traveling between locations is all done by the ship itself. The ship plots its own course based on where it is going and its surroundings.

But just because there is no human controlling the autonomous vessels. Does not mean humans are not in jeopardy of interfering with the prosses. While larger cargo vessels use chart systems where they can plot in their own course and rout and see other ships position and rout. Smaller vessels like leisure vessels often do not have such equipment. So, for them to know the autonomous ships intentions and contact them is a lot more difficult. Furthermore, it is for the same reason more difficult for autonomous ships to indicate their intentions to the leisure vessels. This is where there a problem that needs to be looked more into and find a solution too. With an estimated one million leisure vessels registered in Norway (KNFB. 2018). During the summer months a lot of these are on the water. Which can result in some serious problems if there are not ways of communication between the parties, that is something that needs to be focused on. Autonomous ships are a part of the future and we therefor need to get in place rules and regulations on how the greater public should interact with them. This is especially important when it comes to the leisure vessels. As for them. Most situations where communication is needed might be their first. So, it is important that proper rules of conduct are in place.

The research question is: **How can smaller vessels communicate with and know the intentions of autonomous ships?**

The focus will be on designing an application that lets someone in a smaller maned vessel know the intentions of autonomous vessels and if needed communicate with sed vessel if needed. The goal is to create an application that can be used by anyone in any size vessel and give some ease of mind to both the operators of the leisure vessels and the companies owning the autonomous vessels.

This thesis focuses on using literature and information created and gathered by experts in the field to design a prototype for an application to help leisure vessels safely navigate the waters as autonomous vessels become a reality. the thesis will go through the background of autonomous and nonautonomous operation and navigation at sea. The methods of creating the prototype will then be presented. It will then go through the result. Explaining the proposed solution. Which will then move over to discussing the proposed solution and its flaws and strengths, ending on future work and a conclusion. The intention of this thesis is to help contribute to the change coming with autonomous vessels to be as smooth and safe as possible for leisure vessels.

2. Background

The topic of this paper is to create a solution for communicating with and knowing the intentions of autonomous vessels at sea. It is therefore important to understand what is meant by autonomous vessels and how the interactions between larger vessels and leisure vessels are today. This chapter will shed some light on this and aims to give an understanding on the background of the research that is the background of what this thesis will be looking into

2.1. Autonomy

To best understand antonymous ships and why there needs to be a communication solution. It is important to know what autonomous means. The most basic definition of something being autonomous is for it to be self-regulating and self-governing (Parasuman and Riley. 1997). This means that for something to be fully autonomous. it operates without human interaction and makes its own decisions. Most autonomous objects today fall somewhere between being fully autonomous and manually operate (Steven. Nazir and Sharman. 2019).

There are different scales of autonomous operation levels in use. One of them is PACT. Originally created for aircrafts. It separates autonomy into three modes, (1) Human command, (2) Assisted and (3) Automatic (Bonner, Taylor, Fletcher, and Miller. 2000). These tree modes are separated into 5 levels of autonomy. Ranging from assistance in the form of advice to fully autonomous. These modes describe the degree of computer interaction with the system. Where this differs from what is intended for ships is that even at the fully autonomous level. They still require a pilot to monitor the computer.

In the case of autonomous cars. The levels are a bit different (Ahvenjärvi. 2016). The Society of Automotive Engineers (SAE) has proposed the 6 levels of autonomous driving. Going from (0) No automation to (5) full driving automation.

(0) at most has audible warnings for the driver. Such as warning the driver they are crossing lanes or are about to hit something. But it will not take any actions to prevent this. But relies fully on the driver performing all tasks.

At (1) the vehicle can control and intervene to some degree. It can control at what speed the vehicle is going and adjust that speed dependent on traffic. This includes breaking when traffic slows down in front of the vehicle. The vehicle is also able to perform minor steering maneuvers if the vehicle is veering a bit to one side. The vehicle however cannot perform more than one task at the same time. Which means the driver still has to keep their attention fully on what the vehicle is assisting with.

When it comes to level (2) the vehicle starts to share the task of driving with the driver. The car at this level can take care of both controlling speed and following the road by combing cruise control and lane keeping. The driver still needs to keep their attention on the road and the surroundings. As the car cannot make evasive maneuvers if an obstacle suddenly appears

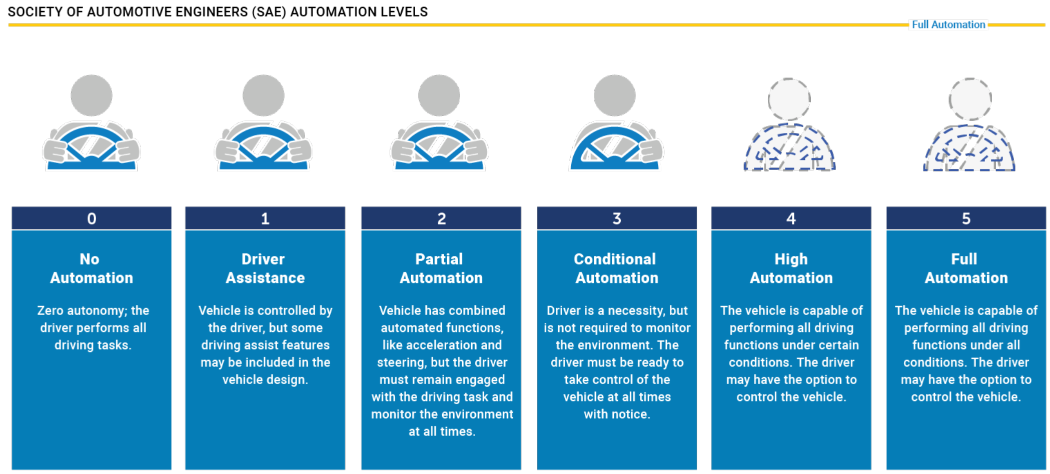


Figure 1 SAE automation levels

At (3) this is where the vehicle starts making decisions. Instead of correcting the speed as it approaches a slow-moving vehicle. I will instead pass it. At this level, the vehicle is able to control speed, steering, and breaking. Coupled with its ability to scan its surroundings. It can change lanes and follow the road for as long as the driver might want. It does however not have the ability to follow a rout. It will just keep following the road until the driver takes over control and changes the rout. It also is not able to make decisions that will have it exit the road. In an emergency situation it can only break or change lanes as long as sed lane is not the opposite lane

Level (4) is when the relationship between machine and man is skewed more to the machine then the man. At this level the vehicle does most of the work and the driver only needs to take back control in very serios situations or if the vehicle requests it. The vehicle does however have the ability to bring itself to a safe stop if necessary. At this level, the car will steer, break, accelerate and monitor the environment and make decisions based on this information. It can handle complex driving situations like rerouted roads because of construction. At this point the vehicle can follow the alternate route even though it means it must go outside the normal confines of the road

The last level (5) is where the vehicle is fully autonomous. At this level. The vehicle in theory needs no steering wheel, pedals, or buttons. The vehicle can make its own decisions based on its surroundings and take the appropriate action to deal with it. This means that there never is any situation where a driver must intervene. The vehicle can react to even the most complex situation.

While the automotive industry has done a lot of work on automation over many years. The maritime industry has only recently introduced similar framework. One of these is The International Maritime Organization (IMO) which came with similar framework in 2018. They separate it into:

- Ship with automated processes and decision support: Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated.
- Remotely controlled ship with seafarers on board: The ship is controlled and operated from another location, but seafarers are on board.

- Remotely controlled ship without seafarers on board: The ship is controlled and operated from another location. There are no seafarers on board.

- Fully autonomous ship: The operating system of the ship is able to make decisions and determine actions by itself.

(IMO. 2018)

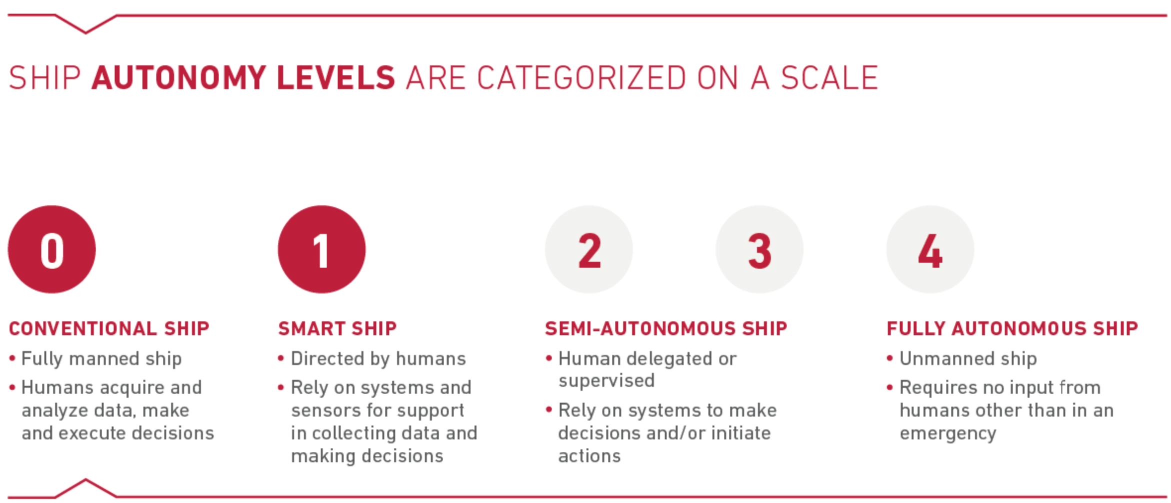


Figure 2 Ship Autonomy levels

Two of these stages at first glance is not autonomous. As a remotely controlled is still controlled by a human. But by Remotely controlled they mean the vessel operates autonomous but with a human controlling that nothing is going wrong. Ready to take over control if the situation calls for it, similar to a level 3 autonomous car. At first there will also be seafarers on the ship who are also able to intervene if the situation calls for it. As the vessels get to a higher level of autonomy. That will be faced out and the ships will be unmanned with someone controlling it remotely. (Richards and Stedmon. 2016). The end goal is to make ships that are fully autonomous. that need no one to control them or watch over them. Companies like Kongsberg Maritime and Rolls-Royce have been working towards this for over 15 years (KONGSBERG MARITIME. 2020) so far one of the only results is the YARA Birkeland which is scheduled to be in testing from the end of 2020 (Maritime. 2018)

2.2. SOLAS and Non-SOLAS vessels

Safety of Life at Sea. Better known as SOLAS is an international convention from 1974 that applies to primarily all ships larger than 500 tons and any passenger ship engaged on an international voyage (Anish. 2020). A SOLAS vessel must follow safety guidelines when it comes to construction, equipment, and operation of the vessel. They must also use AIS (Automatic Identification System) to transmit their position, also other information like identity, speed, and course (Porathe. 2018).

A SOLAS vessel also must make a voyage plan before a voyage. Showing their planed route from port to port.

Non-SOLAS vessels on the other hand are smaller vessels, such as motorboats, sailboats, kayaks, fishing boats, etc. these vessels do not have to have components like AIS or other electronic communication equipment. The only requirement is that they need to use lanterns when it is dark, or visibility is low. The rules vary from vessel to vessel. As an example. A small boat under 7 meters is required one white 360-degree lantern. While a sailboat is required a green light on starboard side, a red on port side. A white 135-degree lantern in the back and a 225 degree one on the top of the mast. Plus, a 360 degree one if it is anchored (RS. 2017). By the lanterns being different colors or covering different degrees. Other vessels can more easily deduce what direction the boat is facing.

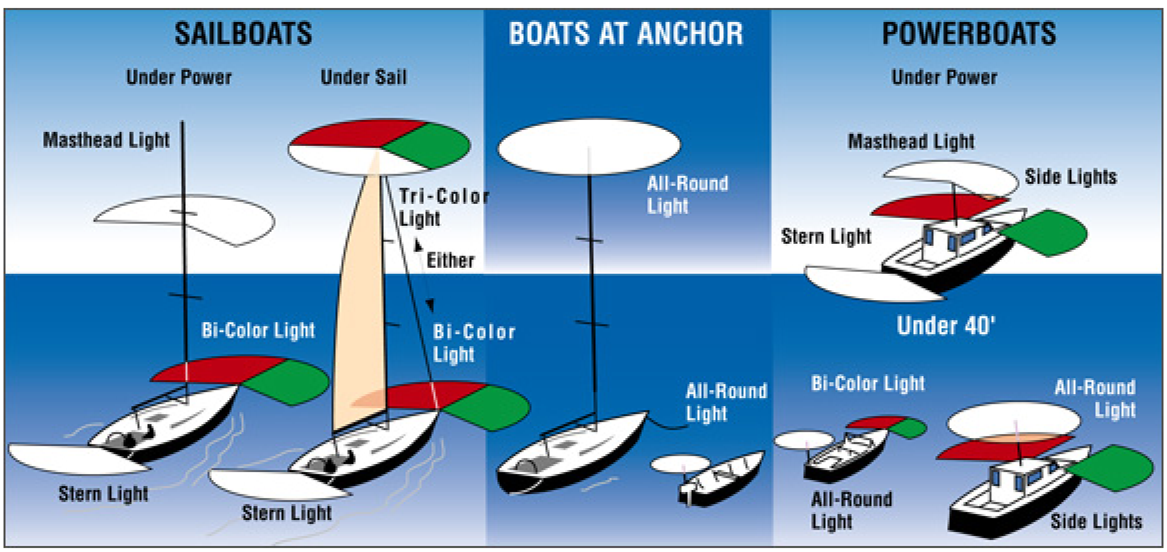


Figure 3 Navigational lights for leisure vessels

2.3. Leisure vessels

A leisure vessel defined by the Norwegian Maritime Authority is:

"Recreational craft are vessels not in commercial use, and with a total length of under 24 meters. Recreational craft are typically used for pleasure and leisure. Among these are sailing and motor vessels, sea kayaks and water scooters. Recreational craft with a total length exceeding 24 meters are regarded as cargo vessels for legislative purposes." (NMA. 2019).

This is however more of a legal definition. In this project. All vessels that go under the umbrella of leisure vessels or Non-SOLAS vessels will be referred to as leisure vessels.

Leisure vessels have been chosen for this thesis. Because while a lot of research has been done on the interaction between autonomous and non-autonomous commercial vessels. The same cannot be said for leisure vessels. While this can be understood, seeing how as a whole. Manned commercial vessels will probably have a lot more to do with these autonomous vessels. These vessels have the benefit of already having systems that lets them see other ships intentions and communicate with them (SOLAS, etc.). They also have the benefit of probably receiving training during the shift into autonomous vessels becoming a reality on the sea (Ahvenjärvi. 2016)

Leisure vessels on the other hands are as the name says, for leisure and the operator/crew can be assumed to not be actively keeping up with modern communication technology and taking courses in how autonomous ships act. Some might have taken their certificate years ago and not been on the sea for a while. So, for them. It is very important for things to go smoothly that they have a way of communicating and navigating around autonomous vessels, that they have the tools to do so.

2.4. Autonomous vessels

It is believed that in 20 years. Many vessels will be autonomous (International Institute of Marine Surveying, 2018). This goes both for commercial vessels like ferries, cargo ships, water taxies, etc. but also military vessels like mine sweepers and other vessels from government agencies like coast guard and rescue vessels. Some vessels are opting for setting of parts of the operations to autonomous systems such navy vessels having autonomous systems take over control of the steering in situations of emergency. While others like ferries and cargo vessels are aiming for fully unmanned vessels (Moore. 2019).

The kind of commercial vessels leisure vessels have the most interactions with as of today are ferries and cargo vessels. So, it is therefore these kinds of vessels that they are most interested in having a way of knowing the intentions off and communicate with. Ferries are today already an element at sea that the operators of leisure vessels must be on the lookout for as they have the right of way and are known to be crossing the paths of leisure vessels. As these often will move diagonally from one island to another. Because they have the right of way and are making scheduled stops. Much like a tram or a bus. They take their right of way very seriously. This means that they will not normally break to let another vessel pass. Because of this. Someone in a leisure vessel will have to make sure not to cross their path when they are near. This will by all accounts not change when they become autonomous, and it is therefore important to be able to know where they are and where they will be when a vessel crosses their path.

2.5. Autonomous vessels and maned vessels

While a lot has been written about how an autonomous vessel might find its way through storms, waters filled with reefs and unforgiving currents. Not much has been written about their relationship with maned and nonautonomous vessels. In theory an autonomous ship should be more easily to interact with since it will follow the rules of the sea. While in the case of a manned ship one can never know completely what the other ship will do. That being said. When it comes to digital systems. They can also sometimes be confusing and act in a way that is not always easy to understand. When it comes to human-to-human interaction. We can at least assume how the other will react based on how we will react. If you are walking down the street and someone is walking towards you. You assume they will step to the side or you will. If they are walking close to the street. Then you might step to the side. This situation is familiar to many. What is also familiar to many is you both stepping to the side. Resulting in you still being in each other's paths. Do the same scenario. But switch out the other person with an autonomous delivery drone on wheels. One is to assume it has a system built in to know what to do when it is about to drive into someone. But what way will it turn? Maybe it will not turn at all because it assumes you will. This is the kind of scenario people are concerned about when it comes to autonomous ships (Porathe. 2018).

Porathe (2018) talks about this, saying:

"An innate tendency of human psychology is to attribute human traits, emotions, or intentions to nonhuman entities. This is called anthropomorphism. We do so because it gives us a simple (but faulty) method to understand machines. It is likely that this will also be applicable to MASS (autonomous ships). We will assume that they will behave as if they had human on the bridge."

If we have nothing else, then the actions of the ship to go off. We might make assumptions that are faulty. Because the basis is rooted in human behavior and not the behavior of computers. An autonomous ship blinking its lights might be it signaling you. But it can also be the scanners needing light for the milliseconds it takes it to gather the information it needs. These uncertainties are what might create problems.

Other authors like Ahvenjärvi (2016) talk more about how the human element will never disappear from the autonomous vessels. even when they are fully autonomous. The human element still plays a big role in the other vessels that do have human operators and, in the human, watching over the remote control bridge. Also, in the humans designing the algorithm the ships are using. Ahvenjärvi (2016) recommends the use of audible feedback to communicate.

2.6. Leisure vessel navigation

Because leisure vessels and none-SOLAs vessels are not obligated to have navigational or communicational equipment. There is not a specific solution that can be looked at and improved. Some vessels like larger sailboats and other large vessels might have advanced systems that let them plot courses into the navigation from a map room and broadcast their positions. While some might only have a map or nothing at all. This means that the experience with navigation on the water might be quite different from vessel operator to vessel operator.

The information that the operator of a vessel needs is also different from one to another. Someone a sailboat with a deep draft might need seeing how deep the water is so to not break the keel on a rock or shallow water. While someone in a small motorboat or rowboat might not be as interested in this.

Figure 4 Leisure vessel navigation system

The main aspects of navigational systems for leisure vessels are showing your planed rout and which direction you are facing. It is also a way to see the depth of the water and where they might be hindrances like islands and other things in the vessels path. The bigger systems are usually used by larger vessels. While smaller vessels usually resort to handheld devices or none at all (Discover Boating. 2021)

2.7. Ship trackers

There are websites and applications where one can see the current positions of large vessels and commercial vessels. Sites like marinetraffic.com (figure 6) lets one see in real time where ships are and where they are intending to go. It uses systems like AIS (automatic identification system) to gather this information. On top of having voluntary smaller vessels share their information. It also offers information on the status of ports, lights, etc. (Mohit. 2021). The database so far records around 800 million vessels positions. This is a community-based project. But it operates 2,000 AIS stations in 165 countries. So, it offers a very large network of vessels. Letting users know where a vessel is and where it is going. Also, where it has gone before. Which can be valuable information in regard to ferries and other vessels that conduct the same journey on a regular basis.

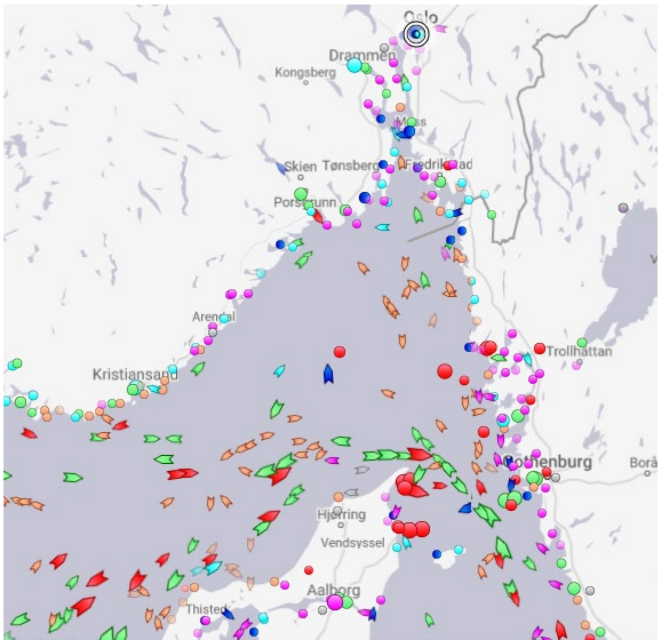


Figure 5 Maritime Traffic in Skagerrak. marinetraffic.com

It also lets the user see a picture of the vessel. Along with information on its current speed, which direction it's facing and if it is currently in motion or not. Many of the other sites, like FleetMon, Shipfinder and Vessel finder, to mention a few. also has these options. Though they do not all have the same size databases of ships and some like Shipfinder focus more on pleasure crafts and leisure vessels. Most of these sites operate of users voluntarily sharing information on their vessel and their position.

2.8. Intended user

To design a solution as good as possible it is important to take the user into consideration. In the case of this thesis. The intended user for this project is anyone on a leisure vessel. That means that not a lot of knowledge about how to operate a maritime navigational device can be expected of the user. There is no specific age or gender either. This because anyone old enough to row a boat or a kayak is a potential user. This does however not mean that the solution should be overly simple. But rather that it needs to be set up in such a way that the learning curve to use it is not too steep and that someone with ease can understand how to operate the simplest and most essential aspects of the solution. The users can be separated into three groups: the primary user. the secondary user and the tertiary user

The primary user in this case is the one steering/operating a leisure vessel. They are the ones that will have the most interaction with the solution and are the ones the solution is primarily designed for. they are also users that are voyage around where autonomous vessels operate. Meaning they must use the solution actively when on the water.

The secondary user in this case are other people on the vessel that do not directly use the solution. But might be asked to check it or use it for a bit here and there. The secondary user is also someone that might not go too much out into the areas where autonomous vessels operate. But might from time to time. And will need to check when the next one will pass or where the closest one is.

The tertiary user is someone that is not often out on the water. But might be for one reason or another. this user will probably just have acquired the app for a quick kayaking trip with friends just to check if any autonomous vessels are passing. This user will have next to none or no knowledge on how to use the app.

The solution needs to be usable for all three user groups. It's therefor important to keep all three in the back of one's mind while making decisions on the design.

3. **Methods**

3.1. Information gathering

The information gathered for this thesis is of a qualitative nature. It is based on research done by other experts in the field. Even though the prototype is meant to be for a specific user group. The user has not yet actually encountered the issue at hand. Since autonomous ships per today still Is only being tested in a few countries and only by a few companies (Bassam, Phillips, Turnock, and Wilson. 2019). It is therefore up to the researcher to find what issues might arise and figure out what solutions might solve this issue.

The papers that have been investigated for this thesis cover both the navigational aspects of the issue and the overall aspect of autonomous behavior. the information in these papers have been combined with talks with people that have experience being at sea and with navigation of leisure vessels. Along with talks with the experts in the field

3.2. Double diamond

The double diamond is an approach to researching a problem and create a solution. The reason it is called double diamond is it is represented by two rotated squares going into each other (see figure 4) these squares are to represent the widening and narrowing down of the prosses.

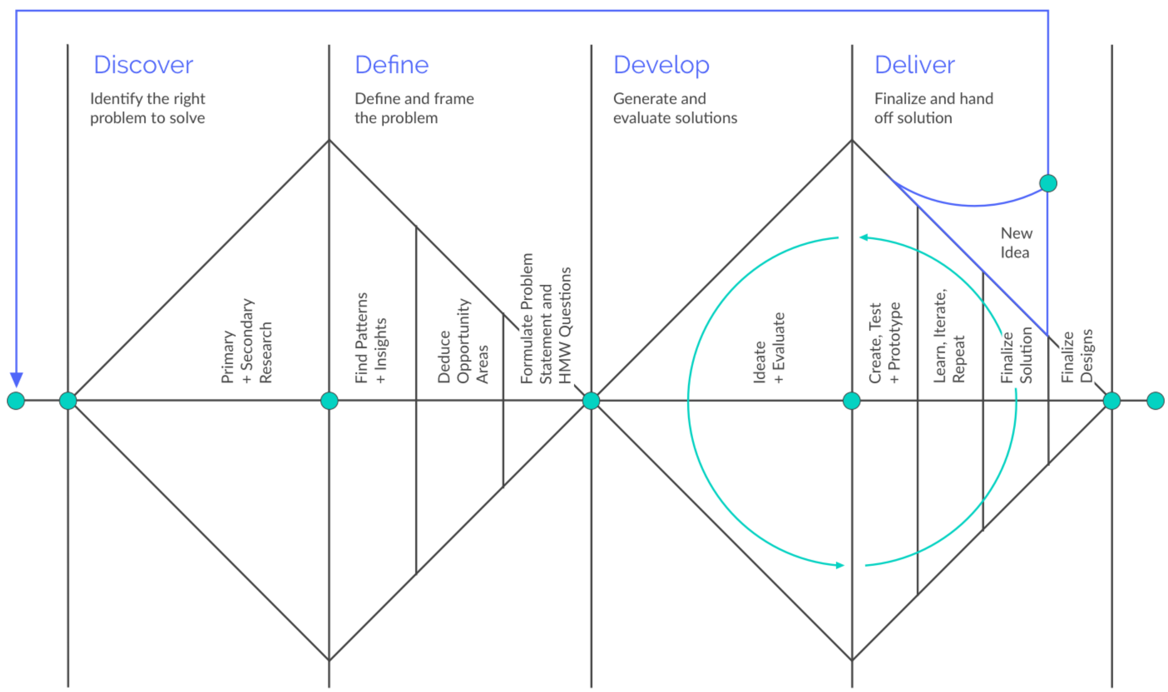


Figure 6 Meret Gotchel double diamond

The first phase of the double diamond is the discovery phase (Design Council. 2020). This is where you gather information and insight into the problem you are facing. This step is about researching the problem. Finding out as much as you can about it. In this thesis this phase consists of reading papers written on the topic and gathering information on vessel interaction in today's environment

The next phase is the define. This is about taking the information you have gathered and making sense of it. Using it to narrow down and define your problem. This step might result in finding a different problem or in finding exactly what the problem is.

The development phase consists of developing and testing solutions to the problem. Here the square expands again. As this phase has one create several answers to the problem.

The last phase is the deliver phase. This phase is where the answers are tested and the ones that are not up to muster are rejected. And the ones that work are improved. This step along with the development phase is often represented with a circle inside it as it sometimes is repeated if no solution is reached, or the solution needs to be made into several solutions that then need to be developed and delivered again. These phases can also have the researcher reaching new ideas. That might result in the whole double diamond prosses being repeated (figure 4)

The double diamond is utilized along with other methods in this thesis to create a prototype. Normally the develop phase is done by co-creating and co-designing with different people. But this part is done by seeking input from similar research and other inspiration instead.

3.3. Prototype

The goal is to create a prototype of an application that can help solve the research question. This prototype will be made based on the data gathered from the research part of the project. The prototype will be to a large degree molded by the data of the research. Seeing how it is supposed to cover the needs of the user.

The basis of the choices made with the prototype is the research done prior to and during its creation. It will take inspiration from already existing solutions and solutions suggested by people writing on similar subjects. But is primarily designed to fit the primary user of this thesis. Which are leisure vessels. It will therefor take into consideration the varying knowledge the operator of a leisure vessel can have when it comes to reading maps and other types of navigation.

The prototype itself is made using Figma. Which lets one create prototype applications for Phones and other handheld devices. Which is what the prototype will be designed for.

Figure 7 Prototype splash screen

To suit any type of leisure vessel. The platform for which the application is running is a phone. This was chosen so that anyone from a large cabin cruiser to a kayak or rowboat can use it. Using a phone as a platform also means the user does not have to get a separate product or get a separate sim card or other device that lets them access the internet.

3.4. Observational test

The prototype needs to be tested by the intended users. This will be done through observation tests. Where the user gets to test the prototype and give feedback on how they find it and what they like/dislike. There will also be done observations while they use it on how long they might take to finish task, where they might have taken extra time, etc. the tests will be done several times before any changes will be done to the prototype, to get better data on where the user group as a whole might have issues.

There is a possibility the testing will show there being a need for different iterations of the finished product based on what size vessel the user utilizes.

The tests will be done both in person and online. A link to the prototype with a questionnaire might also be sent out to gather more general data on it.

3.5. Personas

The insight gathered from talks with potential users and with experts in the field, along with other information learned through information gathering on the subject. Was used to create three personas: Frøya, Phillip and Kim (Appendix B: Personas). The personas were made to fit the three user groups. But is not solely based on each group. As an example. the secondary persona, Phillip. Has some characteristics from a primary user that fit that persona better than the primary personas. The personas were used to mold the scenarios and the prototype and to make sure it was designed in such a way to fit all three personas.

4. Practical considerations

4.1. Ethical and legal considerations

Any data collected in this this study will be anonymized. The only information given about participants is that they have experience with navigation of a leisure vessel. The participants will be mentioned by number. But these numbers might be assigned to them at random and not correspond with in what order they were interviewed. No personal data will be recorded and all data they give that contains personal data will be anonymized before it is stored.

Participants will also be fully informed on what their information will be used for and what information will be gathered. They are given the option to pull out at any time.

5. Results

A prototype was made using the information gathered from the literature. combined with ideas from brainstorming and other activities such as talking to target user group. the aspect of the prototype falls into two themes: Communication and Navigation. the communication aspect being a way for a leisure vessel to communicate with autonomous vessels and them to communicate back. While the navigational aspect being a way to navigate around the autonomous vessels in a way that lets coexistence happen without too much bother to either party.

5.1. Scenarios

Three scenarios were made to help show how the prototype works. These included one where a user is planning a route from Aker Brygge in Oslo to an island called Bjørnen in the Oslo fjord. Another where the user is on a course that is crossing the path of an autonomous ship and needs to contact it and share its position with it. And a third where a user is wanting to check if it is on a safe route. These scenarios were chosen to reflect the main aspects of the prototype and show the different interactions of the prototype. They were designed with the personas in mind. Trying to solve their problem statements.

5.1.1. Scenario 1: planning a trip.

The tester is asked to set up a route for a sailboat from Aker Brygge to Bjørnen in the Oslo fjord. They are told that their boat is at Aker Brygge. But they currently are not. they are also told that because it does not have a port. Bjørnen cannot be searched for. the tester is then shown the front page. where they are then asked to find the button for adding a new rout. When they press the plus. They are taken to the page for planning a rout (Figure 18). From there. They will press the top bar for adding a start position. Because they are not currently at Aker Brygge. They can therefore not use the "my position" option. The previous searched locations underneath do not show Aker Brygge, so they need to search for it using the search bar. When pressing it. A keyboard comes up and they click the keyboard to simulate them typing in the search. This will take them to the next part where it now says "Aker Brygge" in the search bar and it also shows as a suggestion underneath. Along with another port nearby. This is meant as a system for when writing in a city or place the user wants to go. The app then suggests ports nearby there. The tester can now press the suggestion and it will be added as their start position (Figure 20)

Figure 8 Search bar, Navigation.

The next step is to add a destination. Pressing the destination bar will take the tester to the destination menu. Because the destination is not searchable. The tester needs to find another way of plotting it in. since they do not know the coordinates and they are not currently there. They need to use the "Chose on map" option. After looking around the map and finding it. they press it. putting a pin at the position that translates into its coordinate in the destination bar. The only thing left is to make sure the vessel is set to a sailboat. Then press the plot course button. When the course is plotted. The tester can go over it and check it is fine and that it does not cross the path of an autonomous vessel at any point.

The scenario was made to test the usability of the prototype. As well as the intuitiveness of the interactions. As little as possible information is given on how to do the task, so the tester does not automatically know what buttons to push and needs to figure it out themselves.

5.1.2. Scenario Two: Contacting vessel

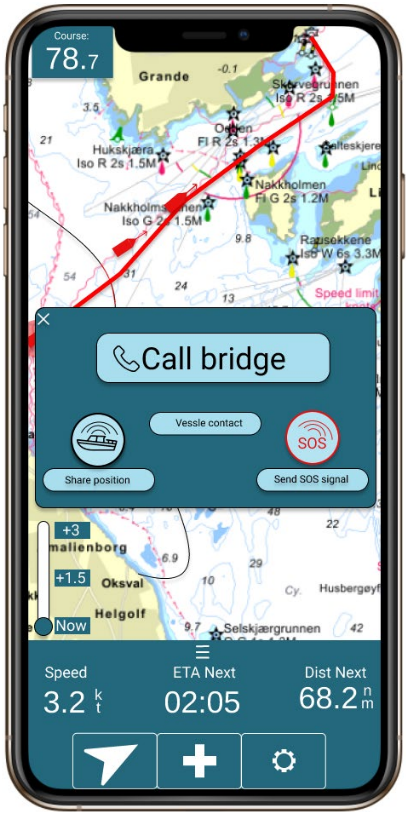


Figure 9 Contact Vessel.

The tester is told that they are in a large, motorized vessel with engine trouble, and they are in the path of an autonomous vessel. They need to contact the vessel to warn it and explain the situation. the tester is shown a frontpage with a warning on it that points at the symbol for an autonomous vessel (figure 13). by pressing the symbol for the vessel. the user is then taken to a pop-up (figure 14) which is red, showing that the vessel is on a path that will intersect the testers vessel. The tester then needs to press the "contact vessel" button which makes a pop-up appear (Figure 15) at this point the tester might either press the "Call bridge" button or the "send SOS signal" button. The tester might also click on the "share position" button to let the vessel know where they are. So, the vessel might go around them.

This scenario is meant to test how a user might react to the situation. along with what option for contacting the vessel they find most useful.

5.1.3. Scenario Three: Checking course

The third scenario has the tester being shown a screen where a path is already marked on the screen. They are told to perform tow tasks. These being to: Check how the map will look in 1.5 hours and track the vessel in the front right of them. The tester is then expected to click the symbol of the vessel. which makes a pop-up appear (Figure 10). Showing a picture of the boat and its speed and direction. By it being green. The user can know it is not on an intercepting path. But they can choose to press the track button. The other task is to see where they will be in 1.5 hours. The tester will need to move the slider on the lower left side of the screen (Figure 11). This will show them where their vessel will be in 1.5 hours If they stay on the rout and where any autonomous vessels will be at that point.

5.2. Design choices

5.2.1. Color coding

Color coding is one of the methods used in the prototype to convey information. Things like shipping lanes are marked red. So, to convey that it is an area the user should try and spend as little time in as possible. The use of color coding is a very simple yet effective way of conveying information.

Figure 10 Color coding for clear or not clear path

The intention is for the user to be able to see if there is a warning quickly by seeing the color change. Their attention will be drawn to the change on the screen and the change of color will then convey quickly that there is an issue.

The use of green and red to indicate clear or not clear is based on these two colors being often used for these kinds of indications. A pattern is also added to the not clear red box to further distinguish it from the green. Especially for people with a color vision deficiency.

5.2.2. Color palette and font size

The color palette was inspired by maritime colors along with the color coding. the use of blues and greens was an esthetic choice. Taking some inspiration from the colors used by modern navigational systems. But mostly from colors of the maritime world. The intention was for it to aesthetically look nice. But also fit in well in a maritime setting. The use of light on dark colors was also to make buttons and information stand out more. Making use of the material design color tool to make sure the text pops properly from the background (Appendix I: Text and readability). To make sure the numbers are properly readable. The text and numbers are also designed with the material design, spacing method. Which states that to be readable by most of the population. The minimum area should be 48pixels. All areas that are to be touched (buttons, sliders, etc.) are made according to this recommendation. So are most informational numbers and text.

5.2.3. Front page

The front page of the prototype was made to be the main page as well. Because of this the design is simple. As to not overwhelm the user. Because the map is the main part of the application. The design was made to place as little as possible over the map. Furthermore, the option to minimize the taskbar in the bottom was added to show even more of the map while still showing the important information.

Figure 11 main page with minimized taskbar and enhanced taskbar

This choice was made after feedback that checking around the map while moving along is a big part of a navigational app and therefor it is nice to see as much as possible of it. In most cases as well. After having plotted a course. Espceially for larger ships. The map is pretty much left alone. So there is no use for buttons to be taking up a lot of the screen when not needed.

The buttons are however designed with principles of universal design in mind and are kept quite large so they are easy to find and press. also because when used on choppy water and other sitautions where the boat is in a lot of motion. Large buttons are preferable.

Buttons to zoom in and out on the map is added to the side. While the user can still use their fingers to zoom in and out like most map apps. Physical buttosn are added so the user can more esaily do it with one hand while otherwise ocupied with stearing or other activities. The option to zoom in on the map is inherent feature to help the app be universal to different size vessels. As different users need different detail depending on what they are piloting. One can assume someone in a rowboat is not as interested in what is 10km away as a sailboat going 11 knots. At the same time. A sailboat going 11 knots down a fjord contrary to someone on open oacian. Might be more interested in a detailed look of the 200 meters ahdead. Looking for any shallows or skerry (reefs). It's therefor important to have the option to chose the area of sight

Because the app is used not only for planing routs and seeing autonomous ships in your visinity. But also seeing looking around the map. A button for returningt he map to the users position is important. So the user in case of a warning or other situation can return the map to their position. This is alos just overall a nice feature to have so the user does not have to find themselves again after scrooling trought he map. The symbol used looks a lot like the kind used by many navigational apps so the user will more easily be able to recognixze it. It does also have the exsplanatory text underneath if the user holds their finger over it. So users that are not faimilar can know what it does without having to press it first

The button to add a new rout is represented with a plus as this is the symbol most fitting as it is a simplistic. Yet effectiv way of conveying that the user can add something. It also conveys that it's not only for adding a rout. But adding in general. So for example adding another stop to the rout. The positioning of the button further inforcing the notion that it is the main button so to speak

The decition to have the settings button on the front page to such a degree is a intentional decition to make it easy for the user to find the settings whithout having a lot of expserience with the app and being able to use it to find help with any problems they might have with the app. In the settings the user can change screen setting such as brightness. Or change colors to fit a specific color vison deficency. They can also set up their user profile. Which includes what kind of vessel they are operating. This info will be used to determine when the user will be alerted of autonomous vessels in their visinity or in their path.

The time slider lets the user see into the future so to speak to make decitions based on how the map looks a few hours into the future. This shows the estiamted postions of autonomous vessels and if the lesisure vessel itself is in motion. This shows where about the vessel will be on the rout based on it's curent speed. This lets the user make decitions on how it can alter a course. Larger vessels gettingr ready for a long trip also sometimes wish to figure out when to leave port in regards to traffic and what not. This feature lets them see a estimation of how the soruounding arae of their intended rout will look when they do decide to leave and they can make decitions acordingly

Figure 12 Position at current time

The time slider lets the user see into the future so to speak to make decitions based on how the map looks a few hours into the future. This shows the estiamted postions of autonomous vessels and if the lesisure vessel itself is in motion. This shows where about the vessel will be on the rout based on it's curent speed. This lets the user make decitions on how it can alter a course. Larger vessels gettingr ready for a long trip also sometimes wish to figure out when to leave port in regards to traffic and what not. This feature lets them see a estimation of how the soruounding arae of their intended rout will look when they do decide to leave and they can make decitions acordingly

Figure 13 Position 1.5 hours from now

On of the most important part of a maritime navigational application is showig which course the vessel is on. On this prototype this is shown in the upper left corner. The main reason for this is so it's always visible. Reagrdless of if a new rout is being ploted inn or if it's just on the main page.

5.2.4. Autonomous vessel interaction

When crossing the path of an autonomous vessel. The user has an option to click on the vessel. Seeing where it is headed. While the app is supposed to warn the user that they are getting too close to an autonomous vessels path. It is still necessary for the user to be able to see a ships path to determine where to go. By clicking on a vessel on the map. Its path will be highlighted, and a pop-up (Figure 12) will give information on the vessel. Like its speed and what direction, it is facing. Including a picture of the vessel so the user can be sure it is the vessel that they are currently looking at. The green background of the pop up and the path indicates that the vessel as of that moment is not on a course that risks any situation between the user and the vessel. Meaning if the user and the autonomous vessel does not deviate from their speed or their course. No situation will occur between them. The choice on making this color quite bright is to make sure it pops out. So, the mental workload of determining that it is safe is as little as possible. the user can choose to track the vessel. Meaning the vessel and its path will stay highlighted on the screen until it is untracked.

Figure 14 Tracking vessel interaction timeline in Figma

This is intended as a way for to be able to actively monitor that a course is safe. As an example. in the situation where the user is crossing the path of a ferry. It can be in their interest to track this ferry. So, its path will turn red if by any chance. There is a chance of a situation. Then the user can take whatever precautions they feel necessary. The intention is to create a feeling of safety where the user can give the app a quick glance to know if they are safe to stay on course. At least in regard to autonomous vessels.

However, when the course is not safe. The user is warned immediately by the course of the ship turning red. This is intended to happen as soon as the application is aware that if both parties continue their intended course and at the speed they are currently at. A situation is likely to occur. the color changing to red is a way to convey this to the user. this is meant to be an early warning system when possible. meaning it will warn the user even if there might be hour until the two parties will meet. The earlier to user is aware of the situation. the earlier they can make correction to their course and speed to prevent it. This does however mean there needs to be levels of warning. So that in the instance that a collision might be imminent. They user receives an appropriate warning. As shown on Figure 13. The vessel is pointed out and a message is shown warning the user that a situation is about to occur if appropriate action is not taken.

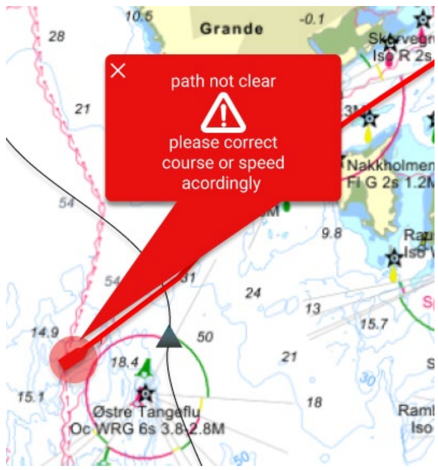


Figure 15 Warning for imminent collision

To stress out the user more than necessary is not ideal in this situation. which is why it says: “path not clear” and not something like “collision imminent”. Stronger language might not be as beneficial in a stressful situation like this. But the wording is still serious enough where it is intended to initiate action. This warning is combined with a loud alarm. To further imprint the seriousness and immediate response that is needed. Warnings about crossing paths might very from small vibrations to sound depending on the severity of the situation.

Figure 16 Information, Autonomous ship on unclear path

The information pop-up the user gets on this ship will also reflect the unclear path by being red with black stripes instead of green. The reason for its black stripes is to further distinguish it from the green for people that might have a color vision deficiency.

The situation might occur where getting out of the path of a vessel is not a possibility. The user might be having engine trouble or other issues where they cannot move out the way. which means they need to be able to directly contact the autonomous vessel. a button is added to the pop-up for just this. This button is there regardless of the vessel being on a colliding path or not. Pressing the button takes the user to a menu with three options:

Call bridge:

which lets the user call the control bridge of the ship. All autonomous vessel for the foreseeable future will have a virtual bridge or control room. Where someone is watching over the ships with the option to take over control in an emergency. This option is not limited to situation where a collision might be imminent. there is a number of reasons that someone would need to contact the bridge of an autonomous vessel. such as to inform them about an issue about the vessel or to ask if they can assist the user in some way.

Share position:

In a situation where the user might need assistance. They might wish to share their position with the autonomous vessel. while the autonomous vessels might have systems to be aware of vessels around them. Sharing one's position might let the ship better plan a rout around the user of they are dead in the water. Furthermore, it can let them find them if it is an emergency and the user needs assistance from the autonomous vessel. one can imagine the feeling of hopelessness of being dead in the water in the middle off the night and see an autonomous vessel chug by with no way of contacting it. This feature might also be combined with calling the bridge. So they know exactly what vessel it is and where it is.

Send SOS signal:

this feature is intended as an emergency measure. It will send an emergency signal to the autonomous vessel. this is intended to be used in situations where immediate action is needed. the intention is for it to be used if impact is inevitable and imminent and the vessel in question is needed to perform a full stop to avoid it. This means that using this option is strongly discouraged outside of emergency situations and it is therefore put under a two-step verification. Where the user needs to press it first from the contact menu. Then is asked to press the button again or wait 30 seconds for the signal to go out. This is meant as a failsafe against someone pressing the button accidentally. Text is also included to properly convey the seriousness of the signal. The reason for the 30 second timer is for the signal to still go through in a situation where the user is somehow not able to verify the request. Like if they must take the wheel to try and steer away or if something happens where they are not able to press it again.

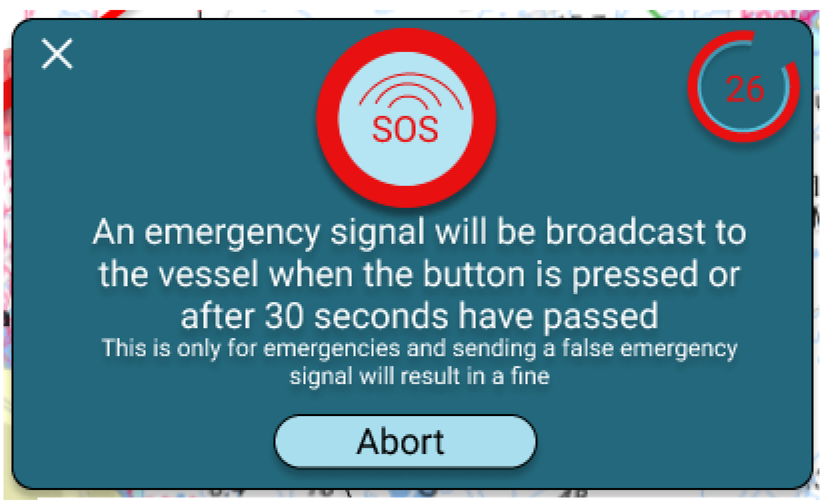


Figure 17 Emergency signal verification

Another aspect of the communication between vessels is the ship icons themselves. The icons for the users and the autonomous vessels are made to look different so there is no confusion, and the user can easily distinguish why they are. Both color and shape are made to be different. The icons for the autonomous vessels also have arrows in the front of them. These will move to whichever side the vessel is turning in the event they are in the prosses of turning. Turning a ship is not as momentary as turning a car. Especially not a large vessel like a cargo ship or ferry. So the arrow will move to whichever side the vessel is turning. Then the icon itself will follow as the actual ship turns. This makes it a lot easier for a user to know where a vessel will go. So they can go the other direction.

5.2.5. Navigation

It was made apparent early in the prosses of this thesis that the solution needed to offer more than just a way of contacting autonomous vessels. To fully work as a tool for communicating and interacting with autonomous vessels. It needs to work both as a preparatory tool and an active tool. Seeing where an autonomous vessel is as the user leaves port is one thing. But having to actively check where it would be both tiring and time consuming. It was there for evident from the start that the best way to make this work fully would be to combine it with a navigational system. By letting the user plot their course on the app. The app itself can figure out where they might cross paths with an autonomous vessel and plan the route accordingly.

the design of the navigational system takes inspiration from both marine and land navigational apps. but mainly based on the literature and the needs of the user.

To add a new route or edit their current rout. The user presses the plus sign on the front page (figure 9). This makes a planning rout page. the page has several options. First being to add a starting position. When pressing this bar. The user is taken to a page with the options to use their position, chose a position on a map, type one in by pressing the bar again or chose one of their previous start position or destinations. (figure 16)

The option to just chose the users position is somewhat evident as the user would probably be most interested in getting a rout from their exact position. But when it comes to navigation at sea. It is not the same as road navigation on land. Meaning the user will often want to plan a rout before venturing out. They would therefor want the option to choose a start position from where they intend to start and not where they currently are. This might occur if the user is planning a trip from home and putting in the port they are leaving from, or they are planning the next days voyage. In the case of planning for the next day. They can press the cogwheel in the top right corner and change the time of departure. This will plan it according to where autonomous vessels are planning to be at the time. the option to choose on map serves a similar purpose. But caters more to planning a rout from a position that is not specific to an area. This could be in the situation where the users start position is a cove or other place that has no specific name or purely in an instance where the user does not know the name of the place they wish to start their voyage from. In this situation. the route will be plotted from the position chosen to the destination. But will also add a route for the user to the start position. Their choice will be shown as the coordinates of where the pin was placed (figure 18)

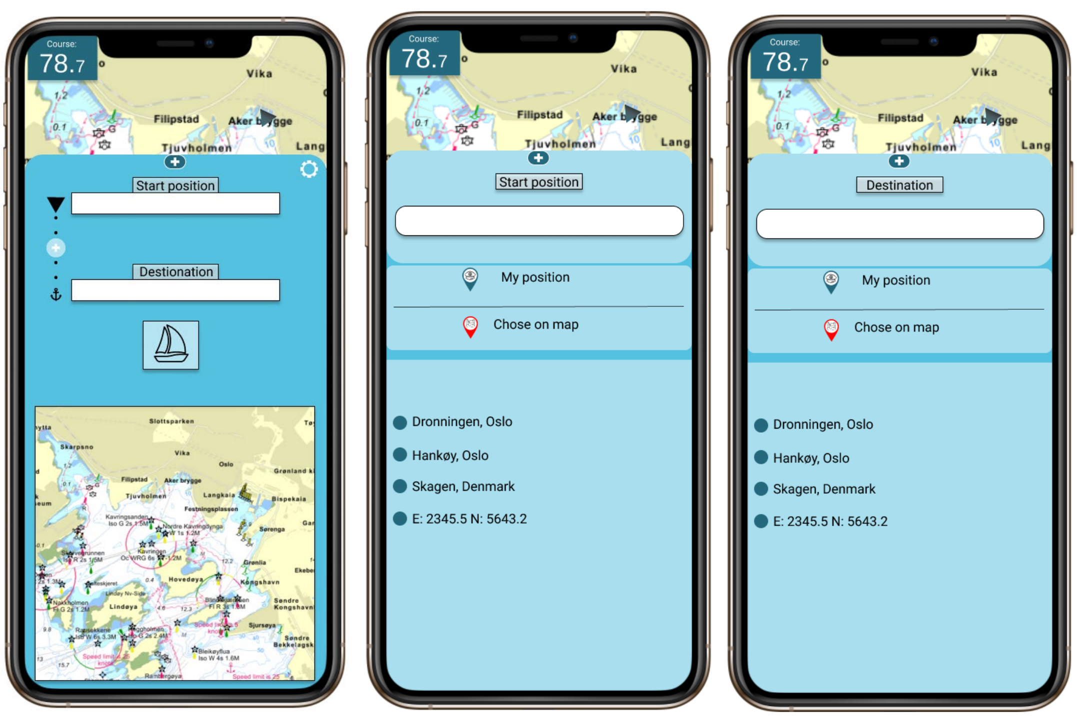


Figure 18 navigation, start position and navigation.

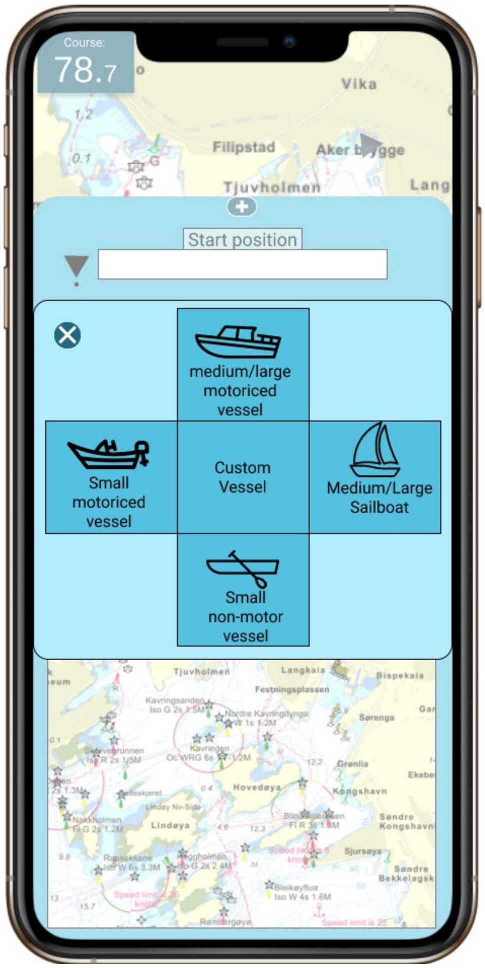


Figure 19 picking a vessel in navigation.

The option to write in a start position is quite evident and a staple of most navigational systems. It lets the user chose the specific port or palce they want to leave from. The app shows previous places that have been searched for reardless of them being looked up as a destination or a start point. This is because the user might have searched for a destination the day prior that they now have spent the night at or they might be headed back and will therefor want to put in their start point from earlier.

A plus button is added betwwen the start position and destination. This is to give the user the option to add postions along the route. Meaning the app will create a route from the start pisition to the next position. Then to the destionation or the next position. Depending on how many postions have been added betwwen the start and the destination. This lets the user plan the whole days route. This could be to fuel on the way or stop for lunch. It can help the user figure out how long their whole journey will be and separate it into stretches. It also helps the user not have to re-plot courses as thye arive at different points of their journay. Keepting them updated on changes that might have occurred with their planed journey

Options for inputting a start postion and inbetween point are the same as for destination. For mostly the same reasons as for the others. The only one sticking out a bit might be the option to use “My position” as why would someone want to travel to somewhere they already are. But this option serves a purpose. Using the option to chose inbetween points. the user might be interested in planing a day trip that will at the end have them back at their curent position. So chosing their curent postion as the destionation makes sense in that instance. It also can be used to plan the return route the user is gonna take after getting to their first intended destination.

Having a map of the users soroundings can also be handy when planing a rout. It also helps the user not having to exit the tab if they wish to check the map

different size vessels travel in different ways. A large, motorized vessel usually will travel in straight lines as long as they can. Far from land while a sailboat will often be crossing back and forth in straight lines or any direction they can go where they have wind in their sails. Also trying to stay far away from land. Meanwhile a rowboat or other small vessels will stay quite close to land. Trying to limit venturing too far out. The app needs to take these differences into consideration. Planning a rout for a large sailboat would probably not fit a kayak as well. Therefor the navigational planer lets the user pick which kind of vessel they are planning the rout for and the rout will be plotted according to the type chosen. Meaning that for a kayak it might try and limit venturing out onto more open waters. Choosing instead to cross in a straight line from one island to another. then keeping the rout closer to land after crossing. It will also take into consideration the speed of which a kayak can move and will warn it of an incoming autonomous vessel that it might not warn a motorized vessel about to the same degree. One of the factors it takes into consideration is not just the autonomous vessel it itself. But also, the wake behind it that if large enough could flip a kayak or small vessel over. The user needs to be aware that this can occur. these different factors very from vessel type to vessel type. With a motorized vessel as an example. the app will plot a route that is further out. Depending on if it is a small or medium/large vessel. it will also take into consideration that the engine lets the vessel change its course more easily to avoid an autonomous vessel. in the case of a sailboat. It will take other considerations. It will still give a straight rout. But will not replot it as the vessel start deviating from it to cross back and forth to catch wind. It will also prioritize wider areas over narrow paths to offer the option to sail rather than use the motor. Nevertheless, the user has the option to add a custom vessel. which will have them set up the perimeters that the system used themselves. Meaning they will specify the size, draft and if it has a motor or not. this option might apply to older sailboats that do not have a motor. But is also just an option for the user to get the rout most fitting to their vessel.

when the start position and destination, along with any points along the way has been put in. the user can plot the course. The button to plot a course does not reveal itself until a destination has been inputted. If a start position has not been picked. The app automatically chooses the users position as the start position. The app will suggest the default vessel of the user. so if they are plotting a rout for a different type of vessel. they need to change that before pressing the "plot course" button.

Figure 20 Plot course and plotted course

Pressing the "plot course" button will take the user back to the main page. which now has a light blue line going from the users position to the destination. The lower numbers show the ETA (estimated time of arrival) of the next destination. If there are more than one point on the course. This number will change as the user reaches one and continues to another. The user can still use the navigation if their internet connection is lost. But only in a limited capacity. The planed rout is still shown on the map and will still be aware of where the autonomous vessels will be at the in relation to the planed rout. But will not take in new information. The user will need to keep track of where they are manually. As the app will not know their speed, course and position without internet.

6. Discussion

The research question this thesis this thesis is trying to find a solution too is "**How can smaller vessels communicate with and know the intentions of autonomous ships?**". Now that the results have been seen. How well does the results "solve" the research question?

1.1 Proposed solution comparison

This thesis sets out to create a way for communicate with autonomous vessels. The way this is implemented is the option to directly contact the bridge and broadcast the position of the vessel. along with the emergency SOS signal. But while these offer a way to communicate with the autonomous vessels. it is limited to the user taking the initiative to contact the vessel and the vessel does not have a way of contacting the leisure vessel. which can be argued is one sided communication. That being said, the autonomous vessels and leisure vessels as previously mentioned. Are not the same when it comes to right of way. while leisure vessels have different rights over each other when it comes to right of way. they all must yield for government vessels and large commercial vessels. Seeing how these are the ones that will be autonomized in the foreseeable future (Rolls-Royce. 2016), they do not have the same need to communicate with the leisure vessels as the leisure vessels have to communicate with them. The communication of the autonomous vessels is them broadcasting their position and speed. Letting the leisure vessels use that information to stay out of their way so to speak. this is why the solution presented in this thesis only covers way of the leisure vessels to contact the autonomous vessel.

The solution purposed in this thesis aims to give the user can overlook over their surroundings. Along with the app itself keeping an eye out and warning the user when they are on a path that might be unwise. While this is a solution to the problem. It can make other problems appear. The user might rely too much on the app. Meaning they will look at the app too much instead of looking around them. While the app shows autonomous vessels. it does not in the iteration proposed, show nonautonomous vessels. meaning the user still needs to look out for them. A situation might occur where the user check for vessels as they are walking under the deck to grab something. Then uses the app to keep a watch out. Neglecting to really check around the boat with their own eyes so to speak. building a type of blind trust in the app. That being said, having the user put too much trust into an app is not a direct flaw in the design. The user is expected to use any system with a pinch of common sense. Even if the app were to show every boat that was on the water. The user would still have to look out for debris, Fishing nets and other things that are not a vessel and would not show up on a map.

The goal is to create a tool for peace of mind and to help create communication. But this solution differs from how others suggest it could be solved. Experts on the field like Thomas Porathe (2018) focuses more on being seen. Having the autonomous vessel communicate to the user that it sees them. The autonomous vessel communicate that it sees the smaller vessel trough use of lanterns. Porathe argues that this is the equivalent of: "As a pedestrian or bicyclist crossing the street in front a car that has stopped, you need to make sure that the driver has seen you…" (Porathe. 2018). The autonomous vessel will signal the leisure vessel that they have seen them. So they can safely cross in front. This solution does not require the use of any equipment. Which the solution proposed in this thesis does. However, the solution in this thesis aims to solve the issues in a different way. the solution proposed aims to prevent situations like the one in Porathe's example. using the same analogy. It aims to have the bicyclist plan their journey in such a way where they do not need to cross the road in front of a car. Or crossing at an opportune time where the car does not need to speed down or stop. Which negates the need to have direct contact with the car. While in the example of the car and the bike. This might not be a good solution. As a road might have a lot of traffic and the openings between might not be large enough to cross trough. The traffic at sea is a bit different. Even a busy port might have such distances between boats that there is no trouble going between. As long as you are aware of when to go. Furthermore, the sea is not like the road. While there sometimes are narrow straights where vessels have to stay on their path and not have enough room to stray much from it. most of the time. there are open areas with enough room for two ships to pass each other with great ease. As long as they are aware of each other's intentions. Porathe's idea does however have a point in that knowing that an autonomous vessel has seen you can help give the user peace of mind. The user might not feel as inclined to contact a vessel if it already knows the vessels sees it. but as previously discussed. There are rules and regulations on the water. Especially when it comes to right of way. while being seen can give peace of mind. The fact that a ship sees you. Does not necessarily mean it will go much out of its way to not hit you. Many larger vessels like ferries, cargo ships and cruise lines follow set routs. Which they do not wish or intend to deviate much from, or not deviate from at all. Meaning that when a leisure vessel is in their way. they will expect it to move and might not do any evasive maneuvers until it is too late. Because of this. The ability to contact them in an emergency situation were moving out of their path is not an option is important.

6.1. Scenarios

The scenarios used for this thesis were meant to help mold the design and figure out the best way to solve the concerns and challenges the user might have. The challenge with this project is that the intended user does not at this date have any experience with autonomous vessels. because of this. The scenarios had to help ease them into the situations they were faced with.

The scenarios were somewhat flawed when it comes to showing the interactions while in motion. While one does cover checking if the coast is clear. This would be preferable if the scenario covered this as the vessel was moving. As an example, have the cursor on the prototype move during the scenario. While this is not entrancingly a flaw of the scenario. Seeing how it could have been implemented in the scenario in the prototype with how the scenario is phrased now.

More scenarios could have helped show more of the aspects of the solution. The scenarios made was made with the personas in mind. But they do not fully show some of the aspects of the solution. Like warning of probable situations occurring in the next few hours and suggested route changes. That being said. The scenarios do fit the personas well. The scenarios take a lot of inspiration from the personas.

6.2. Prototype

the prototype set out to visualize a solution to the research question. The primary focus was on creating a solution that was easy to use with a low learning curve, that helped the user communicate and know the intentions of autonomous vessels. the end result is a navigational app for phones that has a communication solution. A decision made early on to make a navigational system from scratch, though with inspiration from existing solutions. this decision was made as the scope of the app was becoming apparent. To implement the features into an existing navigational system could have also been a solution. But it would have taken a lot of time. maybe more than creating one from scratch. This decision was also made because the way the navigation works in the proposed solution is not the same as with a traditional maritime navigational device or course plotter. The solution to plot different routes depending on autonomous traffic and type of vessels is a fundamental part of prototype. A strength of this solution is that every aspect of the design is made to fit the interaction. The prototype is not made to fit a different navigational system. So, it has every aspect implemented in as ideal a way as possible. if the study was done again however, in a more ideal setting where user testing was not hindered by an ongoing pandemic. a field study with users where they got to try different navigational systems would have been done. the decisions made for this prototype was molded mostly by literature. But if a new navigational system is designed. Getting user input could help strengthen it. as grievances the user might have could be addressed

With traditional systems. Routs are usually plotted only for larger vessels. the prototype also needed to be easy to use. So, it could be used by the operators of smaller vessels that are not used to using navigational devices. This can however have negatively affected the prototypes potential. As the limitations put upon it to better fit the users in smaller vessels have made it not as good a fit for larger vessels. one of these is the choice to make it a phone app rather than a design for a normal maritime navigational system with a mounted interface. For many, using their phone on a boat in choppy waters is not an ideal and not something they are thrilled about. As previously mentioned, the decision to make this a prototype for a phone app, rather than for a navigational interface. Was so the user would need nothing else then their phone to use it. but it does offer some challenges that implementing it into a navigational interface would not have. But on the other hand, using a phone does offer advantages too. The app can be accessed wherever the user is. Not just when they are at their vessel. furthermore, the user can get a phone holder for their vessel. propping it up like a navigational interface would be propped up. Bodystorming the idea could have helped set it more in perspective. Bringing physical prototypes on different vessels and testing the usability. Testing the usability of the app with the phone in a waterproof case would also be interesting. While most phones are waterproof to some degree in today's iterations, most people do not like getting their phones wet. Limiting the usability in choppy waters or rain. Meaning the app cannot be used to the same degree. Therefore, testing with use in waterproof containers or other types of water protection could help reveal weaknesses in the design.

The communication aspect of the prototype is both quite straight forward and complimented at the same time. while the aspect of contacting the virtual bridge is an easy and effective way. It can lead to problems. In a situation involving more than one autonomous vessel or more than one leisure vessel. a communication issue might occur. since the communication in the iteration proposed is only two way. one party will be left out. Meaning that that the operator of one of the leisure vessels might not get through because another is currently talking to the autonomous vessel. another problem might occur linguistically as there might be a language barrier between the leisure vessels operator and the one on the virtual bridge of the autonomous vessel. while this is somewhat helped by the option to share one's position. Letting the autonomous vessel see where the leisure vessel is and take appropriate action. The language barrier might still be an issue that more use of nonverbal communication like sending symbols could solve. This would be an aspect that it would be interesting to look into in further work.

The SOS signal offers its own pros and cons. The pros are a type of emergency button that the user can rely on. Which can lead to the user being calmer around autonomous vessels. but the option to stop an autonomous vessel in its tracks can lead to issues as well. One being that it might lead to other situations where other ships behind it might suddenly also need to avert their course or stop as well. The companies owning and operating the autonomous vessels might not be thrilled about users having a button to stop their ships in their tracks at the push of a button. Therefore, this option must be clear to the user that it is only for emergencies. The option to get the attention of an autonomous ship in the case of an emergency is important. One can only imagine being stranded at sea and seeing an autonomous vessel chugging along by with no option of contacting it.

Because the prototype is meant to be used on a phone. It's way of gathering the information is through the internet. Meaning the user must use their mobile network/internet to operate the app fully. This is the easiest solution and in tune with the idea that the app should be usable by anyone with a phone. Using this system also means the user only needs a phone for the navigation to work. Similarly, to phone GPS apps like Google maps. The drawback is that the app will not work fully when in areas with bad to no reception/internet. Meaning the app will not work as well out at the open sea. While navigational systems made for boats can use the compass and knot measurements to know where the vessel is when it does not have a connection to internet. These issues could be solved in a future iteration. But it's not a big problem as a lot of leisure vessels do not go far out to sea and the ones that do tend to have systems that could be used together with the prototype to let the user know where they are. Though seeing the exact positions of autonomous vessels need internet.

6.3. Limitations

Because of circumstances around the time of this thesis along with other factors. Some limitations occurred. One being that the prototype did not go through much testing. it only received minimal testing towards the end of the design and this testing was done in a neutral setting with not a lot of external factors.

The personas are based on talks with people with some to moderate amounts of knowledge and experience with navigating on water and with being on boats. As well as the literature used to create them is written by experts with much knowledge on the subject. While an effort was made to make the personas as much of a representation of most users. The result is somewhat skewed towards users with experience when it comes to maritime navigation and travel. Which limits the scope of the results somewhat.

Official interviews with potential users and experts were not conducted. Meaning there is no interview logs and transcripts to refer too from the talks with potential users. The unofficial talks that were done with users were also not structured in a specific way. Meaning the opinions of the users on specific issues are not comparable.

The prototype is mostly based on literature written from people from Nordic countries. Because of this. The proposed solution takes a lot of inspiration from navigating Nordic waters. Which limits how much the results can be applied to other parts of the world.

The project was done during the third wave of the covid outbreak in Norway during 2021. Because of this. Testing and interviews that needed to be done in person was limited to next to nothing as interaction with people outside of one's household was almost prohibited.

While emails were sent to companies that are producing and designing autonomous vessels. few of these replied and the ones that did were not interested in sharing much if any information on how their systems work. As this is a very fresh market. They do not wish to give much away about their systems. Because of this. The thesis did not have a lot of information from the side of the autonomous vessel that is not already commonly known.

6.4. Practical implications and further research

This thesis is a brick in the wall. While it is not the first brick. Seeing how it takes inspiration from literature written on the subject. It is far from the last brick. A good amount of further research is needed. the main thing is testing. to properly test this prototype. The user needs to be put in an environment where they can properly grasp the situation. because autonomous vessels are not yet a common occurrence on the water. the best way to test the prototype would be trough a simulator. Where the user could fully grasp how it is to navigate around autonomous vessels. testing of the usability of the app at sea would also need to be done. this would involve both bodystorming and using the app while in choppy waters. While steering, etc. having the user test it in different situations could help find ways to optimize it to fit the user better. This could involve implementing more differences in look and interaction for the different vessel types.

The prototype could be implemented into a simulator. Having it tested both as a phone app and combined with a navigational system. While the prototype is designed as a phone app. Only the feature for contacting vessels fully uses the phone capabilities. Meaning with some further work. A version for navigational interfaces could be created.

A version for the virtual bridges of the autonomous vessels should be created. This would help the communication greatly. As it would strengthen the communication. This could be its own system, or a feature added to their existing systems.

The framework of the prototype could be built on by adding more features for the user. taking advantage of the capabilities of a phone with the access to the internet. adding the option to look for restaurants, fuel pumps, ports, etc. close to the destination. Similarly, to what google maps does. It could also be expanded with access to other ship trackers. Letting the user see non autonomous vessels as well. Changes like these could help the app be more of an all-round tool.

7. Conclusion

Because of the nature of this thesis. There is not really a conclusion to be made. As previously mentioned, this thesis is just a brick in the wall. The research question for this thesis is "**How can smaller vessels communicate with and know the intentions of autonomous ships?**". by this point. A solution to this question has been proposed. A way for leisure vessels to communicate with autonomous vessels is to use a phone app that let users see autonomous vessels and their routes and contact them if necessary. This is probably not the final solution. To reach that it would need more testing. this is however a big step on the path to a solution. the notion that leisure vessels can know the intentions of autonomous vessels have been strengthened. But it is still not perfect, and it probably will not be until there are more practical examples of interaction with autonomous vessels. this thesis helps build a foundation that hopefully can be used to help prevent too much confusion as autonomous vessels become a presence on the seas.

Bibliography

Sources

Ahvenjärvi, S. (2016). The human element and autonomous ships. *TransNav: International Journal on Marine Navigation and Safety of Sea Transportation*, *10*(3). 517-521. Available at: http://yadda.icm.edu.pl/yadda/element/bwmeta1.element.baztech-e99e196c-33d0-4827-bc59-8ad931a746dc (Accessed: 08.02.2021)

Bassam, A. M., Phillips, A. B., Turnock, S. R., & Wilson, P. A. (2019). Experimental testing and simulations of an autonomous, self-propulsion and self-measuring tanker ship model. *Ocean Engineering*, Volum (186*)*. Available at: https://www.sciencedirect.com/science/article/pii/S0029801818320286 (Accessed: 09.03.2021)

Bonner, M., Taylor, R., Fletcher, K. and Miller, C., (2000). Adaptive automation and decision aiding in the military fast jet domain. In *Proceedings of the conference on Human Performance, Situation Awareness and Automation: User centered design for the new Millenium* 154-159. Available at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.123.253&rep=rep1&type=pdf (Accessed: 17.04.2021)

Design Council (2020) Ships. *What is the framework for innovation?* Available at: https://www.designcouncil.org.uk/news-opinion/what-framework-innovation-design-councils-evolved-double-diamond (Accessed: 22.04.2021).

Discover Boating (2021) *Marine GPS for Boats: Understanding the Basics* Available at: https://www.discoverboating.com/resources/marine-gps-for-boats (Accessed: 20.04.2021)

IMO (2018) *IMO Takes First Steps to Address Autonomous Ships* Available at: https://www.maritime-executive.com/article/imo-takes-first-steps-to-address-autonomous-ships (Accessed: 29.11.2020)

International Institute of Marine Surveying (2018) *Autonomous vessels – the challenges and opportunities in design* Available at: https://www.iims.org.uk/autonomous-vessels-challenges-opportunities-design/ (Accessed: 13.04.2021)

KNFB (2018) Båtlivsundersøkelsen *2018*. Available from: https://norboat.no/download-routerfile.php?temp_id=49&file_id=1233 (Accessed: 29.09.2020).

KONGSBERG MARITIME (2020) *ATONOMOUS SHIPPING*. Available at: https://www.kongsberg.com/no/maritime/support/themes/autonomous-shipping/ (Accessed: 09.10.2020)

Leinonen, T., Toikkanen, T., & Silfvast, K. (2008). Software as hypothesis: research-based design methodology. In *Proceedings of the tenth anniversary conference on participatory design 2008*. 61-70. Available at: https://dl.acm.org/doi/abs/10.5555/1795234.1795244 (Accessed: 20.02.2021)

Mallam, S. C., Nazir, S., & Sharma, A. (2020). The human element in future Maritime Operations–perceived impact of autonomous shipping. *Ergonomics*, 12 (3), 334-345. Available at: https://www.tandfonline.com/doi/full/10.1080/00140139.2019.1659995 (Accessed: 21.02.2021)

Maritime, K., (2018). Autonomous ship project, key facts about YARA Birkeland. Available at: https://www. km. kongsberg. com/ks/web/nokbg0240. nsf/AllWeb/4B8113B707A50A4FC125811D00407045. (Accessed: 23.11.2020)

Melheim, L. (2015) Havgående båter og oversjøiske nettverk *Uiniversitetet I Oslo.* Available at: https://www.norgeshistorie.no/bronsealder/0309-havgaende-bater-og-oversjoske-nettverk.html (Accessed:22.09.2020)

Mohit, K. (2021) Top 8 ships Tracking Websites To Find Your Ship Accurately. *Marine Insight.* 07.04.2021. Available at: https://www.marineinsight.com/know-more/top-8-websites-to-track-your-ship/ (Accessed: 19.05.2021)

Moore, R. (2019) *Ferries showcase potential of autonomous vessel technology* Available at: https://www.rivieramm.com/opinion/opinion/ferries-showcase-potential-of-autonomous-vessel-technology-21746 (Accessed: 23.02.2021)

Norwegian Maritime Authority (NMA). (2019) Recreational Craft. Available at: https://www.sdir.no/en/recreational-craft/. (Accessed: 23.11.2020)

Parasuraman, R. and Riley, V., (1997). Humans and automation: Use, misuse, disuse, abuse. Human factors, 36 (2), 230-253. Available at: https://journals.sagepub.com/doi/abs/10.1518/001872097778543886 (Accesed: 01.12.2020)

Porathe, T. (2019). Interaction Between Manned and Autonomous Ships: Automation Transparency. *NTNU Open,* 1(1) 41-46. Available at: https://ntnuopen.ntnu.no/ntnu-xmlui/bitstream/handle/11250/2609208/6-INTERACTION%20BETWEEN%20MANNED%20AND%20AUTONOMOUS%20SHIPS.pdf?sequence=4&isAllowed=y (Accessed: 01.12.2020)

Rothblum, A.M., (2000). Human error and marine safety. In *National Safety Council Congress and Expo, Orlando, FL* (No. s 7). Available at: https://bowles-langley.com/wp-content/files_mf/humanerrorandmarinesafety26.pdf (Accessed: 09.12.2020)

Richards, D. and Stedmon, A., (2016). To delegate or not to delegate: A review of control frameworks for autonomous cars. *Applied ergonomics*, *53*. 383-388. Available at: https://www.sciencedirect.com/science/article/pii/S000368701530096X (Accessed: 20.02.2021)

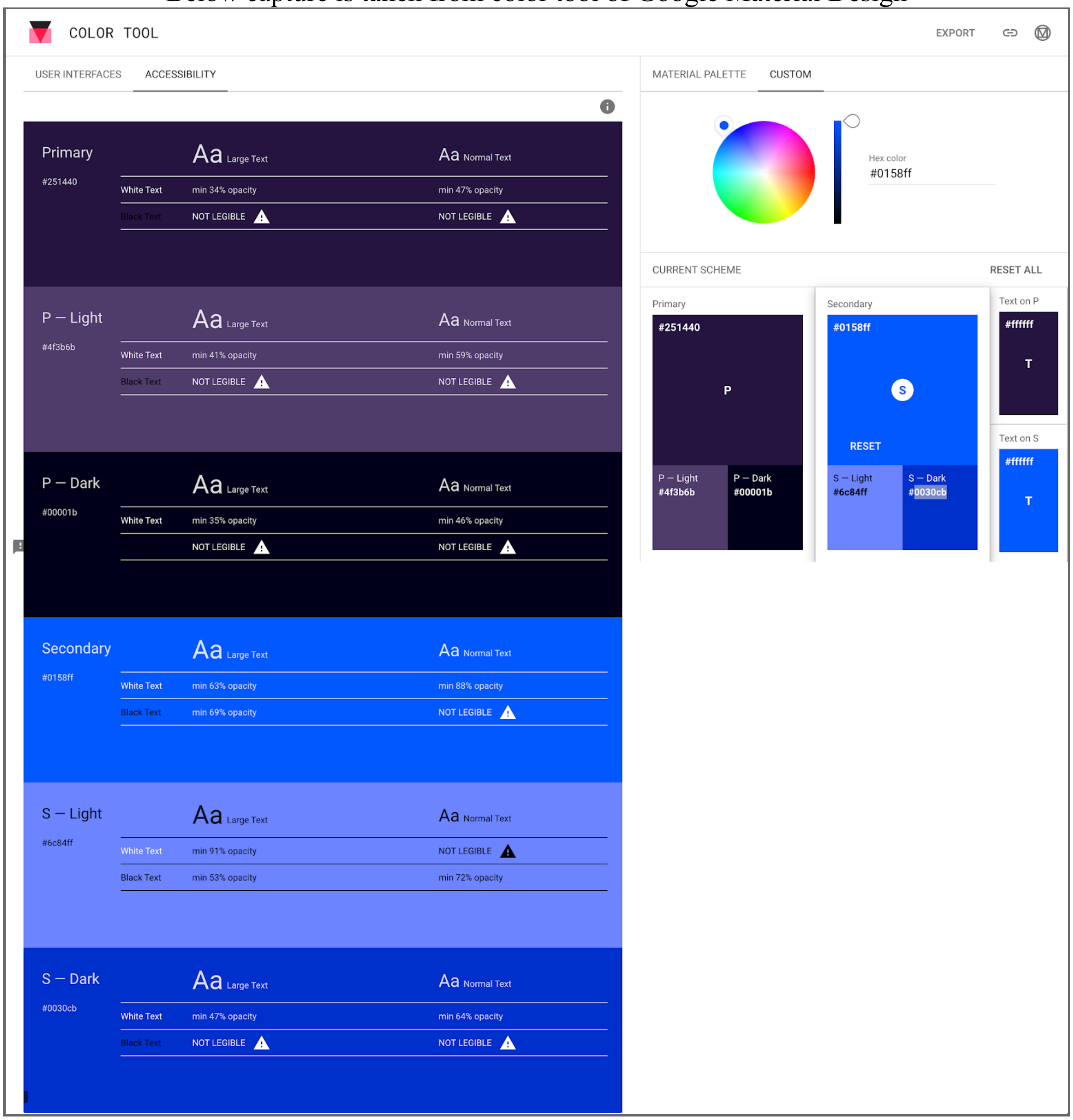
RS (2017) Tipps for trygg sjøferd I mørket. Available at: https://www.redningsselskapet.no/sikker-til-sjos/lanterneforing-i-morket/ (Accessed: 16.12.2020)

Rolls-Royce (2016) *Autonomous ships: The next step.* Available at: https://www.rolls-royce.com/~/media/Files/R/Rolls-Royce/documents/%20customers/marine/ship-intel/rr-ship-intel-aawa-8pg.pdf (Accessed: 10.10.2020)

Vance, J. Albert, E. Davies, J. others. (2020) Ships. *Britannica,* . Available at: https://www.britannica.com/technology/ship (Accessed: 22.09.2020).

Appendix A: Text and readability

Below capture is taken from color tool of Google Material Design



Appendix B: Personas

Personas for the users

Primary user

Frøya, 35

Industrial designer

Owns a sailboat

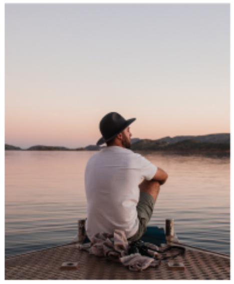
“The problem with sailboats is when you’re in the wind. You wanna stay on course even if you’re getting very close to another ship”

Frøya grew up sailing and has been doing it for many years. Her office is close to where she keeps her boat and she likes to take her colegues out on a lunch trip or an afternoon trip. during her vacations she likes sailing around Norway. Her boat is equiped with navigational systems. But she rarely uses them unless she is going far. She will sometimes open google maps on her phone to check the map quick. Because she sails. she tries to be aware of her soroundings. making sure not to cross paths wiht larger ships

Pain points

- Finds the idea of autonomous vessels uncomfortable. Does not like that she can’t signal them like with a normal boat
- Feels like she can’t understand why they do what they do
- Does not like that a big boat can just turn up on the other side of an island and she has to quicly change her course

Secondary user



Phillip, 28

Accountant

Has access to a boat

“If there’s a person in there. I can wave at them and point where i’m going. I can’t do that with a machine”

Phillip grew up near the coast and has spent a lot of time on boats. But has until recently rarely been the one steering. He got his boating license when he was 16. But has not kept up with the rules and regulations beside the basics. He rarely ventures far away from the islands and mostly uses the boat to go fishing. does not interact much with large cargo vessels and ferries outside of jumping on their wake

Pain points

- Is afraid of accidentally drifting into a shipping path while fishing and not knowing an autonomous vessel is coming
- Finds it uncomfortable that he does now know if the autonomous vessels see him
- Feels he can’t trust that they won’t hit him if he ventures into their lane by mistake

Tertiary user

Kim, 18

Student

Owns Kayak

“I don’t know how autnomous boats act. So i can’t assume anything abou how they will treat me”

Kim likes to go kayaking in her spare time. She lives in an area with a lot of islands and she likes kayaking between them. She rarely ventured out into the open areas where the ferry is. But sometimes during the weekends. She and her friends will go on longer Kayak trips.

Pain points

- Is afraid of being knocked over in open waters by the waves from the ferry
- Checking when the ferry is gonna pass is time consuming and it’s hard timing it right
- Is afraid if she does get knocked over when in the open water that she can’t signal an autonomous ferry for help

Appendix C: Scenario links

Scenario 1:

https://www.figma.com/proto/wLKq5MjBLFwDiDn2QpK3Dw/Untitled?node-id=302%3A212&scaling=scale-down&page-id=110%3A2

Scenario 2:

https://www.figma.com/proto/wLKq5MjBLFwDiDn2QpK3Dw/Untitled?node-id=470%3A12&scaling=scale-down&page-id=470%3A11

Scenario 3:

https://www.figma.com/proto/wLKq5MjBLFwDiDn2QpK3Dw/Untitled?node-id=110%3A4&scaling=scale-down&page-id=0%3A1

NTNU
Kunnskap for ei betre verd