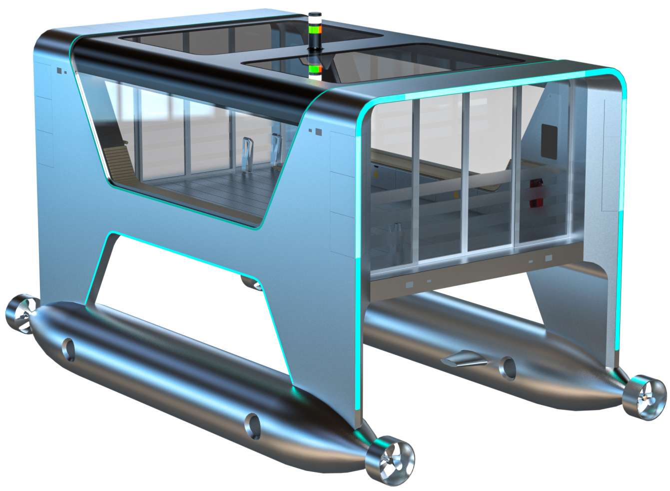
Master's thesis

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

Hilmar Nypan Claes
Malene Liavaag
Vedran Simic

Design an autonomous passenger ferry for urban areas

Master's thesis in Industrial Design
Supervisor: Einar Hareide, Ole Andreas Alsos
Co-supervisor: Leander Spyridon Pantelatos
June 2022



NTNU
Kunnskap for en bedre verden

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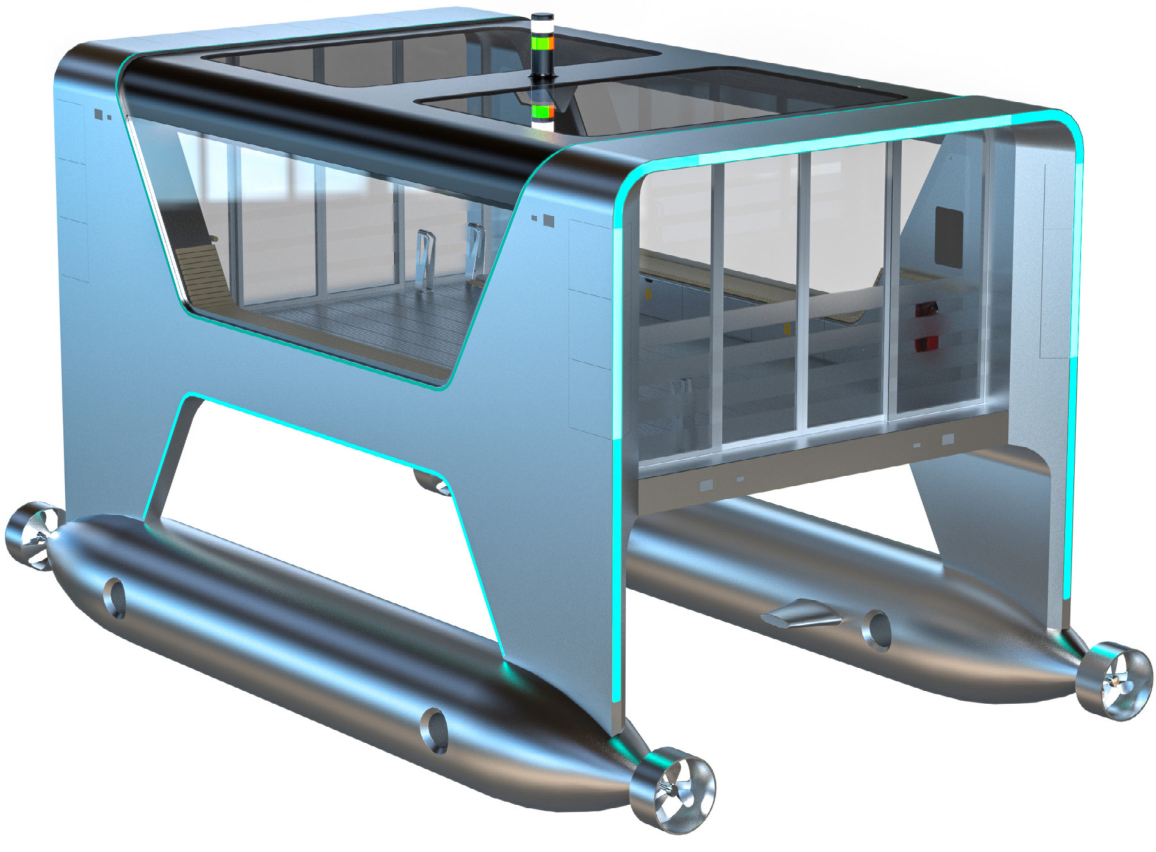


Design an Autonomous Passenger Ferry for Urban Areas

Master Thesis in Industrial Design
Hilmar Nypan Claes
Malene Liavaag
Vedran Simic

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

Supervisors
Einar Hareide
Ole Andreas Alsos
Leander Spyridon Pantelatos

Trondheim, Norway
June, 2022

Preface

We would like to thank everyone that has contributed to our project. A grateful regard goes to family and friends that have supported us, asked critical questions and provided us with food and valuable insights during the last six months. A thank you goes to all the experts we have talked to and the Zeabuz team, giving us a better understanding of hulls, materials and sensors. We also would like to thank Zeabuz for giving us the opportunity to work with such an exciting project and the freedom to pursue our most crazy ideas. A special thanks goes to our supervisor team, Einar Johan Hareide, Ole Andreas Alsos and Leander Spyridon Pantelatos. Your feedback has helped us and pushed us to create something we are really proud of. Lastly, we would thank each other for good teamwork, it's not a matter of course that three strangers can go along so well.

Remember; "It is not a boat!"

Abstract

For this master's thesis a group of three industrial design students has designed an autonomous ferry for 12 passengers intended for use in inshore urban waterways. The work has consisted of a thorough insights phase investigating many aspects of the ferry and its service. Through a creative ideation phase where we used a variety of different design methods, we explored the potential in a field where there is no established design norm. Further on, three of these ideas were developed into concepts and one of the concepts was chosen to be further detailed. We divided the project into three individual parts, where we looked into the passenger journey, the ferry's communication with its surroundings and the ferry's interior.

As a result, we present a design solution of a scalable autonomous ferry concept with the scope of being realised within 5 to 10 years. The design is in line with Zeabuz' values and the discovered users' needs. We propose a solution for an interior layout that provides a good passenger flow coupled with guidelines for creating layouts that comply with universal design principles. In addition, we suggest a solution for a modular furniture system that makes changing the layouts possible. To communicate with surrounding vessels, we have developed lights and physical manifestations that show the ferry's intentions.

Sammendrag

I denne masteroppgaven har tre industridesignstudenter designet en autonom ferge for 12 passasjerer som er beregnet for å gå på urbane vannveier. Arbeidet har bestått av en grundig innsiktsfase hvor vi har undersøkt mange aspekter rundt fergen og dens tjeneste. Gjennom en kreativ idegenereringsfase, hvor vi brukte et utvalg av forskjellige designmetoder, utforsket vi potensialet i et felt som ikke har noen etablert designnorm. Vi utviklet tre av disse ideene videre til konsepter og der et konsept ble valgt for videre detaljering. Vi delte opp prosjektet inn i tre individuelle deler, hvor vi så på passasjerreisen, fergens kommunikasjon med omgivelsene og fergens interiør.

Som et resultat, presenterer vi en designløsning for et skalerbart autonomt fergekonsept med et mål om å bli realisert innen 5 til 10 år. Designet følger Zeabuz sine verdier og de oppdagede brukerbehovene. Vi foreslår en løsning for oppsett på interiøret som gir god passasjerflyt samt retningslinjer for å lage oppsett som følger prinsipper for universell utforming. I tillegg presenterer vi en løsning for et modulært møbelsystem som tilrettelegger for å gjøre endringer i oppsettet av interiøret. For å kommunisere med med omkringliggende fartøy, har vi utviklet lys og fysisk manifestasjon for å vise fergens intensjoner.

List with all related links

Full Miro Board of the project
https://miro.com/app/board/uXjVOW7RaT4=/?share_link_id=897999056345

Miro board with Gifs
related to Communication with the environment – Testing
https://miro.com/app/board/uXjVOwQQ3Ew=/?share_link_id=282003917660

Google forms survey 1
related to the Communication with the environment – Testing
https://forms.gle/KdKZew8j3nPpa12M9

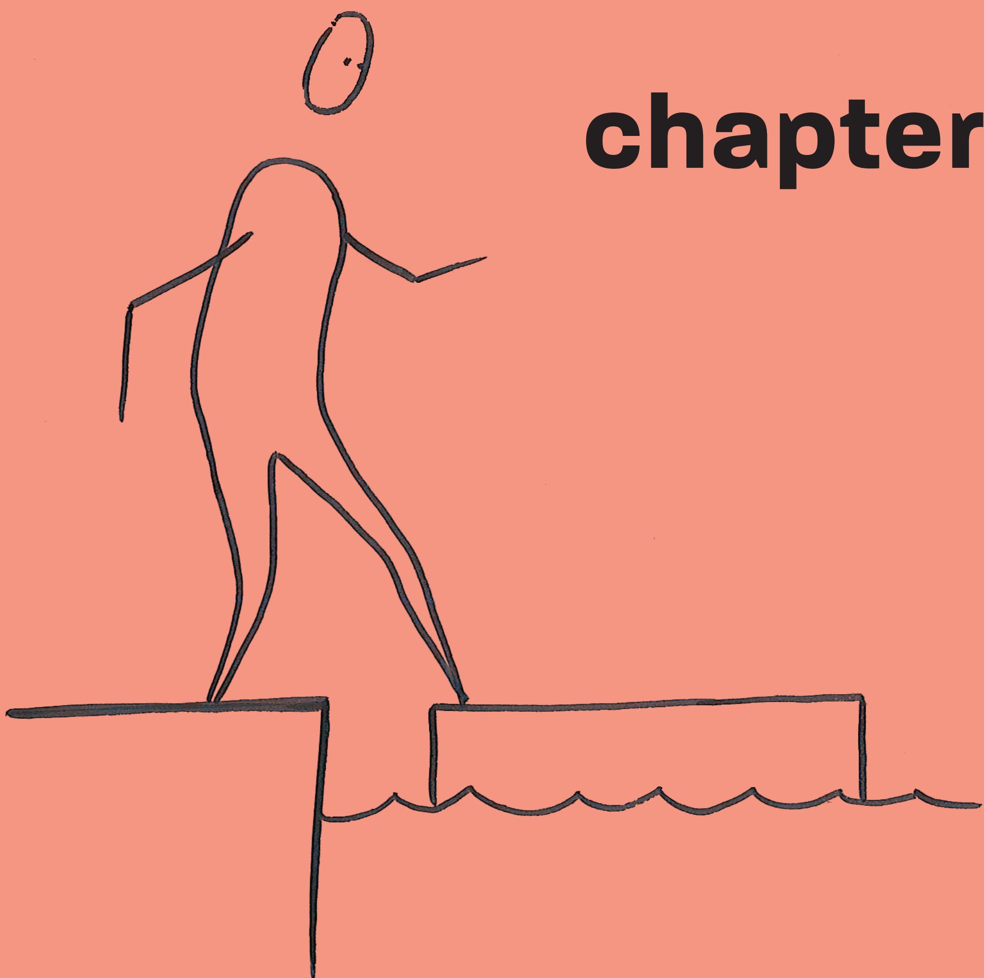
Google forms survey 1
related to the Communication with the environment – Testing
https://forms.gle/XW6aubznDsJ6dXnNA

Youtube Video 1
related to the Communication with the environment – Implementation and Application
https://youtu.be/Qh0J9QtSrlk

Youtube Video 2
related to the Passenger journey – Building a full-scale mockup
https://www.youtube.com/watch?v=Qh0J9QtSrlk

Interactive cloud version of the TwinMotion scene
related to the Results – TwinMotion
https://twinmotion.unrealengine.com/presentation/n1rGNBGSlREFDzg4
Password: NyrYxyY9

chapter 0



introduction

WHO WE ARE

We are a team of 3 design students, all studying at the Institute of Design at the Faculty of Architecture and Design at the Norwegian University of Science and Technology.

Hilmar Nypan Claes
M. Sc. Industrial Design Engineer
During my studies, many of my projects have been drawn to the workshop and the physical part of design. To expand my capabilities and work more conceptually, a project like this was appealing to me. During this project, one of the goals for me has been to develop my skills as a sketcher.

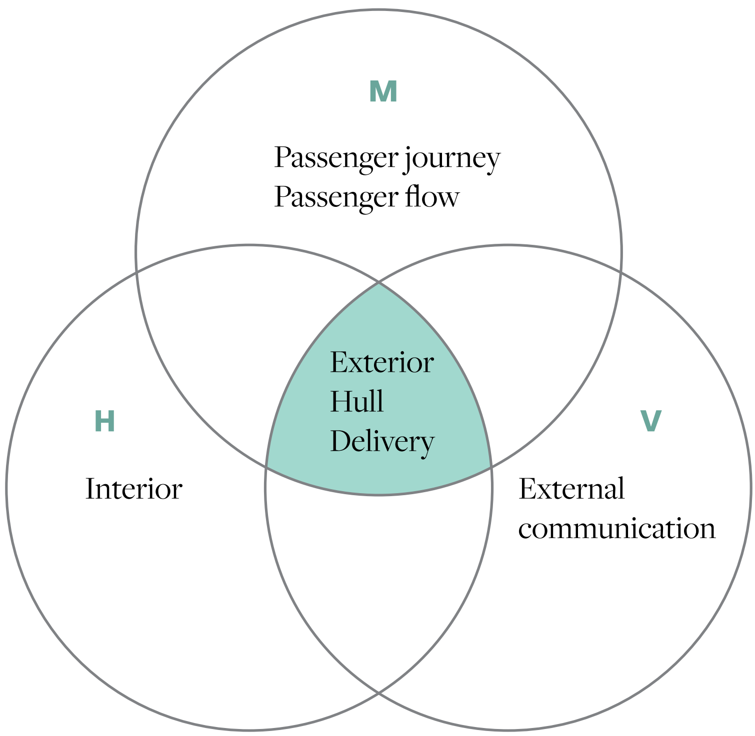
Malene Liavaag
M. Sc. Industrial Design, NTNU
B Sc. Industrial Design Engineering, Østfold University College
With a background as a skilled worker in the shipbuilding industry at the western coast of Norway, I have a strong passion for the maritime industry. Being part of taking this industry into the future urban mobility was what caught my interest for the project. In addition, the possibility of working on a multidisciplinary design project for a start-up company sounded very appealing to me.

Vedran Simic
M. Sc. Industrial Design, NTNU
I did my BA in Design in Croatia. I am super interested in transportation and future technologies.

We have come together for this project, the Master Thesis – as we were all attracted to the idea of working on designing an autonomous waterborne vessel.

HOW WE WORKED AS A TEAM

The tradition at the Department of Design is to write master thesis' either solo or in pairs of two students. For a project at this size, an exception was made and we were allowed to collaborate however suited us best. The initial plan was to share some of our insights, and work individually on each part of one ferry design. Along the way we figured out that we were a group of designers that complemented each other's competences very well. Thus, we ended up working together for major parts of the projects. First we worked together on gathering insights and development of the overall hull and superstructure design. Then we split up to have main responsibilities for three different areas of the ferry design. This was a way to dive deeper in the subjects of interest for all of us, but to also strike a balance between team- and individual work. Malene Liavaag worked with mapping the passenger journey and passenger flow of the ferry design. Hilmar Nypan Claes had the main responsibility for the interior of the ferry. Lastly, Vedran Simic did experimental work on how the ferry may communicate with its surroundings. Hilmar and Malene still worked closely together as the passenger journey, passenger flow and interior of the ferry were intertwined. In addition, all on the team collaborated in building the full-scale mockup for user testing. For those reasons, we chose to deliver all together as one master thesis.



ABOUT THE CLIENT – ZEABUZ

zeabuz

Zeabuz is a Trondheim based startup company, focused on developing a commercial solution based on the success of research on autonomous vessels started at NTNU. Zeabuz has a goal to be a disruptor of urban mobility in areas and cities built around water (Zeabuz, 2022).

PROJECT BRIEF

The project started much before we as a team were involved in it. The original idea proposed to the Department of Design was to have a master student design a unified sensor rig, that combines all sensors needed for controlling and sensing the surroundings of an autonomous passenger ferry. Additionally, there have been projects like MilliAmpere 1 and 2, testing the waters of what it means to make an autonomous passenger ferry. Furthermore, Zeabuz is currently working on its first product – Zeabuz 1 which they are hoping to have operating in the waters of Stockholm in summer 2023.

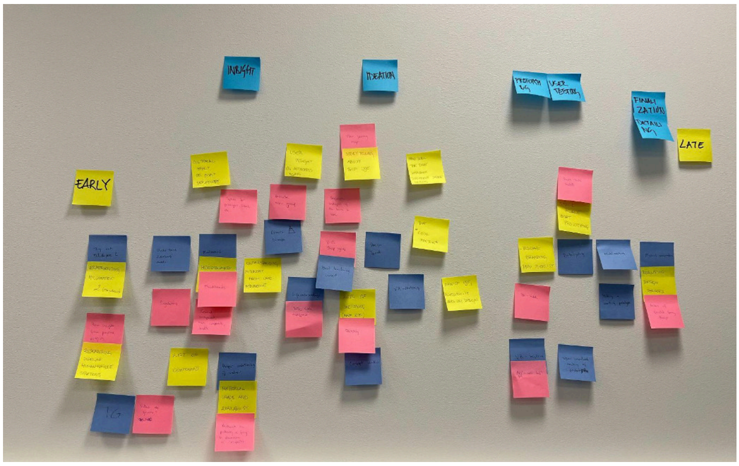
The task we have been delegated as a team is to design the next generation Zeabuz, as a passenger ferry of the future unencumbered by tight 'around the corner' deadlines or currently limitation of technologies and production methods. We were to develop an urban mobility solution focused on the best possible passenger experience to the end user. The projection of the time frame of the design was 5-10 years from 2022.

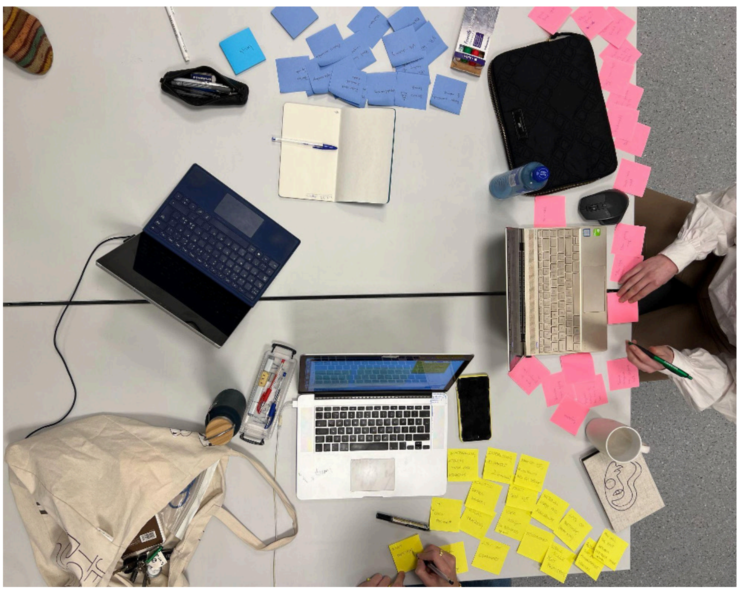
MilliAmpere 1

MilliAmpere 2

INTRODUCTION
PROJECT PLANNING

To kickstart the project planning, we had a 7 minute long brainstorming session with post it notes for mapping project activities. Afterwards we placed the notes on a timeline, depending on when in the project we thought the different activities should be carried out.





The full Gaant Chart can be seen at:
https://miro.com/app/board/uXjVOW6hHQ4=/?share_link_id=253877452133

Most of the activities from the brainstorming were linked to the insight phase. We realised then that we should plan for spending a sufficient amount of time gaining insights, before diving into ideation and conceptualising.

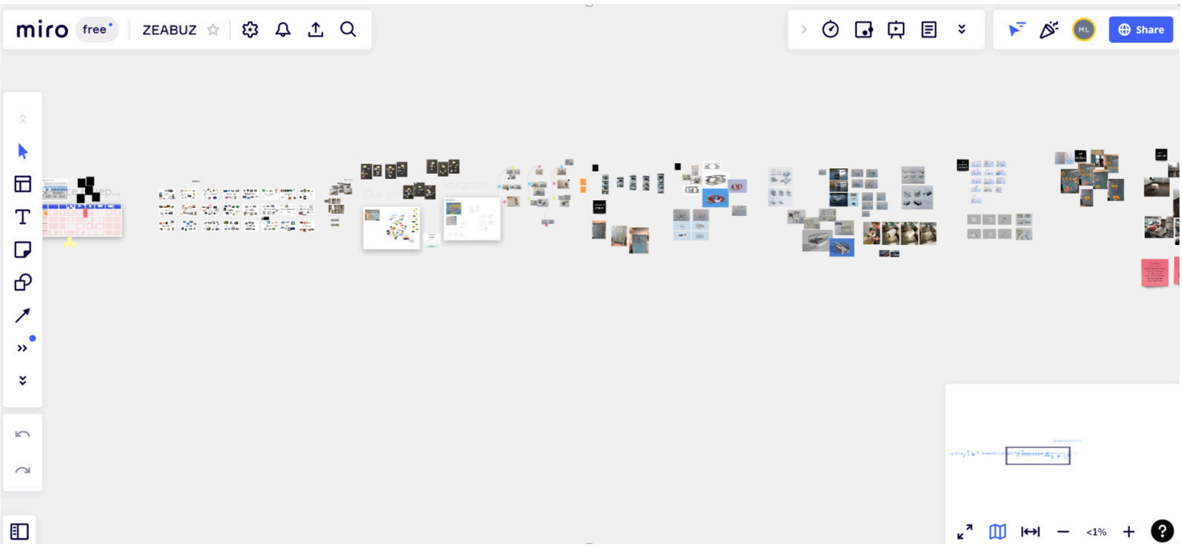
A Gantt diagram represents a linear design process. We knew that not all activities would be conducted 100% according to that sort of diagram, because we work iteratively as designers. Still, we decided it is better to have some sort of plan than no plan. Thus, all activities from the brainstorming were placed in a Gantt diagram in the collaboration tool Miro.

The plan was discussed with our supervisor Einar Hareide. His recommendation for us was to do sketching throughout the whole project, as the level of insights you have will change your creativity and the outcome of your ideas. Another advice he gave was to keep the level of detail on sketches and illustrations in accordance to where we are in the project. This is to avoid misunderstandings between the designer and the client, and to ensure an effective time of use.

DESIGN PROCESS

Being a team of three students working together has affected our process in many ways. We were invited to use one of the available rooms at NTNUs Shore Control Lab at Nyhavna as our permanent group working office. This became an environment where we were able to have loud discussions, put ideas and pictures on the walls, do prototyping and have workshop sessions. The ability to always take a discussion during a workshop has led to some really good reflections on different topics.

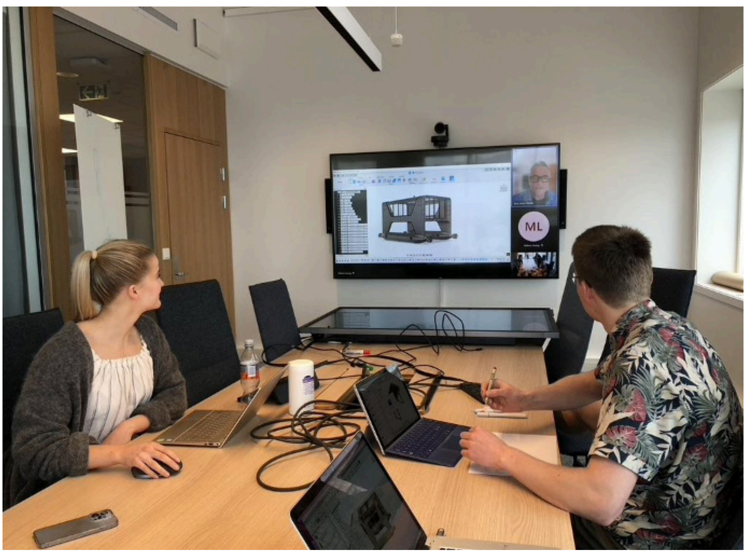
Most of our findings, sketches and renders we have organised in Miro, together with post-its and pictures taken during the process.



The full Miro Board can be seen at:
https://miro.com/app/board/uXjVOW6hHQ4=/?share_link_id=253877452133

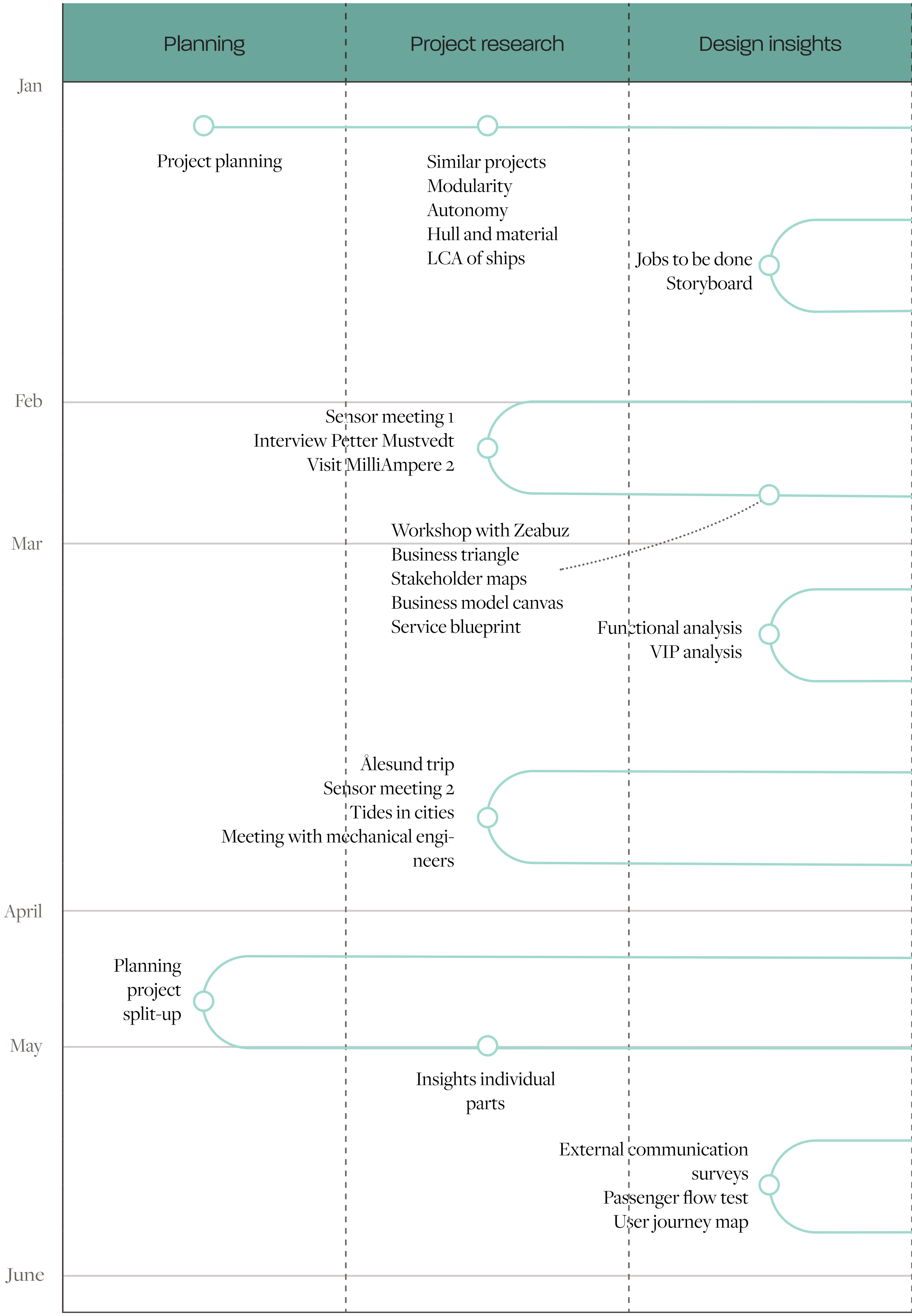
As our supervisor Einar Hareide does not live in Trondheim, our supervision sessions were done on teams. Here we also used Miro to show our progress and to discuss and evaluate our ideas and concepts.

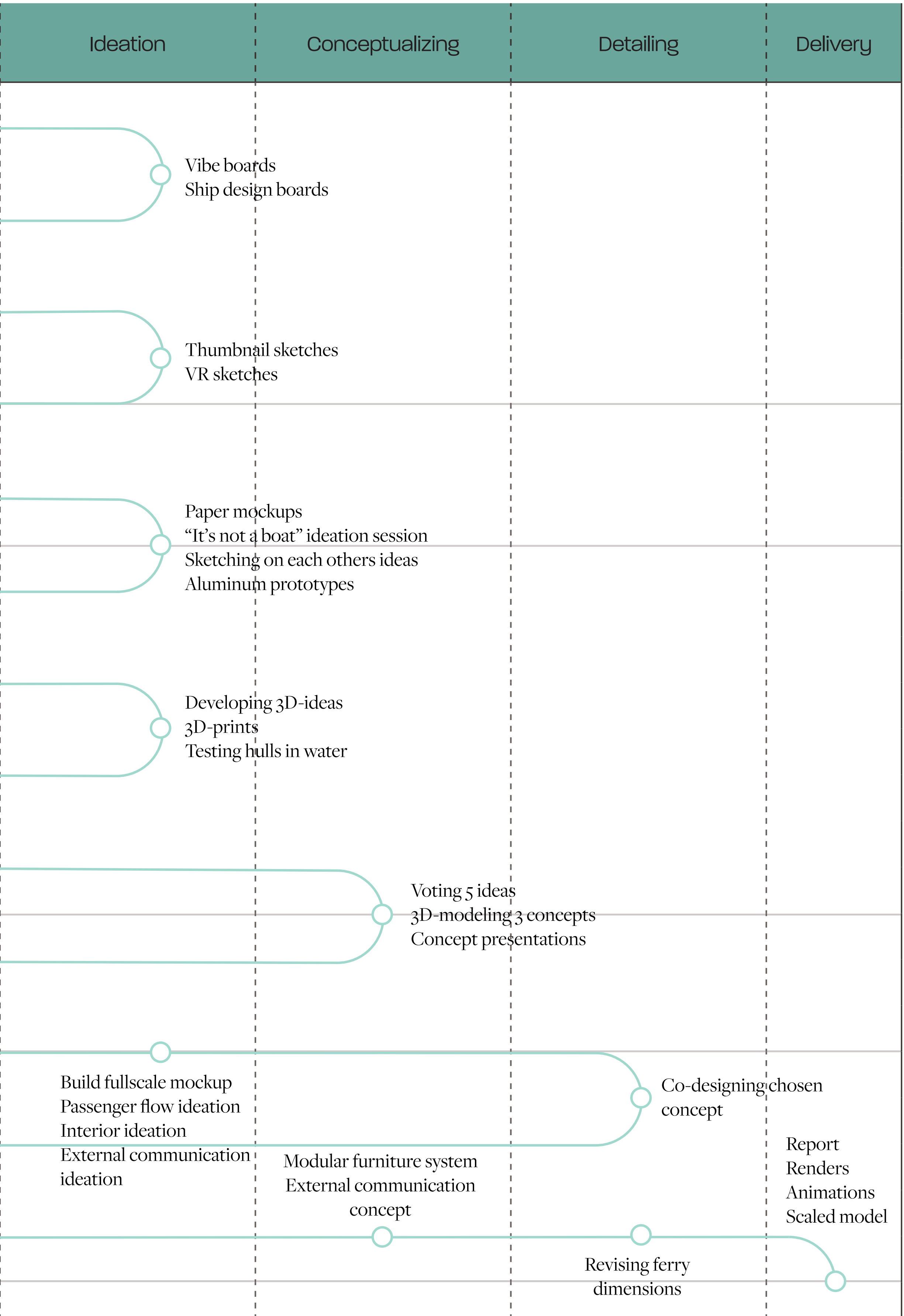
During our master thesis work our process has involved a lot of different methods of design. We have by purpose been broad in our methods to develop and enhance our design.



Typical meeting with Einar Hareide

Graphical representation




Ideation
Conceptualizing
Detailing
Delivery
Vibe boards
Ship design boards
Thumbnail sketches
VR sketches
Paper mockups
“It’s not a boat” ideation session
Sketching on each others ideas
Aluminum prototypes
Developing 3D-ideas
3D-prints
Testing hulls in water
Voting 5 ideas
3D-modeling 3 concepts
Concept presentations
Build fullscale mockup
Passenger flow ideation
Interior ideation
External communication ideation
Co-designing chosen concept
Modular furniture system
External communication concept
Report
Renders
Animations
Scaled model
Revising ferry dimensions

INTRODUCTION

SHOWCASING OUR PROJECT

Having the chance to work visually also means its ease to present the work we are doing. On several occasions we were asked to present our work to people visiting the Shore Control Lab. A committee from the Paris Olympic in 2024 wanting to have autonomous vessels on the rivers in Paris, visited Zeabuz to discuss partnership. We presented our work at that stage and they admired our work and gave feedback on it. Members of the Trondheim Municipality also visited SCL and were presented our work. The Minister of Trade and Industry, Jan Christian Vestre, also had a chance to see the visuals of the ferry when visiting the SCL.

Us presenting for the Paris Olympic Committee delegation

Jan Christian Vestre visiting the Shore Control Lab

INTRODUCTION

PARTNERS AND PEOPLE THAT HELPED

Ole Andreas Alsos - Associate Professor at Department of Design and our supervisor
Einar Johan Hareide - Professor at Department of design and our external supervisor
Leander Spyridon Pantelatos - Research Assistant at Department of Design and co-supervisor
Erik Veitch - Ph.D candidate at the Department of Design
Oyvind Smogeli - CTO at Zeabuz (our contact person at Zeabuz)
Erik F. Wilthil - Lead developer SITAW (situational awareness) & Co-founder at Zeabuz
Jarle Vinje Kramer - Sr. Systems Engineer at Zeabuz
Tore Fiskerstrand - Maritime Partner AS
Severin Åkervik Ulstein - Vard Design AS

COOPERATION AGREEMENT

Since we have not worked together before in a team, we decided to set up a cooperation agreement at the start of the process. This document not only helped us establish a foundation of our cooperation but also served as an initiator of the close partnership that was needed to successfully approach this assignment.

Team contract

1. Group members

Hilmar Nypan Claes
+47 93614392
hilmarc@stud.ntnu.no

Vedran Simic
+47 45843553 or +385 992937131
vedransi@stud.ntnu.no

Malene Liavaag
Phone: +47 94820041
malenl@stud.ntnu.no

2. Decision making

The goal should be that everybody is happy with the solution, if that is not possible we can vote. (thirds) we will try to avoid that. Talking to supervisor as well, to resolve decision that are not unanimous.

Talk and discuss about things we do not agree with. Honesty.

3. What do we expect to achieve with the team work?

Expect to achieve greater, better and bigger things, than what we could do individually. Focus on quality as well. Discussions, develop a thought deeper than you do alone. Teamwork as an element that pushes each other to be better and work harder.

Have fun!

4. What do we expect of each other when it comes to the tasks?

Try to finish on time (deadline), inform others about possible delays. No sloppy work.

5. Meetings

Malene: Available Monday – Friday

Vedran: Available: Monday after 11, Tuesday, Thursday before 11 and after 17, and Friday.

Hilmar: Available: Monday, Wednesday - Friday

Come to the meetings. Inform the other team members if you cannot come in advance. Make up for the lost work if needed.

Group meetings: Monday after 12.00, and Fridays.

Zeabuz meetings:

Supervisor meetings:

6. Breaks

It should be ok to take breaks every hour. Say when someone want a break.

7. What do we expect of each other as a team?

Honesty! If you don't like something, say it.

8. Signature

Malene Liavaag	Hilmar Nypan Claes	Vedran Simic
Malene Liavaag	Hilmar Nypan Claes	

INTRODUCTION
MASTER AGREEMENT

The Master agreement we have submitted at the start of the thesis has included an appropriately open description of what the brief for this project was. This core idea, presented in the project brief, remained true throughout our process and our final delivery.

NDA (NON-DISCLOSURE AGREEMENT)

This Master Thesis is also signed under a Non-Disclosure Agreement (NDA). The expected release date for is in 2 years from signing (start of 2024). This decision has been made in agreement with our supervisors and the client (Zeabuz). This was determined to be the best option for us as students, as it meant that we can be working much closer to Zeabuz.

Masterthesis for student Hilmar Nypan Claes, Malene Liavaag and Vedran Simic

Title Design an autonomous passenger ferry for urban areas
Tittel Design av autonom passasjerferge for urbane vannveier

90 % of the world's urban areas are located near waterways and all over the world, urban seaside industrial areas have been transformed into an attractive mix of housing, offices, business, culture and recreation. Still, while water is a free, available and sustainable infrastructure, the waterways are underutilized for mobility. Norway is a coastal nation, where waterway transport has been and still is important. Many Norwegian cities are localized near the sea. Development of autonomous ferries is part of the ongoing research at NTNU and aims to take back the use of urban waterways to increase mobility.

Zeabuz is a highly ambitious spin-off from the progressive research center for Autonomous Marine Operations and Systems, at the Norwegian University of Science and Technology. Based on the experience with both the milliAmpere ferries, Zeabuz will design and launch the first ferry system in 2022. Even though the company is currently working on launching its first autonomous passenger ferry, the focus of this project is developing Zeabuz 2, the successor to the first one.

This project will be joint work from three students, that will later be split into three complimentary projects focusing on different tasks of the overall ferry design. The goal of the project as a whole is to deliver a comprehensive design concept to Zeabuz that can later be put in production.

The first step – the joint project will focus on designing the superstructure of the passenger ferry, an important part that will be the basis from which other individual student assignments will start from. Those topics could include working on the docking system, ferry interior, the onboard operator station and sensor placement, among other relevant topics connected to the superstructure function. In addition, circular aspects and sustainability should be considered as important design factors, as this ferry aims to become a part of sustainable mobility.

Work may non-exclusively include:
- Collecting relevant insights
- Analysis of previous work on the milliAmpere project
- Developing concepts
- Developing digital and physical prototypes
- Presentation of a new passenger ferry concept

All work will be conducted according to the "Guidelines for Master's Thesis in Industrial Design".

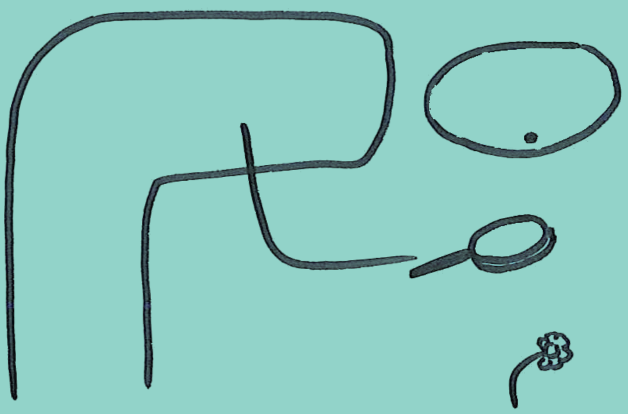
Supervisors: Einar Hareide and Ole Andreas Alsos
Co-supervisor: Leander Pantelatos
Company contacts: Øyvind Smogeli, Henrik Stray

Starting date: 7.1.2022
Submission date: 7.06.2022

Trondheim, NTNU, 07.01.2022.

Einar Hareide
Supervisor

Sara Brinch
Institute leader



chapter 1

insights

The insights gathered in the project have been divided into two main sections; The first is Project research and the second is Design insights. The former covers the technical and ship building insights and the latter covers insights we have gained through the use of design tools.

The insights we have gathered for designing the ferry includes literature review, investigating similar projects, insights from Zeabuz and other expert interviews.

Historical aspect

In the initial meeting with Zeabuz, it was discussed how they are planning to "take back" the use of urban waterways. The history of urban waterways and their future potential are being discussed in a paper by Beck et al. (2019). Our first civilizations were created around rivers (Middleton, 2012, s.48). From the industrial revolution, major changes were done to the rivers to fit new purposes. Some of these changes were to turn them into canals for shipping, waste, for producing hydro power or making drainage channels. Other rivers were completely removed from the urban areas.

Today, however, the potential of urban waterways have been rediscovered across the world (Beck et al., 2019). One of these potentials is to use urban waterways for transportation (Tannum and Ulvensøen, 2019). Where many urban passenger ferries have been replaced by tunnels and bridges, there is a potential for having autonomous passenger ferries that can serve as a more sustainable option. The ferries may reduce the need for tunnels and bridges with a car-free option, that can work as a supplement to trains, buses, bikes and other mobility options (Tannum and Ulvensøen, 2019).

 Photo credits: Joël de Vriend

Cultural impact

Creating a transportation system has a larger impact than just carrying passengers from one place to another. Since around 40% of all people live in coastal areas (Reddy et al., 2019, as cited by Goerlandt & Pulsifer, 2022), people can benefit from using transportation modes on water, utilising the vastness of such open areas. Water transit systems have in the past proved to benefit the area they were placed in. An article by (Thompson et al., 2006) points out how ferry and cable car deployment influenced the quick growth of the eastern side of the San Francisco Bay Area in the 19th century. Economic development has been documented in other cities as well. Göteborg, for example, has experienced population growth in areas where the ferry has a stop and those areas today are viewed as well connected and developed (Tanko & Burke, 2016). These ferry terminals influence other transportation options as well. Research has shown that multimodal transport leads to growth in many of the included services and that advancements in public transport directly encourage creation of sustainable and smart cities. This means that designing the ferry of the future also means understanding its impacts in culture and environment.

A research paper by Tanko et al. (2019) investigates the public's perception on water transit. This article identifies a few key advantages why using waterways for transportation can be beneficial both for the users and for the city. To start, water transport offers a benefit with its view as the vessel travels in a different environment than ground vehicles. In addition, increased comfort levels and less noise have been noticed by users when choosing to travel with ferry systems.

Trust

Design for trust

Intel is discussing designing for trust in autonomous vehicles in a report. Intel claims that evolving autonomous technology has received much more attention than learning consumers to trust the technology (Intel, 2016). Håkonsen and Jensen (2021) investigated how design practitioners can design for trust in their master thesis Design for trust. They had an interview with Gunn Dogeset, CTO of Applied Autonomy, who works with developing autonomous buses. Dogeset explained that trust in technologies does not come from making every detail transparent or making explanations of how an algorithm works. In fact, Dogeset argued that it is about reducing risk, and introducing the unfamiliar in small enough steps to make the users willing to accept them. Through expert interviews with many experienced design practitioners, Håkonsen and Jensen concluded that the gap between the known and unknown must be reduced so that users are willing to take the leap - and here can designers' roles be to bridge those gaps (Håkonsen and Jensen, 2021).

Through our meetings with Zeabuz, we have gotten the impression that their strategic plan for introducing the service is to a degree in line with these recommendations. Having an autonomous ferry without an operator on board is not allowed according to current regulations. When releasing their service in Stockholm in June 2023, Zeabuz' plan is to have an operator on board. The operator will first and foremost make the passengers feel safe, and can operate the ferry if necessary. When people get used to the fact that the ferry is doing every operation autonomously, and they learn to know that the operator does not do much besides being there, it may lower the threshold of acceptance.

For the ferry designed in this project, we believe Zeabuz has passed through the first initial steps upon time of release. Thus, we have designed the ferry without an operator station and assumed that the ferry is being monitored from shore. In case Zeabuz wishes to use our design at earlier steps, we have made visualisations of how they may include an operator station.

Vandalism in autonomy

Vandalism is defined as 'action involving deliberate destruction of or damage to public or private property' (Oxford 2022). The risk of having no operator on board, is that no one is there to intervene in case of a mishap or unlawful behaviour, except other passengers and onlookers.

Vandalism tends to occur less often at spaces that are designed open with more visible control, and spaces that have sufficient lighting. When equipment is damaged, the risk of vandalism to nearby equipment increases (Yavuz, 2010). These risks have been kept in mind while designing the ferry. For example, we have opted for robust material choices that are easy to clean and maintain. Furthermore, we decided to design a ferry with a lot of insight and lighting at night, so that vandals are easy to spot. We have also tried to make sufficient space in the hull to install technical equipment out of reach for passengers (Yavuz, 2010).

Being blasé

The concept of being blasé has been popularised by a German sociologist Georg Simmel (1903). It is a specific phenomenon of people living in big cities, where everyday life is so hectic that they become numb to the happenings of the outer world. As the habitants' senses are constantly bombarded by various stimuli, they become completely disinterested in what is happening around them. In a way, it is lowering the threshold of what will catch someone's attention. It happened as a mechanism to protect the individual from overstimulation. As humans have a limitation on the amount of their emotional resources it is only possible to care about so many things. For example, it has been characterised that riders of the New York City Subway system act as complete strangers (Ocejo & Tonnelat, 2014). Unfortunately, sometimes it results in situations in which bystanders would completely ignore norm violations and other external occurrences.

This means that we cannot rely on the passengers to look out for each other when there is no operator on board. Thus, we recommend Zeabuz to install camera surveillance, for increasing the visible control (Yavuz, 2010). In this way the passengers can be watched from shore control centres. Additionally it may reduce the risk of vandalism occurring.

Universal Design

It was of vital importance to us to design a ferry that can be used by all people. An action plan made by the Norwegian Ministry of Children and Equality in 2009 stated that the Norwegian Government's vision is to make Norway universally designed by 2025. Many international organisations are also making recommendations for better accessibility for disabled people, such as UN, EU, Council of Europe and Nordic Council of Ministers (Norwegian Ministry of Children and Equality, 2009). A report by BufDir (2018) summarises that disabled passengers in Norway have had many challenges with passenger ferries. To make sure our design is universally designed, we tried to make a design that does not require steep ramps for accessible boarding. In addition, we tried to follow recommended principles for passenger ferries. That included an online document by Universell Utforming AS and one by the Norwegian Association of Disabled (NAD). The recommendations are for ferries with length over 15 metres. As there are no recommendations available for ferries at the size we are designing, we have tried to follow the principles we were able to. Details on the principles we have followed can be found in the User journey and Passenger flow chapters.

The sightseeing ferry Vision of the Fjords, designed by Torstein Aa and built by Brødrene Aa AS, is an example of a vessel designed with universal principles in mind.

Photo credits: Brødrene Aa

Similar Projects

Experiences from MilliAmpere 2

As mentioned in the project brief, MilliAmpere 2 is an autonomous passenger ferry made for researching autonomous vessels. This project is a multidisciplinary project at NTNU. The goal of this ferry is to take passengers over Nidelva in Trondheim, from Ravnkloa to Fosenkaia. At the start of our project, we visited MilliAmpere 2 when it was brought to shore for maintenance reasons. In this visit, we also had the chance to have a chat with the project leader Egil Eide.
We got to inspect both the deck and the hull, and had a meeting with Egil Eide on board. Our initial thoughts were that Milliampere 2 was much bigger in real life than what we had imagined. An explanation for this may be that only half of the ferry shows when it is in water, with the hull below sea level.





Main takeaways from the meeting:

- MilliAmpere 2 has 2 tons of batteries installed. Consider where the charging should be integrated into the hull.
- Monohull was chosen because it is more stable when passengers are standing at one side.
- At least a small on-shore installation is necessary for docking
- The size of MilliAmpere 2 is right for 12 passengers. It is not too crowded and not too big.
- Think about where to place a temporary operator station
- Think about the use of contrasts to increase ease of use. MilliAmpere was initially designed with a wooden floor. Now there is only wood at passenger contact points, such as the bench and railings. The wood on these details stand in contrast to the aluminium floor.
- With an open deck - consider condensation, leaking into hatches and heating in floor to avoid frost
- Plan for sufficient space for equipment and how to access it for service
- Think about manufacturing when designing the hull. The hull design of MilliAmpere 2 was not suited for aluminium manufacturing.

We also had an interview with Peter Mustvedt, to learn about his experiences with designing MilliAmpere 2.

Main takeaways from the meeting:

- Main criticism of the thesis was not including users to a larger degree. Ended up being an engineering project. Mustvedt advised us to test a physical prototype and make improvements based on user feedback.
- Should have taken a more holistic approach. Was pragmatic about the physical design and did not focus on interaction and communication of the ferry
- Have a workshop with everyone involved at an early stage. That opens up for discussion and to get a consensus on a direction.
- Putting someone’s idea on paper is a powerful tool. It opens up for discussion and shows what works and does not work.

Later in the process we also visited MilliAmpere 2 on water. We took a trip at Ravnkloa and experienced what it is like taking a trip in an autonomous vessel. The ferry felt very stable, fully in control and most importantly safe. Other passengers that took the trip with us confirmed that as well.




Other autonomous vessel projects

Looking at other similar projects was useful for the project for getting an overview of where Zeabuz is in the market. Most of the projects are targeting different markets than Zeabuz. We learnt that the only project that has succeeded within the market of smaller ferries is the Roboat project in Amsterdam. They have a slightly different approach than Zeabuz, as they are not developing a shore control centre. We believe Zeabuz has an opportunity to become market leaders if they focus on the service, the user journey and universal design principles. For example, the Roboat is not universally available for all people as you must "climb" on board the boat. Thus, we decided these areas must be considered in our design process of the ferry.

CAPTN Vaiaro

- Developing urban mobility on water in Kiel
- Planned a research vessel
- Concept done by Master's students of industrial design

Photo credits: Muthesius Kunsthochschule Kiel

Roboat

- Research project on small autonomous vessels in Amsterdam
- Collaboration between MIT and AMS
- Modular concept, where the superstructure is interchangeable
- Use Cases: passenger transport, garbage collection, goods delivery and on-demand bridge
- Not universally designed

Photo credits: Reuters Photo

Hyke

- Norwegian company aiming the Norwegian market
- Emission free vessels
- Imagine operator on board, varying degrees of autonomy
- Covering larger distances and more passengers

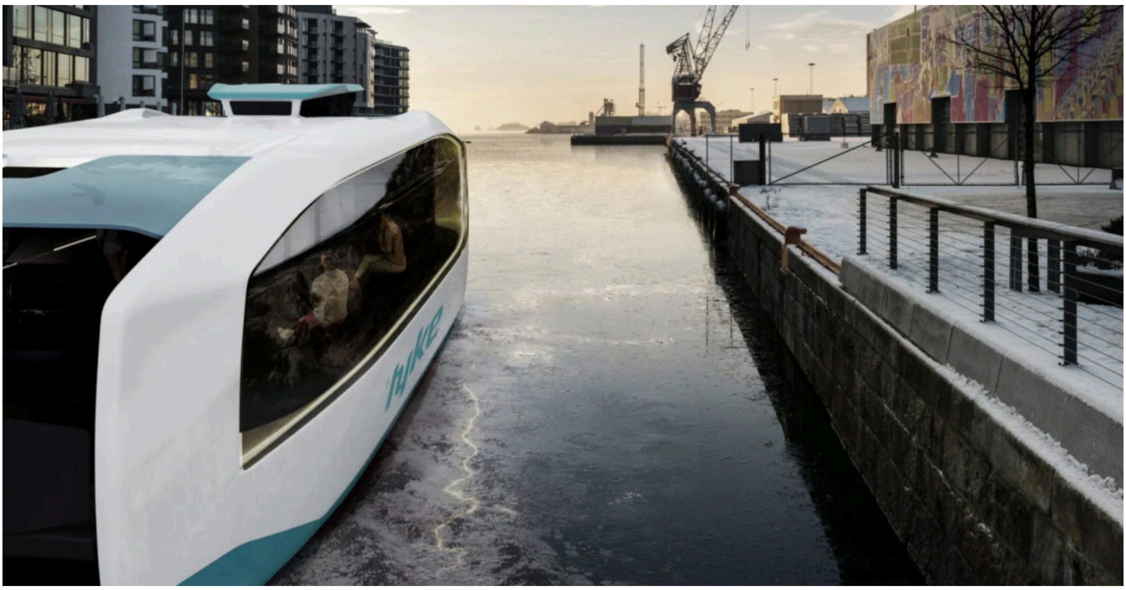


Photo credits: Hyke

Kongsberg

- World leading in development of autonomous technology on ships
- Aiming for different segments within autonomous ships
  * Cargo
  * Military
  * Apply autonomy on existing vessels

Photo credits: Kongsberg

INSIGHTS

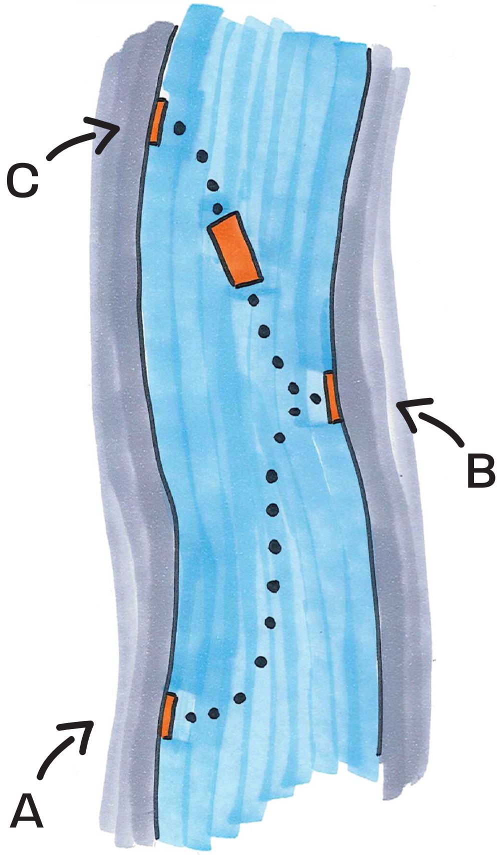
PROJECT RESEARCH

Logistics

Logistics of deploying an urban autonomous passenger ferry get more challenging depending on the goal of the service. MiliAmpere 2 serves as a shortcut between 2 sides of the channel, crossing in less than 5 minutes. It also moves back and forth, like a pendulum, taking in passengers from one side and letting them out on the other. This simple operation becomes a bit more complex if the ferry's goal is to be as flexible as a personal vehicle or a taxi. If the ferry is to be available to everyone it needs to be able to dock in a large number of places. The problem appears when investigating capabilities of the current ferries, which only stop at a few designated spots where docks and other infrastructure is built. A truly flexible taxi system, which is an idea Zeabuz aspires to once make possible, requires some way of allowing for the ferry to stop anywhere. Deploying more than one boat would also make the system more complicated.

If, for example, there are more than just 2 points in the ferry's system, A and B, what pattern does the ferry take when servicing those stops. Perhaps the boat goes from A to B to C and then to A again. Another option is for the boat to dynamically switch positions depending on the demand on one particular spot. Furthermore, timing of the ferry greatly influences the logistics of the system. If a ferry operates on a time schedule, departing every 5 minutes for example, passengers on one side of the crossing will have to wait until the ferry reaches their place of departure. On the other hand, if the ferry is an on-demand service, there needs to be a way for prospective passengers to call for the boat if it is currently on the other side of the channel.

All of these things can influence the design of the ferry's experience, creating different advantages and disadvantages in particular scenarios. (Further discussed in the Passenger Flow chapter)


C
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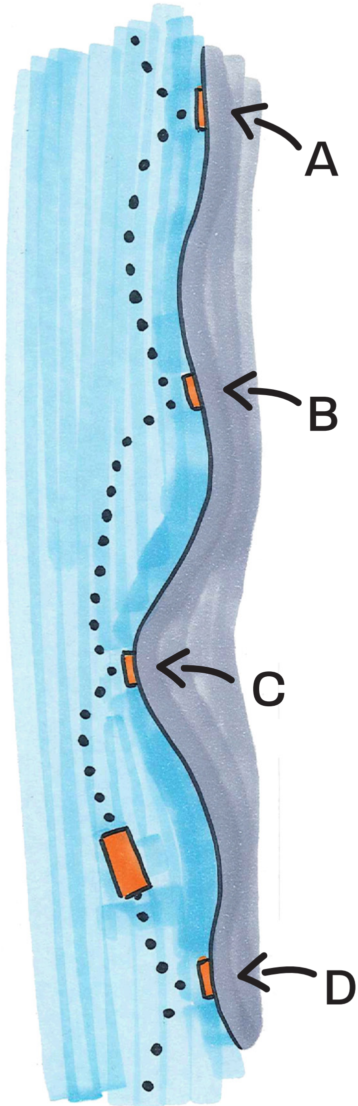
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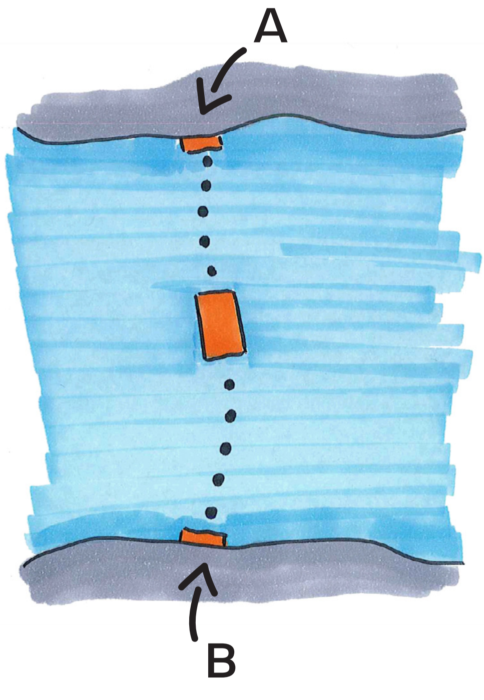

A
B

PROJECT RESEARCH

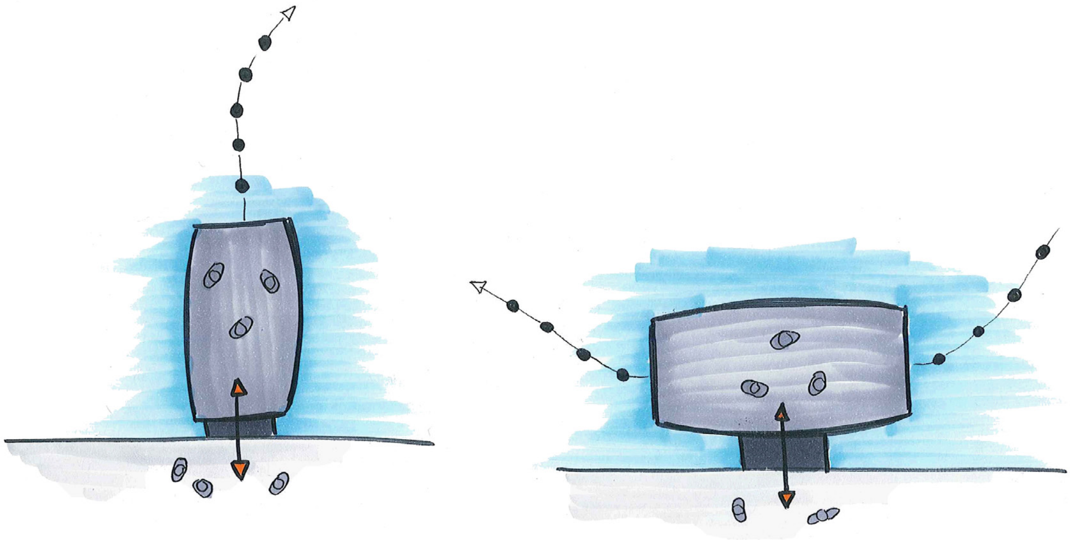
Docking

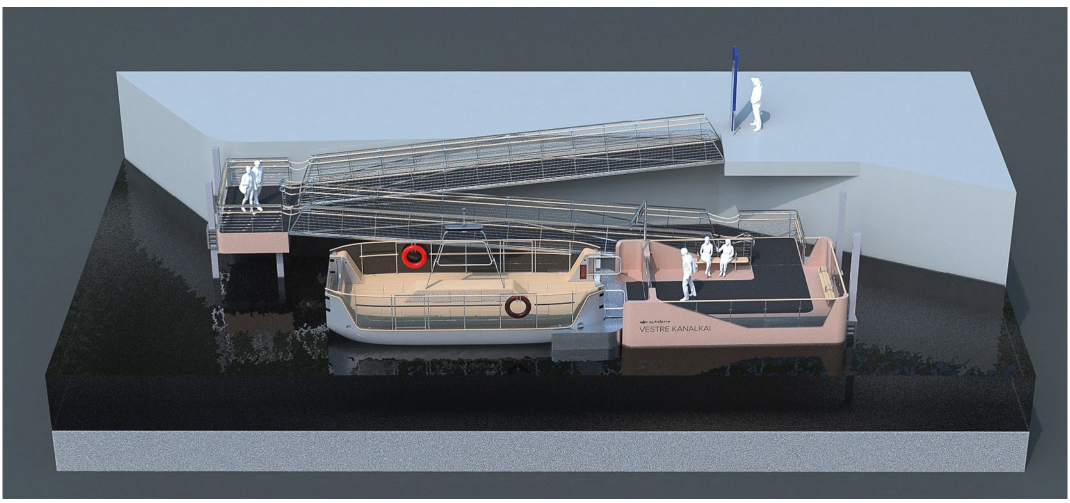
As previously said, a boat crossing connects two points, A and B. The vessel in that case moves along one axis back and forth and a logical way of solving docking is to have an opening for the passengers at the front and the stern of the boat. If the boat moves along a coast, canal or a river, or docking at multiple stations along a path, it makes more sense to have a docking solution on the longer sides of the vessel as it would eliminate the need to steer 90 degrees into place upon every docking procedure. Such a docking requires more space at the quay.

Docking usually requires land-based installations to assist connecting the ferry to the shore. Investigating how the docking situations could be solved, we first looked at how it had been solved for the MilliAmpere 2 project. In their masters thesis, Glesaaen and Ellingsen (2020) designed a dock to match the Milliampere 2's aesthetics and functionality. To adapt to Trondheim's elevation in tide waters, a floating dock with a long descending pathway was needed to facilitate universal design.

As the Milliampere2 has openings at the bow and stern of the boat, the dock was made to accommodate this docking to the front and the back of the vessel (Glesaaen and Ellingsen, 2020). Looking at other Norwegian fast ferries, many of them are also made to have docking on the sides of the vessel, but then also dock directly to the quay. As a consequence of some extreme differences in tide water in Norway, some of these ferries have boarding from two different decks, in addition to an integrated elevator for wheelchairs.

A floating dock is flexible enough to accommodate tide and quay changes, but it is still a physical thing that needs installing at every potential docking location. If for example, one would like to dock at any location, that would mean docking directly to the quay, which immediately raises the question of safety and executability. A dock would also mean there is a visible and physical place for passengers to know where the boat stops, but it also means that Zeabuz needs to not just develop an autonomous passenger ferry but to also make sure there is something on shore in places they would like to dock to.





Floating dock by Glesaaen and Ellingsen (2020)

Charging

Charging is an integral part of the operation of the ferry. Since it is battery powered, charging the vessel will be a daily occurrence. A possibility is to charge at the dock, while the ferry is stationary, replenishing the power of the battery often. Another idea Zeabuz have had is to deploy a single place of charging , not connected to the shore, which is placed in the water. This piece of equipment could charge itself during the day collecting solar energy and then charge the ferry during the night, when the demand for it is not as high.

An existing charging solution implemented in Norway includes a design by Siemens for the MF Munken and the MF Lagatun ferries, operating between Flak and Rørvik (Trøndelag fylkeskommune, 2019). Every time they dock, they charge with 4,5 MW of power. In 1 minute, this is enough to fully charge an electric car, and in 5 minutes to fully replenish the same amount of electricity a single household uses in a day. These kinds of solutions are only going to be more available and advanced in the future and the next generation Zeabuz ferry can surely take advantage of it.

MF Lagatun docking by the charging station at Flakk. Photo credits: Karl-Henrik Linder

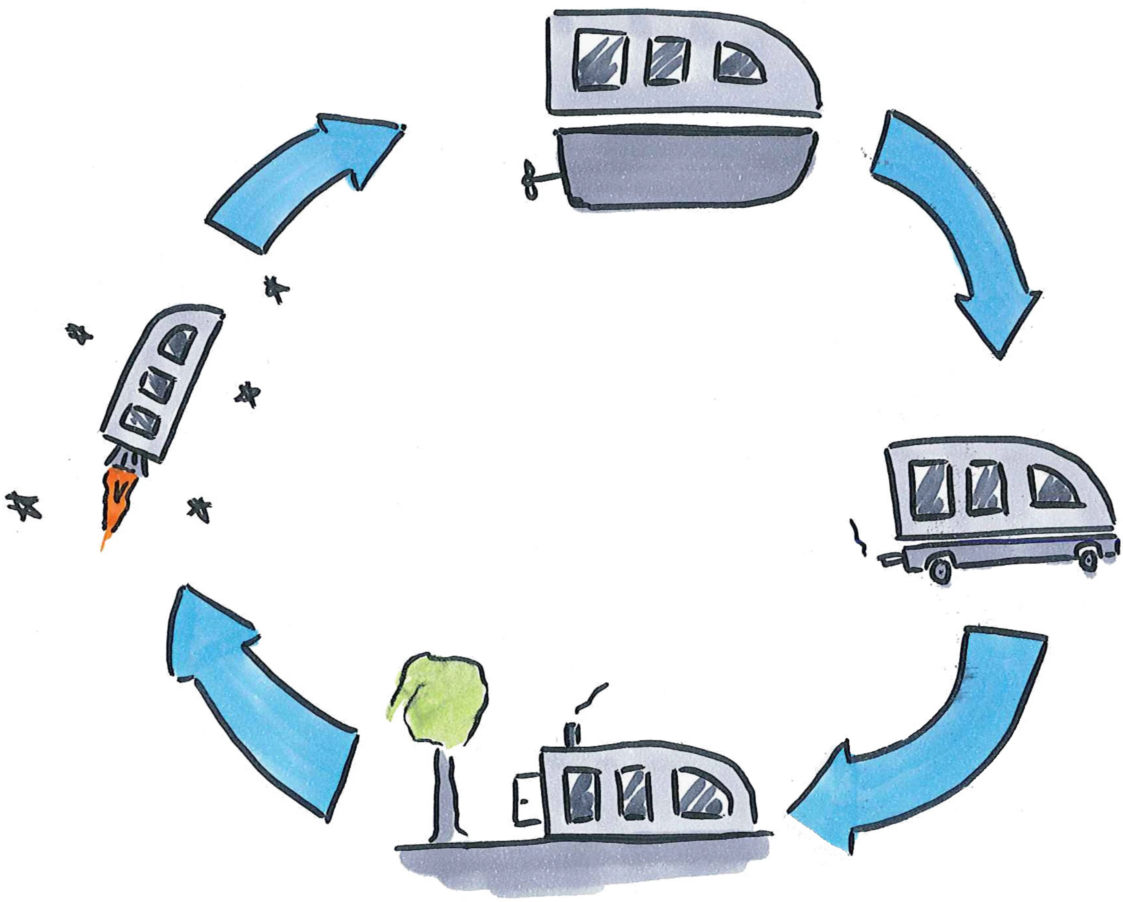
Scaling & Modularity

Modularity in ships can be many different things. A European research project called TrAM occurs to be in front regarding the research on modularity in ship building. Their perception on ship modularity is more on the construction of the superstructure of the ship, having different sections that can be combined to generate different designs dependent on use and needs. Thus reducing the cost in the development phase of building a ship.

We believe modularity in ships can contain much more than that. Modularity can for example be that the superstructure can facilitate different use cases during its lifetime, making it easy to make changes is the use cases it's needed for. A research report by Schank et al. (2016) discusses modularity and flexibility in US military ships. They suggest that flexibility is something different from modularity, and that the best way to design for flexibility is by making sure to have enough space. This is because you don't know what future technology will be, and by making new ships more spacious, you ensure that this technology can be included in the future. Flexibility may also mean that the regulations may change in the future, such as the number of passengers.

It is also interesting to see what happens with the boat after its operational time. Can it be refitted, retrofitted, or converted into different uses? This is something that can be considered during the design phase, giving the vessels built a longer life and maybe new life after it has completed its intended task.

By creating a design that is possible to scale up or down, different markets can be entered such as having larger vessels going on longer distances. This goes also for deploying in new cities, where flexibility in the design can make for changes that fit the needs of the market.



Operating Environment

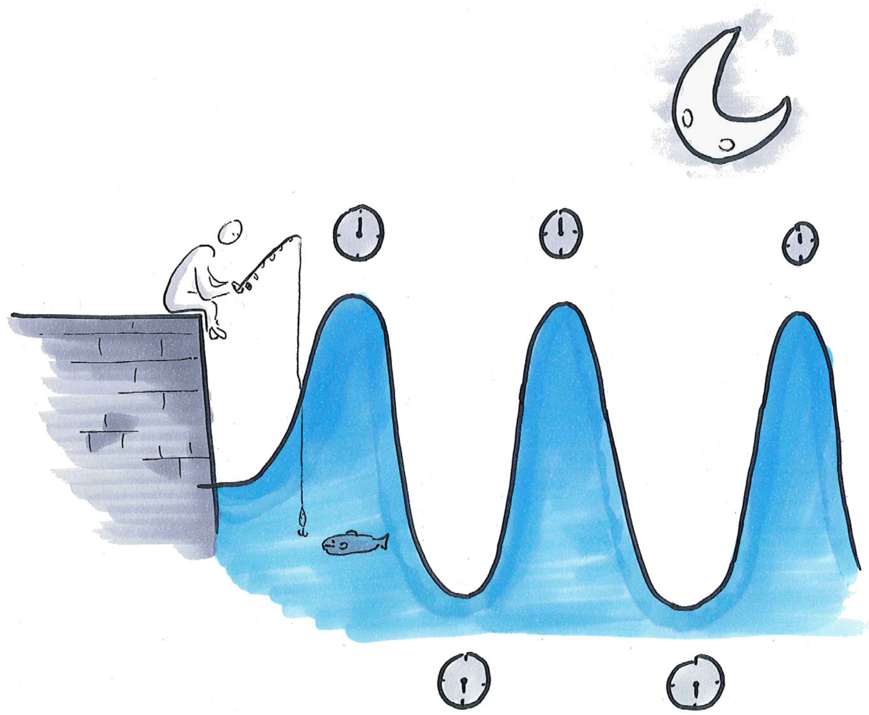
Compatible Cities

As previously mentioned, Zeabuz's first product will be the Zeabuz 1, placed in the waters of Stockholm. Since one of the goals for Zeabuz is to deploy their vessels in other cities as well, we have done research on possible urban areas that are suitable for such a vessel. Those included metropolitan cities like Copenhagen and Helsinki but also less densely populated cities such as Haugesund and Kristiansund.

It was found that the difference in tide heights can be greatly different depending on the location. For example, the delta in tide height for Copenhagen is around 20 cm, while the delta for Kristiansund is around 250 cm. This is a variable that greatly affects the design of the passenger vessel, as it is of most importance that it can dock safely, handling both lows and highs of the water it is in. We did not choose a specific city to design for. Instead, we kept in mind that the ferry design in the project should be scalable, as mentioned in the previous chapter, so it can be tailored to cities with different tidewater heights.

Quay Heights

Quay heights is another parameter that has to be considered along with tide water heights. As the ferry needs to dock securely to let passengers come in and out, the quay together with the dock need to accommodate a range of possible quay heights. Quay height implies the distance between the water height and the top of the quay, which varies depending on the tide, type of city and area in the city. The ferry somehow needs to be able to dock regardless of the size of the quay or water tide, which suggests that some part of the operation needs to be flexible. Ideally, this approach between the quay, dock and the ferry is universally accessible, meaning there are no stairs, steep ramps or similarly designed items unsuitable for everyone.



Hull Design

For the design of the hull, we gathered insights from talks with Zeabuz, Egil Eide, the project leader of MilliAmpere 2 and Maritime Partner AS.

Catamaran hull

This hull is often seen in fast speed ferries. It has good stability at the width length. Thus, it is a good option for transporting passengers. The down-side is less space for components in the hull.

Monohull

As the name says, this hull consists of one part, that is deepest in the middle. MilliAmpere 2 is a monohull design. The stability is poorer for passengers. There is a lot of space for machinery and components under the passenger deck, which is an advantage.

Swath hull

Øyvind Smogeli, CTO at Zeabuz advised us to check out the swath hull after seeing one of our ideas. This is often used for crew transport at wind farms. The swath hull is even more stable than the catamaran hull. It uses the same technology as submarines, to go up and down in the water with ballast pumps.

Bidirectional hull

A bidirectional hull is often used for pendulum ferries. The hull is then symmetrical, so both ends can be the front end, depending on which direction the ferry is going. This requires double up of many components, thus, it is a more expensive design. The advantage is that the boat does not have to turn around when docking. This leads to good passenger flow if the entrance is at the front-ends.

Unidirectional hull

A unidirectional hull has a bow at front and a stern at the back side. It will mainly go in one direction.

INSIGHTS

PROJECT RESEARCH

Ålesund Trip

This part of the process started as a result of us finding out that the client – Zeabuz, had not yet decided on the shipyard they were planning to use for the building of Zeabuz 1. In addition, we were interested in contacting different shipyards to learn about manufacturing and ship design processes. Among others, two companies stood out to us the most, Vard Design AS and Maritime partner AS.

Vard Design AS

Vard Design AS designs specialised off-shore vessels that vary around 100 metre in length. The company caught our interest because we thought their visual expression and the quality of visualisation stands out from other ship designers on the market. Their vessels are built in steel.

Main takeaways:

- For the design process, they start with clients reaching out with a requirements list, then moving on to making general arrangement sketches and analysing the hydrodynamics of the designs.
- Good design attracts customers, because it awakens their emotions
- All designs are built and tested as small-scale prototypes, usually at up to 9 metre length
- Vard uses VR to showcase their designs to customers
- Rendering software used is V-ray

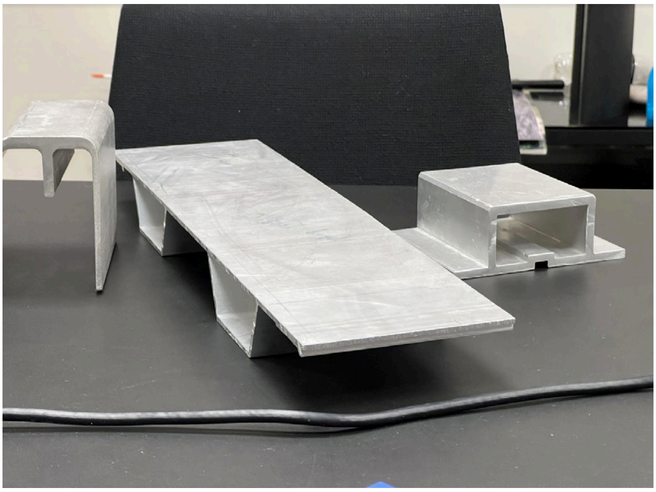

VARD
a Fincantieri company

Maritime Partner AS

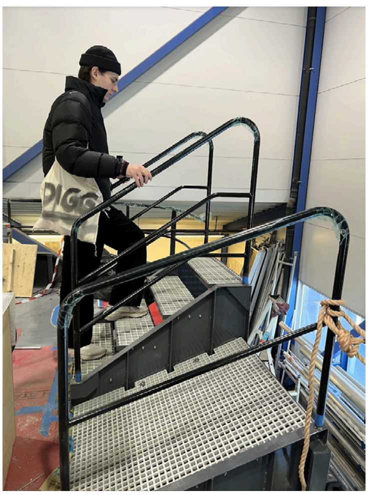
Maritime Partner AS designs and equips a range of smaller vessels than Vard Design AS - from small rescue boats to speed ferries and tourist vessels. They mainly deliver vessels in aluminium, glass fibre polymers or carbon fibre reinforced polymers.

Main takeaways:

- The design process starts with a requirements list from the customer. Then they decide to go with a monohull or catamaran hull. Furthermore they continue to work with 2D-sketches to make a general arrangement. An important part is also to create a budget and contract with the customer.
- It is important to get the weight as low as possible for sustainability reasons
- If designing for aluminium - single curves are cheaper and easier to get nice than double curves. Friction stir weld is a recommended joining method that can be used for up to 12 metre long aluminium sheets. Try to opt for more bends and less welds to make the manufacturing cheaper.
- For the use of glass as windows - glass should flush with the hull to prevent the glue from deteriorating. Corners of the windows may be designed both sharp or rounded. It is also possible to make curved glass. Glass is not considered a bearing structure for vessels, but if that changes in the future, it would be possible to get the weight of vessels lower.
- When visiting their workshop, we learnt that the welds on aluminium are very visible, thus it should be considered where they are placed.






Life cycle assessment of vessels

LCA (life cycle assessment) is a standardised framework for considering the impacts and environmental aspects of a product and its system. The assessment addresses all aspects of the life cycle, from raw material extraction to disposal of the product (International Organization of Standardization, 2006) . There are few LCA case studies on maritime vessels described in literature (Favi et al., 2018; Fet at al., 1998; Schmidt and Watson, 2014;). We have investigated these assessments, for gathering an understanding of what processes contribute the largest impacts of a vessel's life cycle over a lifespan of 20 years.

An LCA performed by Schmidt and Watson (2014) compared two ferries of the same design, where one was produced in steel, and the other in carbon fibre resin. The results showed that the carbon fibre resin ferry was superior to the steel ferry in all impact categories, with aprox. 50% lower impacts over a life cycle. The life cycle of the ferries was divided into four parts: construction, maintenance, operation and disposal. Most of the impacts over a life cycle were connected to the operation phase of both ferries (Schmidt and Watson, 2014). For our project, this may indicate that keeping the weight of the ferry as low as possible, is the main factor for making the ferry more sustainable.

Favi et al. (2018) compared four different material choices for the production of a luxury yacht in an LCA. The four options were: 1) The whole yacht built in carbon steel, 2) The whole yacht built in aluminium, 3) Hull in aluminium and hatches in carbon steel or 4) Hull in aluminium and hatches in carbon fibre composite. The results of the analysis shows that alternative 4 has the lowest environmental impacts (Favi et al., 2018). Alternative 3 is a good option as well, with slightly higher impacts than alternative 4. This LCA also shows that the lower the weight, the lower impacts over a ship's life cycle. Another aspect that was mentioned during our interview with Egil Eide, was the need for fire insulation if the MilliAmpere 2 was to be built in carbon fibre instead of aluminium. This is also the case for the LCA by Schmidt and Watson (2014). The carbon fibre resin ferry needs 60% more insulation than the steel ferry. This LCA shows that the impact of adding insulation material is insignificant over the life cycle of the ferries compared.

Material

Aluminium

Aluminium has been considered an attractive material for marine applications since the industrialization, because of the ratio between strength and lightness. The interest has increased especially after the second world war, because of better joining methods and alloys with improved corrosion resistance and higher mechanical properties (Ferraris and Volpone, 2005).

Expert interview with Hydro

To learn more about aluminium, we arranged a meeting with Trond Furu, Research Manager in Norsk Hydro ASA. Our main takeaways from the meeting was:
Design for recycling

- Do not use better properties than what is needed
- 5052 aluminium series is a sheet metal that is often used in ship building
- Include traceability in your design, so that it easy to sort the material at end of life
- Friction-stir welding is joining two profiles with the use of a high-speed rotating pin that melts the profiles together. Usually you do not need filler material.

Glass

Glass can be used to open up surfaces that would usually appear closed off or opaque. Properties of glass include recyclability, very high compressive strength and a resistance to corrosion (Pariafsai, 2016). A recent advancement in glass technology has been electrochromic glass. It is a special type of glass capable of switching from clear to opaque in less than a second by using electrical current that will alter the wavelengths that can pass through it. It is also known as dynamic frosting, and has been used for building public toilets, large glass building surfaces, but also, in the automotive industry, as a changing sunroof.

The last example is particularly interesting for this project as it allows a see through panel on demand, while still being able to be opaque when needed. When darkened, this glass can block off about 98 percent of all incoming light and thus reduces the greenhouse effect present in closed-off spaces. This reduces the need for air conditioning (if one is present), or just simply reduces the heat during hot summer days.

Photo credits: Porche.com

Choice of Material

It was important for us to choose material early on, so that we could design with the material in mind. From the LCA analysis that has been investigated, it seems like the most sustainable choice is the lightest material, if one is measuring sustainability in CO2-equivalents (Favi et al., 2018 and Schmidt and Watson, 2014). In meetings with Zeabuz, it was said that a ferry built in lightweight materials such as aluminium or carbon fibre reinforced polymers were the preferred choice of material. We have encountered many different opinions on this matter, as there are many aspects in addition to the weight when it comes to shipbuilding.

In our meeting with Maritime Partner AS, Fiskerstrand recommended the use of aluminium. In his experience with building small rescue and passenger boats, many customers want adjustments to the design after production starts. With aluminium, it is easier to make structural changes. With carbon fibre reinforced polymers, the design you make in the mould is the design you get. In addition, Fiskerstrand emphasises the good recycling properties of aluminium. Furthermore he argued that aluminium does not require the same amount of fire insulation and surface treatment as carbon fibre reinforced polymers (Fiskerstrand, personal communication, March 3th 2022).

We learnt that the choice of material depends on who you are asking. Brødrene Aa are the leading experts in the field of making fast-speed ferries in carbon fibre reinforced polymers (Brødrene Aa, 2022). In an article written by Teknisk Ukeblad in 2015, the CEO Tor Øyvin Aa expresses his thoughts on why the speed ferry Fjordbuss should not be built in aluminium. Aa stated that choosing the lowest weight possible on the structure will create a domino effect on the rest of the ferry. A heavier structure requires heavier batteries. Aa argued that a carbon fibre reinforced polymers structure is 30-40% lighter than an aluminium structure. CEO Hege Økland in NCE Maritime Clean Tech commented that carbon fibre reinforced polymers were considered as the material choice. Nevertheless, aluminium was chosen because of the life cycle aspects. Økland argues that the aluminium can be manufactured with Norwegian hydropower, it requires less maintenance in the use phase and it can be recycled (Stensvold, 2015).

When looking at the bigger picture, one cannot state that one material is better than the other for all sustainability aspects. After discussing in the group, we felt that we were leaning towards choosing aluminium. To make the ferry in a recycled material, that can be recycled into a new ferry after its use creates a closed loop in terms of circular economy. To create a more sustainable future, we believe honesty is the way to go. We liked the idea of using a mono-material that can be exposed to seawater and to the users. With the emerging technologies of recycling carbon fibre reinforced polymers, it may be a better option in the future. For now, we chose to not bet on recycled carbon fibre reinforced polymers to be available on the market within 5-10 years. Instead, we chose to rely on Norwegian gold - Aluminium.

INSIGHTS

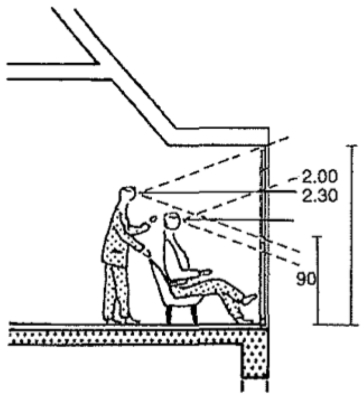
PROJECT RESEARCH

Closed off or open superstructure

When designing the superstructure, we decided to go with a more closed off space, in contrast to the Milliampere 1 and Milliampere 2. The reason for this is based on the idea of providing adequate weather protection to the passengers of the ferry. As during the trips, passengers have nowhere to go, except stay in the boat, the instance of bad weather conditions will affect the whole journey. In addition, you avoid the issue of frost and condensation on the deck, as mentioned in the meeting with Egil Eide.

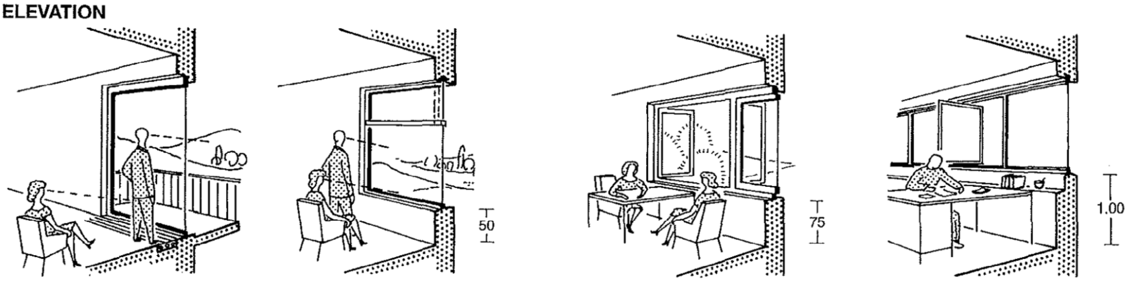
As a result, windows will need to be placed. Since the superstructure needs to have support, in the decided material - aluminium, an opaque material, it is important to have windows placed at the appropriate height level. At the average eye-level height while standing and sitting down there should be as few obstructions as possible to make it possible for all passengers to have a clear line of sight, making the compartment they travel in feel airier.

This will make sure the cabin does invoke the feeling of claustrophobia, or other unpleasant emotion connected to those spaces that might appear relatively small. Additionally, it will provide a view out of the vessel to the surrounding environment enabling passengers to see where the ferry is moving and also give the opportunity to gaze at the city around them.



7 As dormer window; see p. 85

ELEVATION



9 A scenic view and projecting building elements

10 Room with a view

11 Normal window height (table height)

12 Office

(Illustration: Neufert, 2012, pp. 96, 102)

Repairability and maintenance

When visiting Milliampere 2, and talking to Egil Eide, we learned that the design of the equipment storing boxes of Milliampere 2 did not facilitate easy access, thus making repair, service and changes a pain. The service hatches are small and the space within them is fully packed with electronics and sensors. The takeaway from this is that the new design should have easy maintenance doors to ease access to components such as sensors, computers and batteries.

As seawater and dirt might clutter the optical sensors, being able to access these for cleaning and maintenance is important. This is something that should be carried out daily or weekly. An overall cleaning of the superstructure is needed on a monthly basis. The vessel should be hoisted out of the water to maintain the hull as a yearly routine.

By building the vessel in aluminium, repairing damages or doing changes is easier than for example a carbon fibre structure. The interior can get damaged or vandalised and therefore should be easy to repair, replace or clean.

For these reasons, we kept in mind the repairability aspects at all design phases.




Requirements & Regulations

The brief from Zeabuz was open regarding requirements we needed to comply with. They were stressing that the rules for autonomous vessels were hanging behind and that Zeabuz were working with the lawmakers regarding new laws and regulations for autonomous urban mobility vessels.

Nevertheless, we looked into what current laws and regulations would affect our design, focusing on the Norwegian legislation. From what we found out there was only one law, but multiple regulations and standards covering the scope of our vessel. The Småbåtloven(småbåtloven, 1999) covers all vessels less than 15 meters, and this law focuses on the suitability of the driver of the boat. Making an autonomous vessel, an exception from this law is probably needed.

The Nordic Boat Standard is a standard developed by all the Nordic countries describing how boats should be constructed and requirements for safety. Regarding the design of the superstructure and passenger compartment there are three chapters we did take into account. Regarding passenger safety measures on railings, there are detailed height and opening requirements. Regarding emergency exits, there needs to be two on each side. The exits need to be easy to open from inside, and sliding doors need to have handles. In case a person falls overboard, the vessel needs to have a fixed ladder on the side (Nordisk Båtstandard, 1990).

In the Regulation for security in passenger areas (Forskrift om tryggleik i passasjerområdet, 2022) regarding steering position in passenger areas, it states that standing and sitting places should be arranged in such a way that it does not interrupt navigation. This is relevant in the introduction phase, where Zeabuz plans on having an on board operator, and in the worst case needs to steer the vessel manually (§14). In the manner of passenger travel goods, like bikes, trolleys and suitcases, a dedicated space should be allocated for this and it should be possible to secure it. It should not block emergency exits (§15). The regulation also states that interior elements need to be properly secured(§16).

The Regulation for vessels less than 24 metres and carrying less than 12 passengers (Forskrift om fartøy under 24 m som fører 12 eller færre passasjerer, 2020) describes among other things the rescue equipment needed. For the type of vessel we design the needed rescue equipment needed(§16) is:

- **Liferaft**
- **Life jackets**
- **Lifebuoy**
- **Throw ring with 30m rope**
- **Flares**
- **Device for picking up people from the water**

The regulation also states that children need dedicated life jackets. If the vessel is less than 8 meters, the passengers need to wear life jackets when on board. The life jackets stored on board need to be stored easily accessible, well ventilated. This determines some guidelines for the design of the interior of the vessel, being both storage and bench.

The Regulations on the prevention of collisions at sea(Forskrift om forebygging av sammenstøt på sjøen,1977) provide requirements on light and sound communication to other vessels. With a vessel less than 12 metres long, the required light is one top lantern with a range of 2 nautical miles and two side lanterns ranging 1 nautical mile. The side lanterns need one green on the starboard side and one red light on the port side of the vessel. If the service we will design is a pendulum ferry, then the red and green light has to change every time the ferry shifts driving direction. The vessel also needs to have a device to be able to make a powerful sound signal.

Photo credits: Markus Spiske

Overview of sensors

Sensors are a big part of making a vessel autonomous, as they are the ears and eyes of the algorithms and also for the operator in the shore control room that can intervene if something unexpected happens. There are different types of sensors needed and the amount of them. Zeabuz has the philosophy that they want to have the most data possible but still consider cost, that provides the best situation awareness. In a talk with the sensor expert at Zeabuz, Dr. Erik F. Wilthil, we have found out most of the information about sensors needed for the ferry and their specificities.

The sensors that can be used in this type of vessel are optical camera, infrared camera, ultrasonic, lidar and radar. The optical camera is used by the operator on land, but can also, tied with AI, give a lot of situation information to the autonomous computing. An example of that is the self-driving Tesla cars, which only have cameras to create situational awareness. The camera technology is cheap and well proven. The infrared camera photographs heat rather than objects, making it effective in situations where poorly illuminated objects need to be identified. The ultrasonic sensors are used to get a precise distance estimation when docking.

The Lidar sensor is used to make a point cloud of distances, this is then used to create a 3D representation of the environment. It uses the reflection of laser beams to measure the distances to objects. This technology is being developed a lot for use in the automotive industry, but is also seeing its way to consumer electronics. As the development progresses it is in a smaller form factor and cheaper units. This allows for having more sensors to get a better situation awareness. The smaller form factors also allows for better integration into a hull or superstructure and making it less visible. The lidar technology has a limited range distance.

Lidar used in MilliAmpere 2

The radar technology is utilising radio wavelength to get a bird view representation of its surrounding objects. The technology was put on ships already before the second world war, and has been mandatory on larger ships for many years. In recent years with commercialisation of the technology also smaller leisure boats have gotten this technology on board. With the development for driverless cars, radars also see improvement in size and price, making it more affordable to integrate into the superstructure.

Simrad 4G radar

Communication technology is also an element that needs to be integrated, and here GPS antennas and 4G/5G antennas are what is required to both know the vessel's exact position and the ability to transfer data to the shore control station on land.

These sensors need to be placed strategically on the ferry, to cover as much area as possible without creating big 'dead zones', which are places where the vessel does not 'see'. To combat this, sensors are usually placed in the corners of the vessel, with the exception of those that can be placed on top, like the radar.
One idea that we have been presented by Zeabuz, is that in an ideal scenario they could place sensor towers on the shore of the operating city. This would mean that the tower would collect enough data and transmit it to all Zeabuz ferries, which then would not need sensors themselves.

Ultimately, this would result in a fewer amount of sensors needed, reducing the cost of the vehicles. Another idea, that was somewhat previously attempted in Milliampere 1, was to make a combined sensor rig that contains most of the needed sensors in one package. This idea would strongly influence the actual design of the ferry because any obstruction would cause multiple sensors not to function properly. A sensor rig concept would unlock a lot of possibilities for the future of the company. For example, Zeabuz would only produce sensor rigs and service them, while the skeleton body of the ferry can be made anywhere as long as it supports the mounting of one of those rigs.

Sensor Package Prototype

Sensors and Design

To integrate the sensors in the design of the next generation Zeabuz, we were met with an interesting challenge. Should we try and use these standardised sensor modules as distinct design features or should we try our best to hide the sensors within the ferry's design, essentially camouflaging them? These sensors can be used as a powerful tool that actually acts as a sign that the ferry is autonomous. In a talk with Zeabuz, they have expressed their openness to the solutions. They stated that if the design of the ferry itself is something different enough, that there is no need to make sensors an obvious part of the concept. The sensors could be tightly integrated in the superstructure, even if it means less flexibility for the service.

Following this, we can make several assumptions about the future of sensors by looking at current and past trends in the sensor space. For instance, one radar already available on the market today is the Continental ARS540, measuring just 137 x 90 x 39 mm (Continental, 2022). Furthermore, a lidar set to release next year, the ibeoNEXT, has a footprint of 40 x 70 mm (Ibeo, 2022). These sensors currently do not offer as much range or field of view, but in the future these values will increase and the sensors will become the standard. Knowing this, we can presume that large sensors like the Simrad 4G won't be needed on the autonomous ferry, and will be replaced by much smaller, credit card sized sensors that can easily be integrated in the superstructure of the vessel. To confirm this assumption we had a talk with Dr. Wilthil again, where he confirmed that these sensors will be the future of autonomy, especially with the increase of interest in the automotive space. Dr. Wilthil also added that even though current costs for these smaller sensors is high, their price will go down in the future while their availability will increase as well.

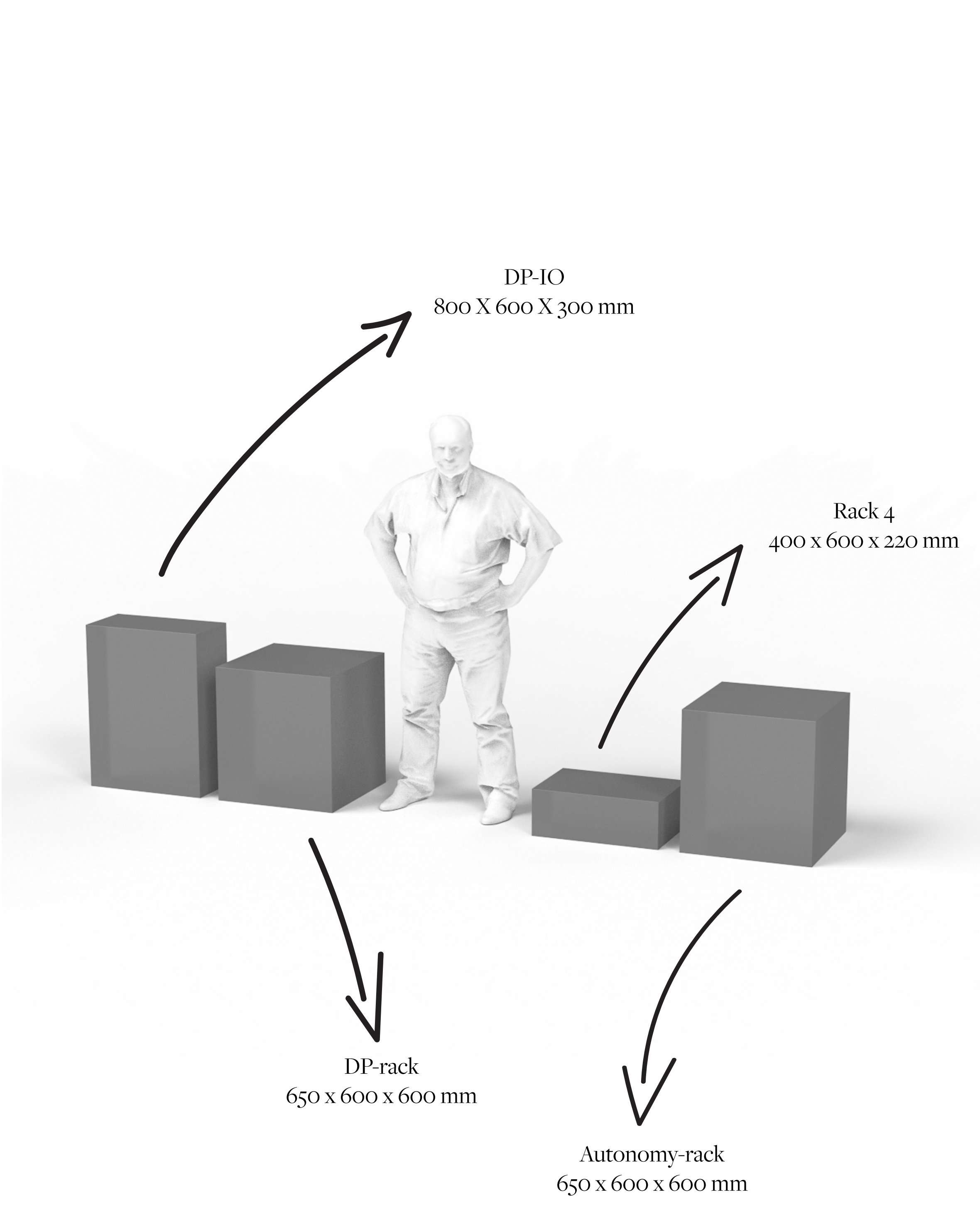
Dr. Wilthil also gave insight on the maintenance needed for these sensors. He stated that regular maintenance for these sensors mostly includes wiping them down if needed and making sure nothing is obstructing their view. This could range from once a day to once a week. A bigger service interval for calibration of the sensors is expected to be around once a year, adjusting the system if needed and going over a general check that ensures all of the equipment is in order.

Dimensions

We had few limitations when it came to the design of the next generation Zeabuz ferry. The only requirement from Zeabuz dimension wise was that the ferry must have a length between 8 metre and 12 metre. This is to avoid falling under the regulations of small boats, that requires all passengers to wear life saving vests on board at all times (Nordisk båtstandard, 1990)
Jarle Vinje Kramer, Senior System Engineer at Zeabuz, provided data about the sizing of necessary equipment on board.
There are four racks with equipment, shaped as boxes.

Dynamic positioning-rack (DP-rack) = 650 x 600 x 600 mm
Rack for DP-koblinger (DP-IO) = 800 x 600 x 300 mm
Autonomy-rack = 650 x 600 x 600 mm
Rack for connection between sensors and the rest = 400 x 600 x 220 mm

The racks could be placed anywhere, but as there will be cables in between, they needed to be placed relatively close. These boxes were used as dummies in the 3D-models, to make the dimensions of the ferry concepts as realistic as possible. However, these are requirements for systems that exist today. We assume that this is something that will change over the next few years, because of the evolution of computers and the development of connectivity. With increased connectivity more of the processing power needed can be moved on shore, and eventually even completely.


DP-IO
800 X 600 X 300 mm
Rack 4
400 x 600 x 220 mm
DP-rack
650 x 600 x 600 mm
Autonomy-rack
650 x 600 x 600 mm

INSIGHTS

DESIGN INSIGHTS

This chapter includes insights gained by the use of different design methods.

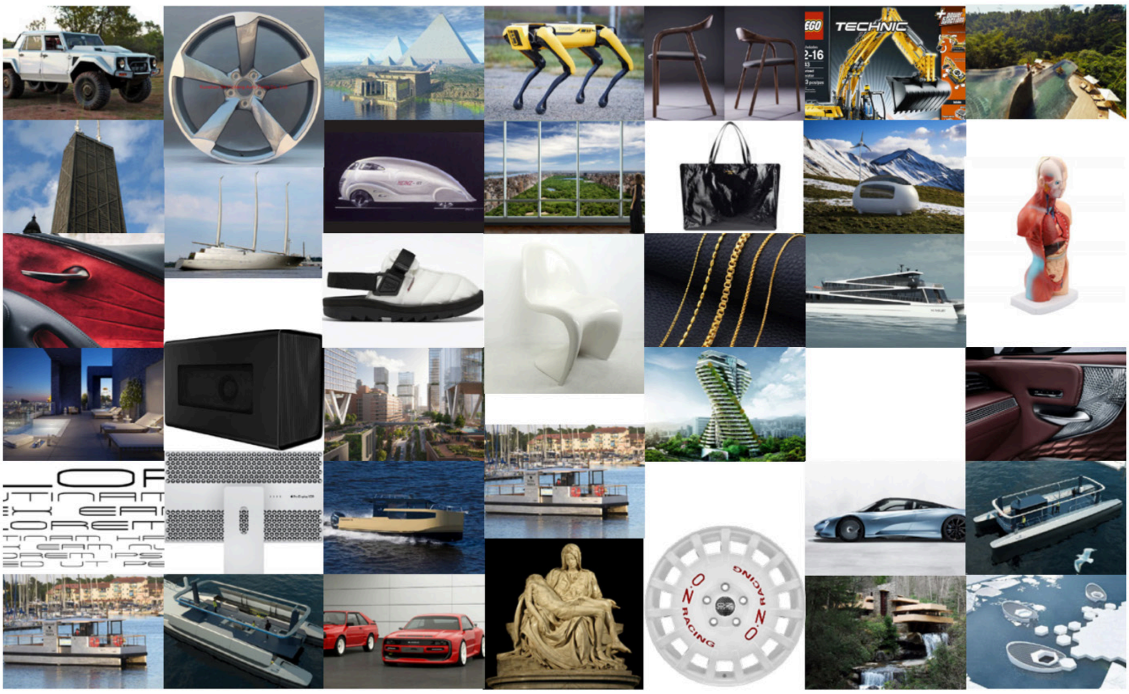
Moodboards

Individual Vibeboards

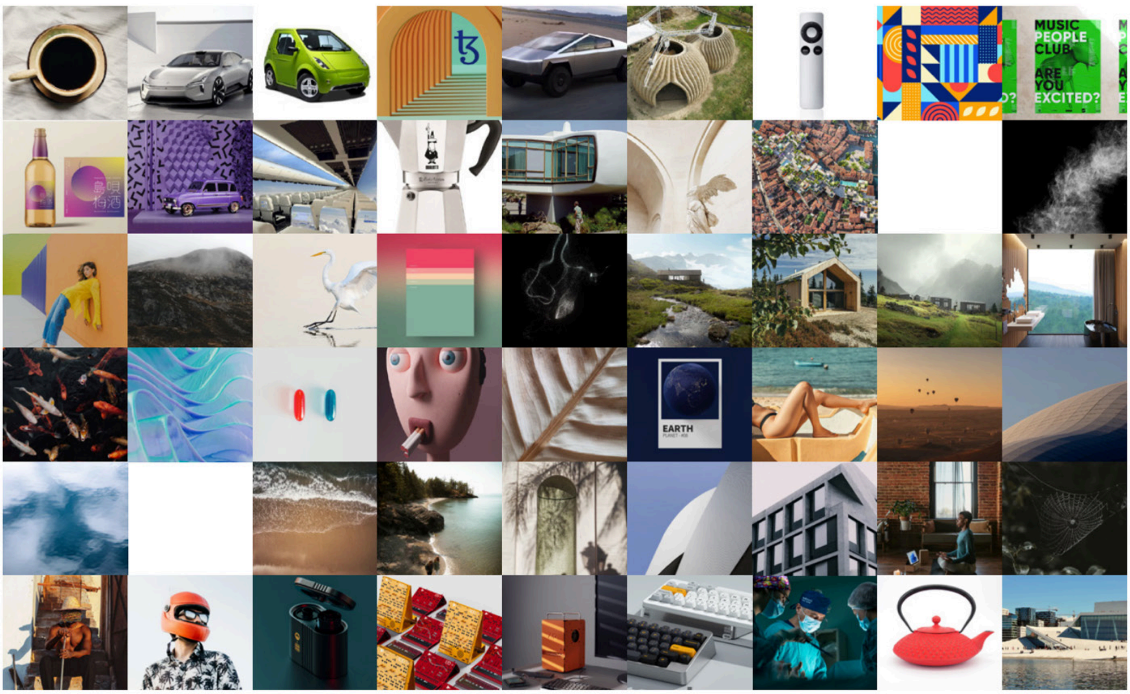
For about an hour we individually collected images of different things that we felt inspired by, from graphic design, architecture, product design, cars, art etc.

Afterwards we went through all the images and talked about why they were included. We learnt that this was a fun exercise to spark inspiration, pushing us further in the process and to help to get a more common understanding of our visual preferences.

Malene's Vibeboard



Vedran's Vibeboard



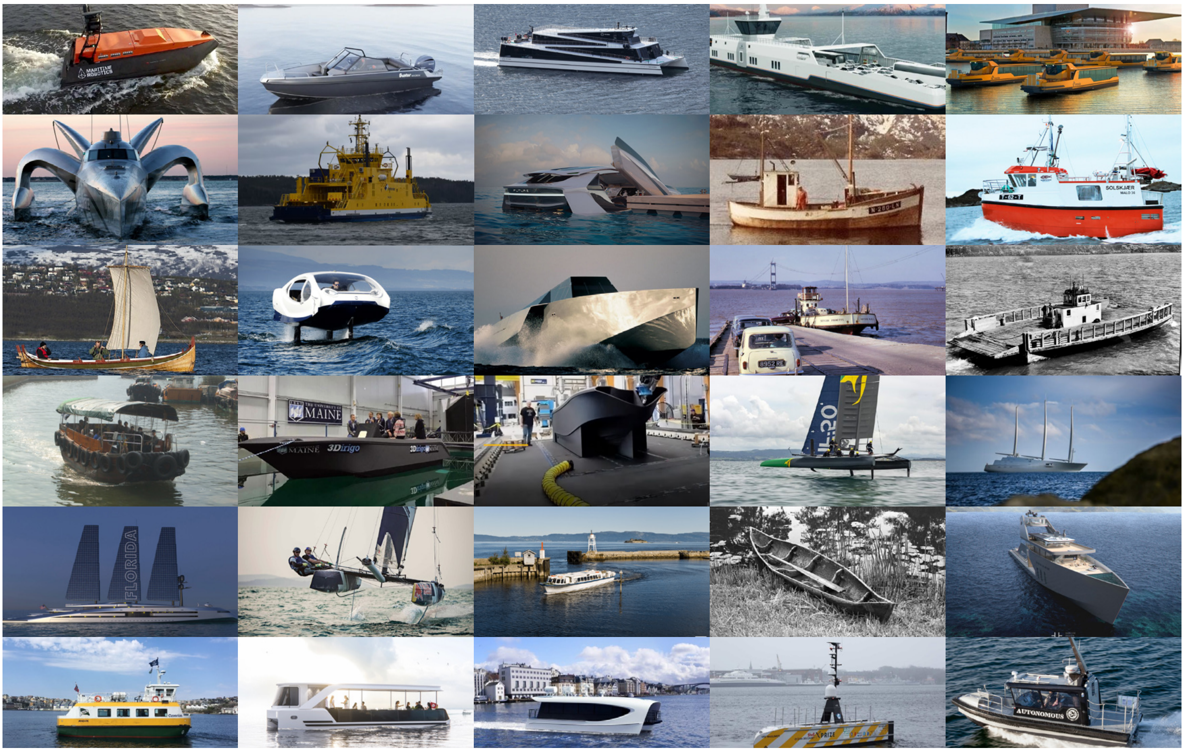
Hilmar's Vibeboard

INSIGHTS

DESIGN INSIGHTS

Moodboard with boats

Additionally, a moodboard with similar projects was made. This included everything from bigger vessels that still operate on water but also smaller ones, that tackle similar challenges we have encountered during this project. These served a purpose not only to get an overview of 'what is out there' but to also get an idea of the design expressions those vessels used, as none of us have previously had the experience of designing a passenger ferry.


MAINE
3Dirigo
FLORIDA
AUTONOMOUS

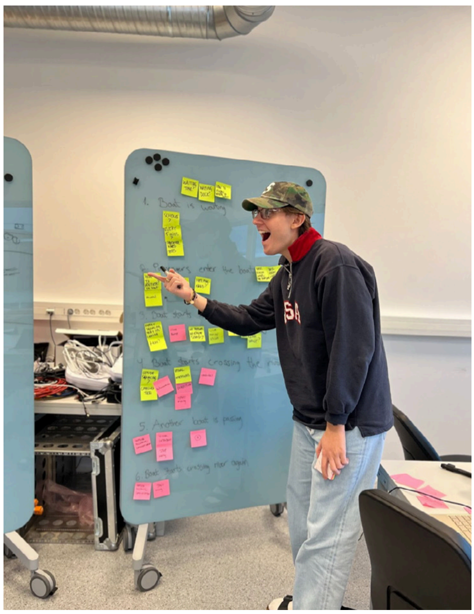
INSIGHTS

DESIGN INSIGHTS

Jobs to be done

We made a Jobs to be done analysis to understand what the ideal actions of the ferry might be when travelling from A to B when crossing a river in an urban area. We sketched the ferry in the river from a bird view, and tried to analyse each task that the ferry must carry out when serving mobility for a group of people. Important design aspects were noted on post-its for each step. The analysis gave us initial insights of design elements that we had not thought of. How do you count passengers when boarding/unboarding? What if someone takes the ferry alone? We learnt that interaction with passengers is a complex element that will need attention. For example, the ferries movement, or the use of sound or light. It needs to be resilient and universal.

Another aspect we had not thought of initially is how the ferry communicates with the surroundings. For example, how can it show direction of movement? We found out that this tool can be used early in the process of designing for an emerging technology, as the tasks of the ferry itself must be designed for this specific situation.



1. The ferry is waiting
2. Passenger(s) enter the ferry
3. Ferry starts undocking
4. Ferry starts crossing the river
5. Another boat is passing, ferry stops
6. Ferry starts crossing the river again
7. Ferry starts docking
8. Passenger(s) leaving the boat
9. The ferry is waiting

The steps we concluded the ferry should perform when traveling from A to B.

INSIGHTS

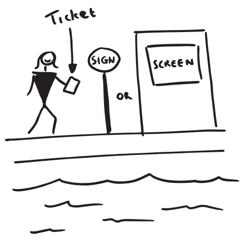
DESIGN INSIGHTS

Storyboard

While the jobs to be done analysis took the ferry's tasks into consideration, we tried making an initial storyboard to see the steps from mainly the passengers perspective. We made a sketch for each step of the journey from the passengers view, and wrote down important keywords of design issues we discovered.

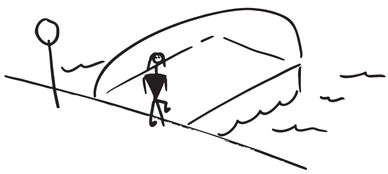
Doing this analysis after the task analysis of the ferry was useful, as we knew how we wanted the ferry to act. We got a deeper understanding of the users needs, and also considerations for making this journey as universal and inclusive as possible.

We realised that the ticket system may be of vital importance, as well as the passenger flow, how the ferry communicates its intentions and that an onboard activity may be considered.

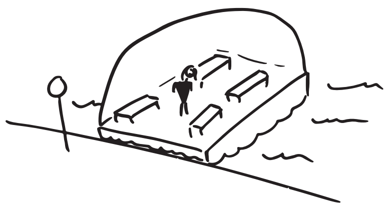


1 Gyda is waiting for ferry

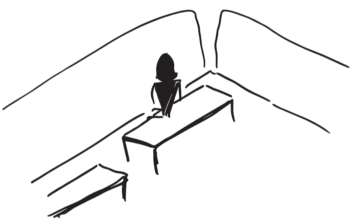
2 Ferry arrives at stop



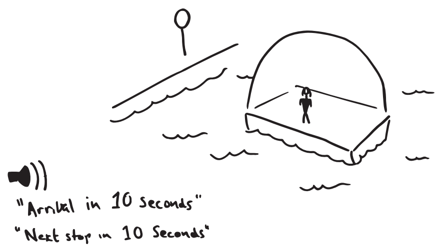
3 Gyda boards the ferry



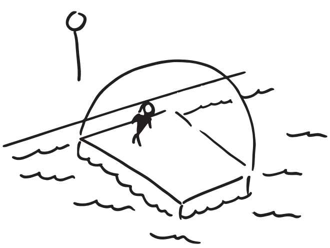
4 Gyda looks for a nice place to sit



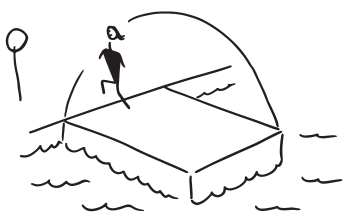
5 Gyda enjoys the view



6 Gyda walks to the exit



7 Gyda watches the docking



8 Gyda unboards

Workshop

From meetings with our supervisor Einar Hareide, we learned that it is valuable to include the client in the design process. Constraints from the client may make it easier for the designer to make choices, and the client will feel more ownership to the design. We decided to have a workshop together with a selection of the Zeabuz team, to get to know their values and visions early on in the process. Einar suggested three methods he has experience with from the industry - The value triangle, Letter from the future and functional analysis. Mustvedt (2019) also used these methods for designing MilliAmpere 2, with great success. Thus, we were interested in testing the methods for this project as well.

Preparations

Activities

Superhero exercise

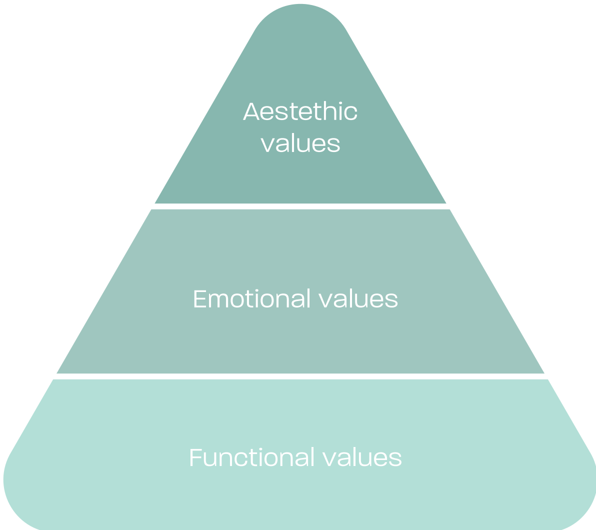
A warm-up exercise is used in the beginning of a workshop, to make the participants more comfortable with their co-participants and more creative and open to new ideas. An exercise that was made by Hilmar and tested for the workshop, was the Superhero exercise. The participants get 5 minutes to sketch themselves with superhero powers. Afterwards, the sketch is passed on to another participant, who has to guess the superhero powers.

Letter from the future

The goal of the exercise is to clear the clients heads from their daily tasks, and boost their imagination for what the future of their company/product may look like. The client is supposed to write 1-2 A4 pages of where the company is at in 10 years from now. In addition, they should define three keywords for the future with three describing pictures. As people have different views on what the same words may mean, the pictures are meant to help communicate the keywords in the most clear way.

Value Triangle

The goal of the value triangle is to define a client's values from a functional, aesthetic and emotional perspective. Both keywords, pictures and 2-3 sentences description of the keywords should be included to make sure that there is a consensus of how the keywords affect the design of a product. The Value Triangle can be used throughout the design process, to guide the designers to make the product fit the client's values.



The Value Triangle, invented by our supervisor Einar Hareide, to capture a clients values for a design

Functional analysis
To help set requirements for the design, we decided to include a functional analysis in the workshop. To make sure the requirements only describe the functions and not the looks, every requirement should be formulated by a verb and a noun. For example, instead of having "bench" as a requirement, it can be "provide seating". To help sorting what requirement is the most important, they should be graded as 1, 2, 3 or N. 1 is the most important, while N stands for Not necessary.

Plan for activities
An initial plan for the workshop with timeline activities and responsibilities was made in Miro. We invited 8 persons working at Zeabuz, from different parts of the organisation. Both people from the board, technical team, automation team and service design team were invited. The goal for us was to get people from different fields to get together and discuss the future of Zeabuz. It was also important for us to have a physical workshop, as we have experiences with participants being more engaged then.

For the photos of the Value Triangle, we decided to make a selection of photos and print out in advance. Despite making the exercise somewhat biased by us, we took the freedom as designers to make some understandable design directions the participants could choose from. We feared that having the whole internet to select from would be very time consuming during the workshop. In addition, it could have made it harder to get a consensus on what pictures describe the future designs of Zeabuz the best.

DESIGN INSIGHTS

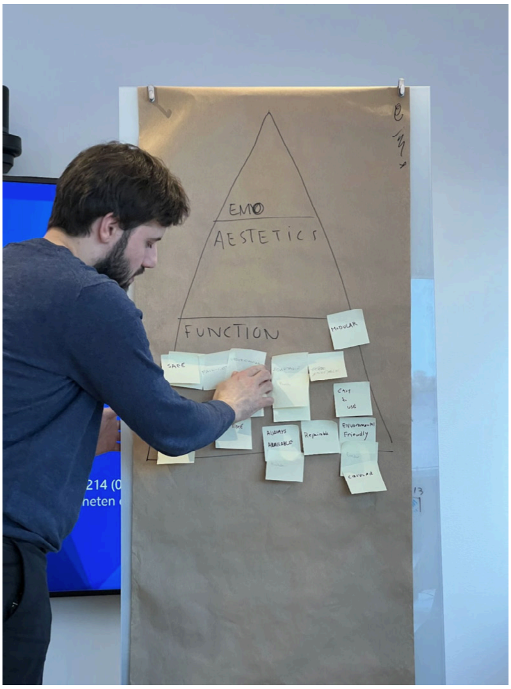
Selecting images for the Value Triangle 1

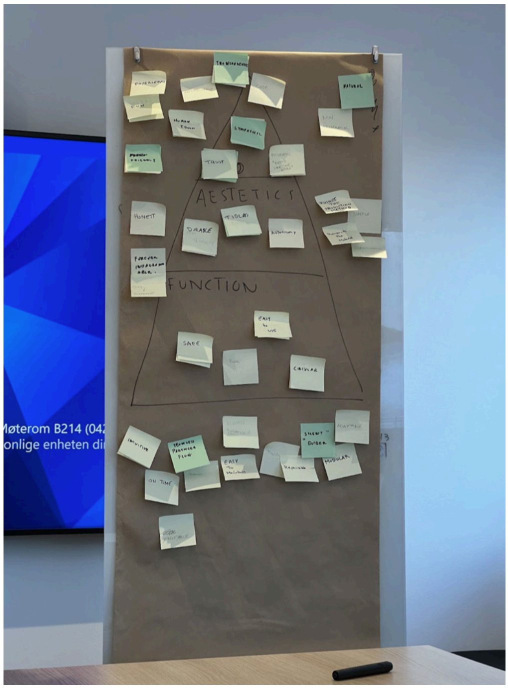
We had a session for choosing photos on our own. Afterwards we presented the photos for each other, and printed out a selection of them. We did one more selection round after printing, to remove pictures we felt were irrelevant or misleading.

Trial workshop

To test if the workshop plan was realistic, and to investigate our own thoughts of Zeabuz' future prior to the workshop, we had a trial workshop together with Leander. We learned that we were too ambitious with the workshop plan. We figured out we did not have time to do the functional analysis for the time slot we had available with the Zeabuz team, and decided to do it later on.

We also learned that the photos were not very representative of how the ferry should look. A photo of water for example, does not help us with deciding the design of the ferry. For the chosen values, several were not the best for describing a design. Our supervisor Einar Hareide also suggested that we should write 2-3 sentences for each word, to make sure we have a common understanding for what they mean.


EMO
AESTETICS
FUNCTION
MODULAR
SAFE

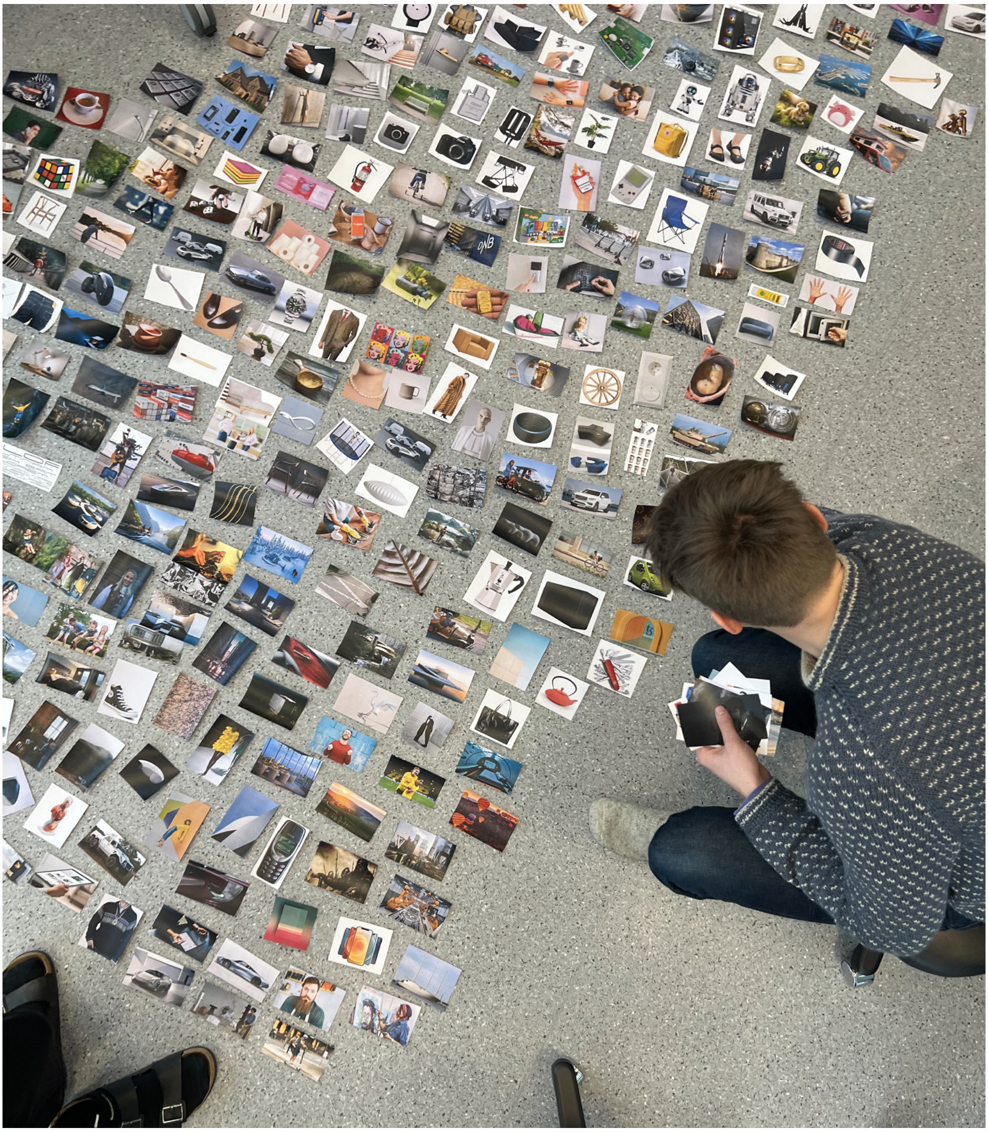

AESTETICS
FUNCTION
SAFE
CIRCULAR
MODULAR


EASY
to
USE
SAFE
CIRCULAR

DESIGN INSIGHTS

Selecting images for the Value Triangle 2

Furthermore, a second round of selecting photos were carried out. We were not happy with the outcome of the photos of the values in the trial workshop. They were very abstract, thus not helpful for our further design process. We tried to use the values from the trial workshop, and wrote down several additional values that describe a design, as directions for the selection of photos. We tried to find 6 - 12 photos for each category. The photos were printed out, and went through one more round of selecting.

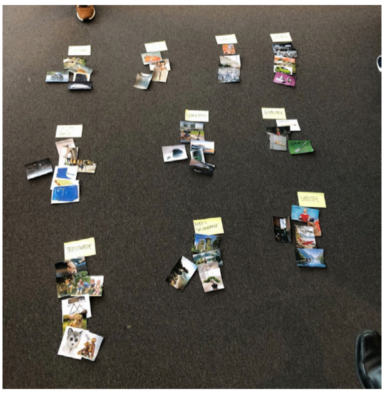


Doing the workshop

Process

In total eight people attended the workshop. The superhero exercise turned out to be a success, as the participants were laughing a lot, and seemed to get more relaxed. Over to the next exercise, we had the challenge that only three of the participants wrote the letter in advance, despite getting several notifications the week before. We decided to read out loud the three letters we had received. We learned that it was challenging to follow along and make notes, thus, it was difficult for us to start discussions afterwards. If we had redone the exercise, we would have gone through the letters the day before, and just made a presentation for the Zeabuz team of their ideas. That was not possible at the workshop, because two of the letters were received 5 minutes before the start of the workshop.

The value triangle led to many interesting discussions of what words they felt described Zeabuz' values the best. The chosen photos did not help as much as we hoped with describing how the design may look like.



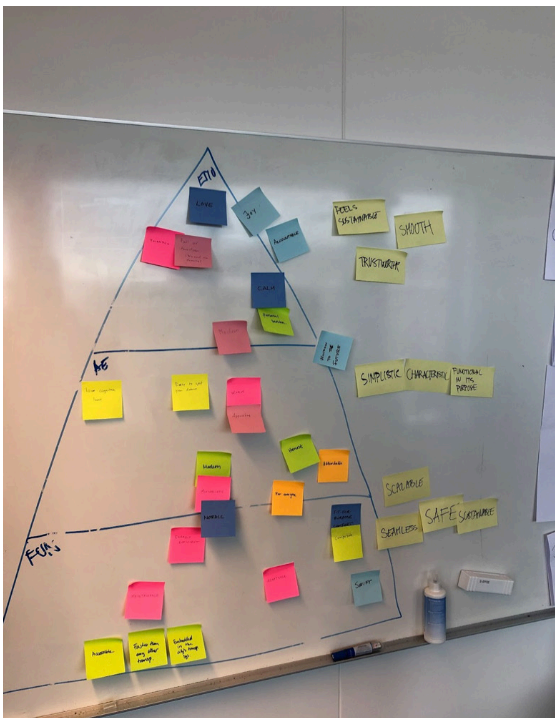
Results from the Zeabuz workshop

The participants were very happy with the exercises and that we were able to finish on time. We learnt that it is important to respect the client's time, and make the most out of it. We were asked if we could do a follow-up workshop the week after, as several of the participants felt like they did not understand the tasks of the value triangle fully until after they had done the exercise. For example, the value "trustworthy" was described by a photo of a Golden Retriever dog. The participants agreed that this photo was not really helpful for us, and that they would have chosen something else for another round.

We learnt that it may take several rounds of discussion before the designers and clients have a common understanding of what the values means. Because the participants had many different opinions, we felt like another workshop would just lead to discussions not ending anywhere. Thus, we decided to redo the visual consensus on our own, and rather ask the Zeabuz team afterwards if they agree or disagree with our visual interpretation of their chosen values.

What we learnt

Overall, we learnt that spending time on making a bulletproof plan with delegations and a timeslot, that are being tested in advance, increases your chances of a successful workshop. In addition, you must be prepared for the unexpected, because you cannot rely on people to show up or do their homework on the specific day.



DESIGN INSIGHTS

Redoing the visual consensus

The first thing we did after the workshop was to go through our notes. We wrote down 2-3 sentences for each value, based on the Zeabuz teams comments. Afterwards, we had a session where we chose one picture each, for each value. We discussed the photos in common, and had a final voting for one photo for each value. In the next supervision meeting with Zeabuz, we showed the results of our visual consensus. Øyvind Smogelid approved our interpretation of the values. See the final chosen values for Zeabuz, with photos and describing sentences.

Functional values

Scalable

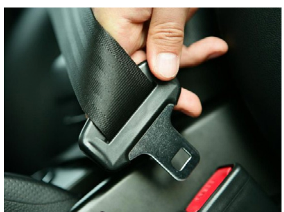
Means cost-efficient to produce and possible to expand to new markets. Means modular.

Seamless

As part of the journey . Means user friendly and the lack of inconvenience instances.

Sustainable

A more sustainable option for the city. Means being made in sustainable materials and not changing its environment.



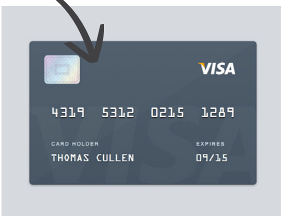
Safe

Must be technically safe.

Emotional values

Smooth

Means the user journey is problem free. Next generation Zeabuz ferry is clever and effortless.



Trust worthy

Means the design feels friendly, and safe and steady to use. Users builds a relationship with the product.

Feels sustainable

Calls for the appropriate surrounding materials, and choosing the right environmental option.

Aestethic values

Simplistic

Means reducing the design to its bare minium. The design should include only the necessary elements. Simplistic is nordic design.

Characteristic

It is not a boat. Means that the design has its unique design expression, compared to the time and place in its environment. The design is easy to identify.

Functional

Means that one can understand its purpose just by looking at the design. It is easy to understand, and it is honest about its intentions.

DESIGN INSIGHTS

Cool factor – 'Instagrammability'

During the initial brainstorming session at the start of the project, making a list of which topics would need to be addressed for the complete delivery of the vessel, the idea of a cool factor has been brought up. Although not crucial for the success of the design, a cool factor can often be something that incentivises users to try the passenger journey for the first time and therefore gives the service an opportunity to leave a positive impression on a first time user. Often, an overall good and well rounded product is not enough so a cool factor can be an element that brings the experience to the next level. This hypothesis was further confirmed in the trial workshop with our supervisor Leander Pantelatos (chapter 1 Workshop), where he suggested one of the values the vessel should be designed around is 'forever instagrammable'. This component was explained in regards to it being desirable to be seen and experienced, rather than being seen as a pure necessity of transportation.

Furthermore, this exact point was again brought up in the actual workshop with Zeabuz, in which 'instagrammable' was discussed as something important for attracting not only users already present in a town where Zeabuz already operates, but also to entice those interested in the Zeabuz platform to come and visit. Knowing that, a question follows up; how does one define something to be instagrammable, or having enough of a cool factor to be satisfactory or fulfil that purpose? Further on, how does one ideate on that?

Service blueprint

A service blueprint was used to envision the future service with all its elements and interactions. Pain points both for the user but also deeper in the system will be more obvious and can be dealt with in an early stage. We decided the user to be a walking commuter that already was familiar with the service, and defined eight steps that the user went through. The service starts with the commuter waiting for the ferry, the ferry arrives and they walk on board, the ferry takes them to the destination and they walk off.

What we discovered with this session was that early in the process we had to make a lot of assumptions regarding the service, since many elements were undefined. We also discovered that there were not many interactions between the passenger and the ferry. Payment was an interaction that we marked as a pain point, as this was something we had not defined and could potentially make the journey more cumbersome. It is unclear how Zeabuz envision how their service will be paid for. If this is a service Zeabuz provides for a municipality, it is obvious to integrate it with the local urban transport payment solution. If Zeabuz is providing their service as a standalone urban mobility provider, then they also need to have their own payment solution.

	STEP 1	STEP 2	STEP 3	STEP 4
Physical Evidence			Dock Sign Information screen	Dock App Terminal
Customer Actions	Want to reach place B	Needs to cross a body of water	Goes to the dock	Waits for the ferry
Frontstage Inter-action			Sign of the dock Interact with information screen	
Backstage Inter-action			Estimating the arrival of the ferry	Ferry mooring Operator monitoring
Support Process-es	Advertising and marketing	Awareness of existence		Coordinating docking Autonomy coo dination

STEP 5	STEP 6	STEP 7	STEP 8
Ferry	Ferry Passenger area	Ferry Dock	
Boards the ferry	Waits for journey to end Enjoys journey Listens to music Eats food Sits down Talks to people	Unboards the ferry	Continues to destination B
Signal when boarding	Interacting with ferry or passive	Signal when unboarding	
Operator monitoring	Operator monitoring	Operator monitoring	
Operator being able to take control of the ferry Autonomy coordination	Operator being able to take control of the ferry Autonomy coordination	Operator being able to take control of the ferry Autonomy coordination	

Business Model Canvas (BMC)

To gather a deeper understanding of Zeabuz' service, we made a business canvas model.

Key partners

- Shipyard
- Sensor manufacturer
- Service and ferry designer
- NTNU
- Operator company

Key activities

- Production of service
- Production of autonomy
- Developing ferry hard-ware

Value propositions

- Mobility service
- Connecting rural areas
- Experience when using ferry
- Autonomy software & hardware

Key resources

- Autonomy data
- People (HR)
- Service
- Financial investments
- Sensors
- Milliampere 1 & 2
- Support people

Cost structure

- Design & build ferry
- Develop service
- Design & develop autonomy technology

Customer relations

- Currently none

A mobility service that is smoother and more efficient than other options

Customer segments

- Municipalities
- Mobility companies
- Commuters

Channel

- Web page
- Social media
- E-mail

App
Ferry & onshore installations

Revenue streams

- Norwegian Research Council

Bids & fixed contract
Usage fee

INSIGHTS

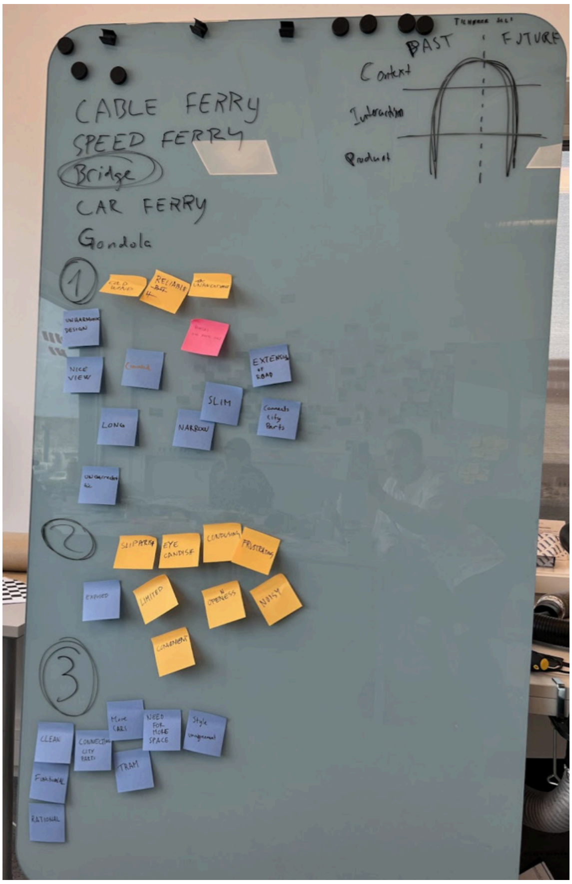
DESIGN INSIGHTS

Vip

The Vision in design method developed by Matthijs van Dijk and Paul Hekkert is about analysing a current product, its interactions and trying to imagine its designers intentions. From there a future context is defined and its interactions, first then you start to design a product that fits in the context and has the preferred interactions. This is to ensure that you innovate new solutions for the future, and not to solve today's problems.

We had a session with this method, but had it quite late in our process. The current product we analysed was Elgeseter bridge in Trondheim, as there does not currently exist any autonomous ferries or other ferries that serve the same purpose as the bridge. After trying to envision the thoughts of the creator of the bridge designer, we set the future context to be cities divided by water in the product segment waterborne urban mobility within a scope of 8 years. The statement we made to describe the future scenario was "We, the designers, want to effortlessly cross a body of water, while enjoying it". When we started to ideate on the product that was fitted into the context and interactions, we quickly recognized that we had done this before and were coming up with the same ideas.

We did not gain any new insight or ideas from this method and that is probably mostly due to the fact that we did not fully implement this method in our process, and the session we had came too late. What we did get from this was that we got confirmation that we had been through the same steps, just in a different manner. It also showed that a different method gave the same result.


PAST
FUTURE
Context
Interaction
Product
CABLE FERRY
SPEED FERRY
Bridge
CAR FERRY
Gondola
NICE VIEW
SLIM
LONG
NARROW
EXTENSION OF ROAD
CLEAN
TRAM


Future
AREA OF CONTRIBUTION
URBAN MOBILITY
check research
Statement (what you want to offer people?)
We, the designers want to
HONEST
PHYSICAL PRODUCT
A SERVICE
SYSTEM
DURABLE
INVITING
COOL

INSIGHTS

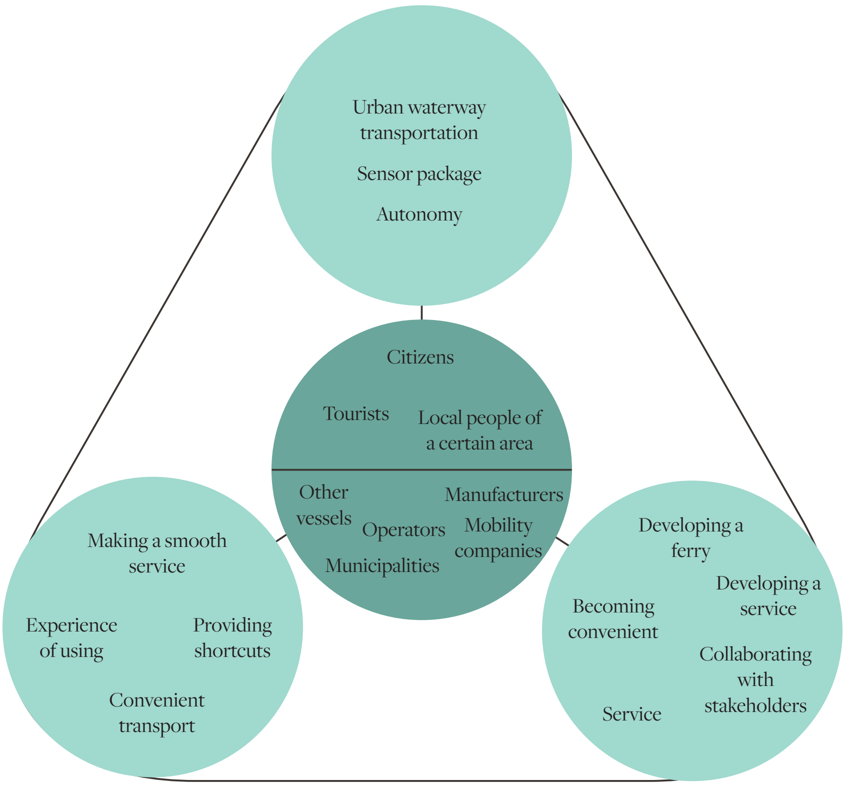
DESIGN INSIGHTS

Functional Analysis

As the functional analysis was not done during the workshop, we did this on our own. Einar Hareide has good experience with making this analysis together with the client. In this case, he suggested we do it without the client. He feared that if we got too much input at the point we were at, we would try to solve everything with our design. As a design always is a compromise to some extent, we agreed that it would be better for our creativity to do the functional analysis with the insights we had at the point.

Verb	Noun	Grade	Comment
Provide	Safety	1	Boundaries for passengers
Connect	Shore and vessel	1	
Reduce	Risk	1	
Accomodate	All humans	1	Universal design
Provide	Mobility service	1	A ←→ B
Provide	Entry/exit	1	Barriers
Manage	Passenger flow	2	
Provide	Experience	2	
Ensure	User satisfaction	2	
Give	Feeling of safety	2	
Provide	Sustainabilityw	2	
Increase	Travel smoothness	2	
Accomodate	Urban mobility	2	
Communicate	Information	2	Ferry ←→ passengers Ferry ←→ environment Dock ←→ users
Provide	Weather protection	2	
Adapt	To different environments	2	
Provide	View	3	Windows
Provide	Comfort	3	
Inform	Departure time	3	
Provide	Resting place	3	
Pursue	Enjoyment	3	
Introduce	Autonomy	3	
Provide	Privacy	N	
Provide	Entertainment	N	

Business Triangle



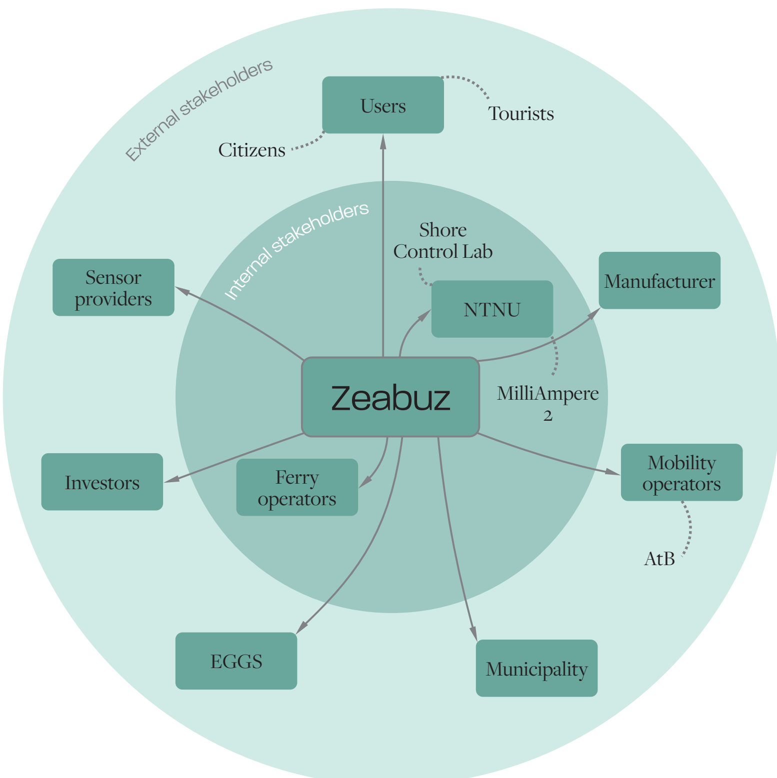
Stakeholder Map

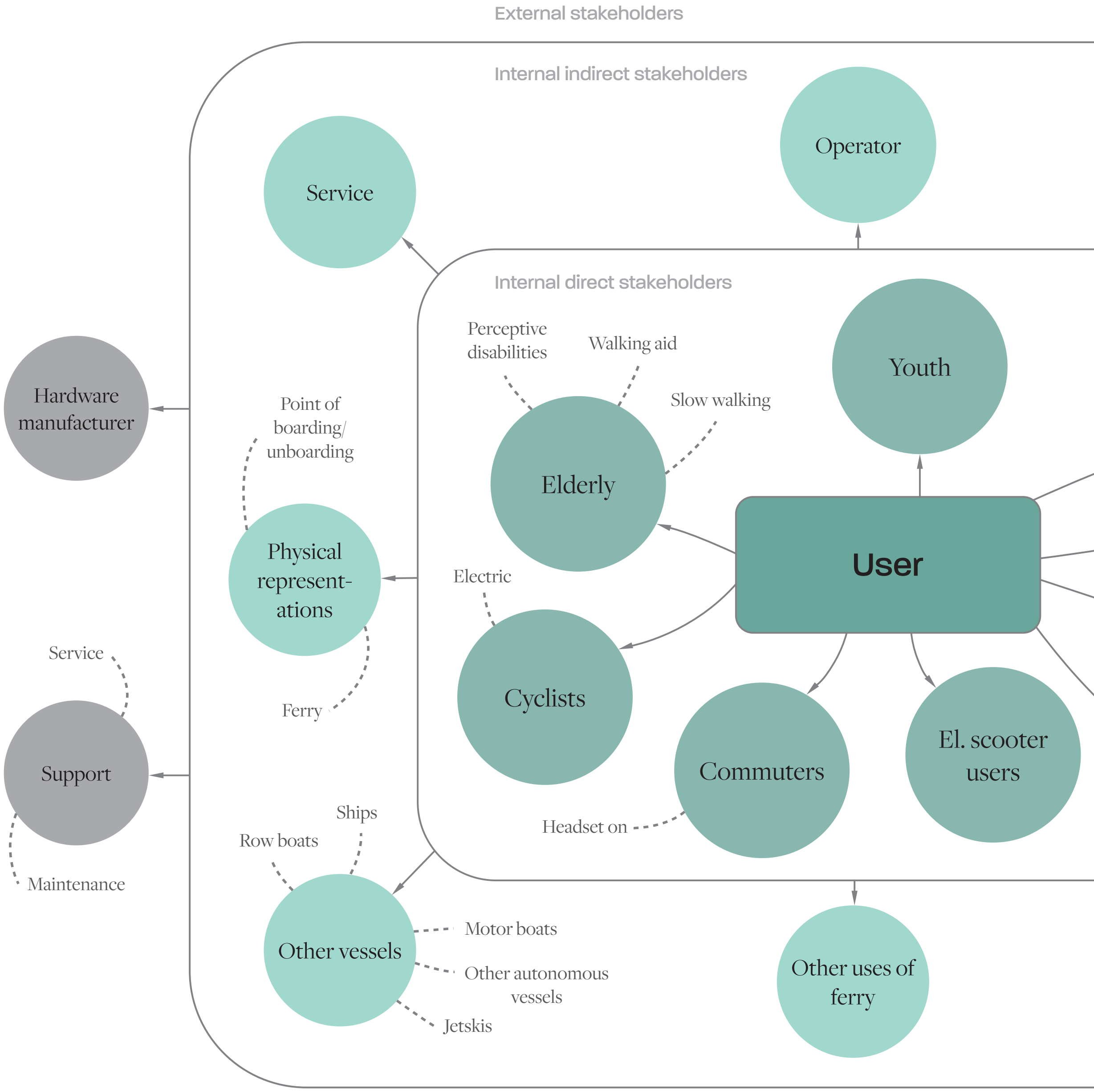
When creating a stakeholder map for the user, we first had to define who our users might be. See "User groups"-chapter. The stakeholders involved in this map were defined by those in direct contact with the user and those only in indirect contact.

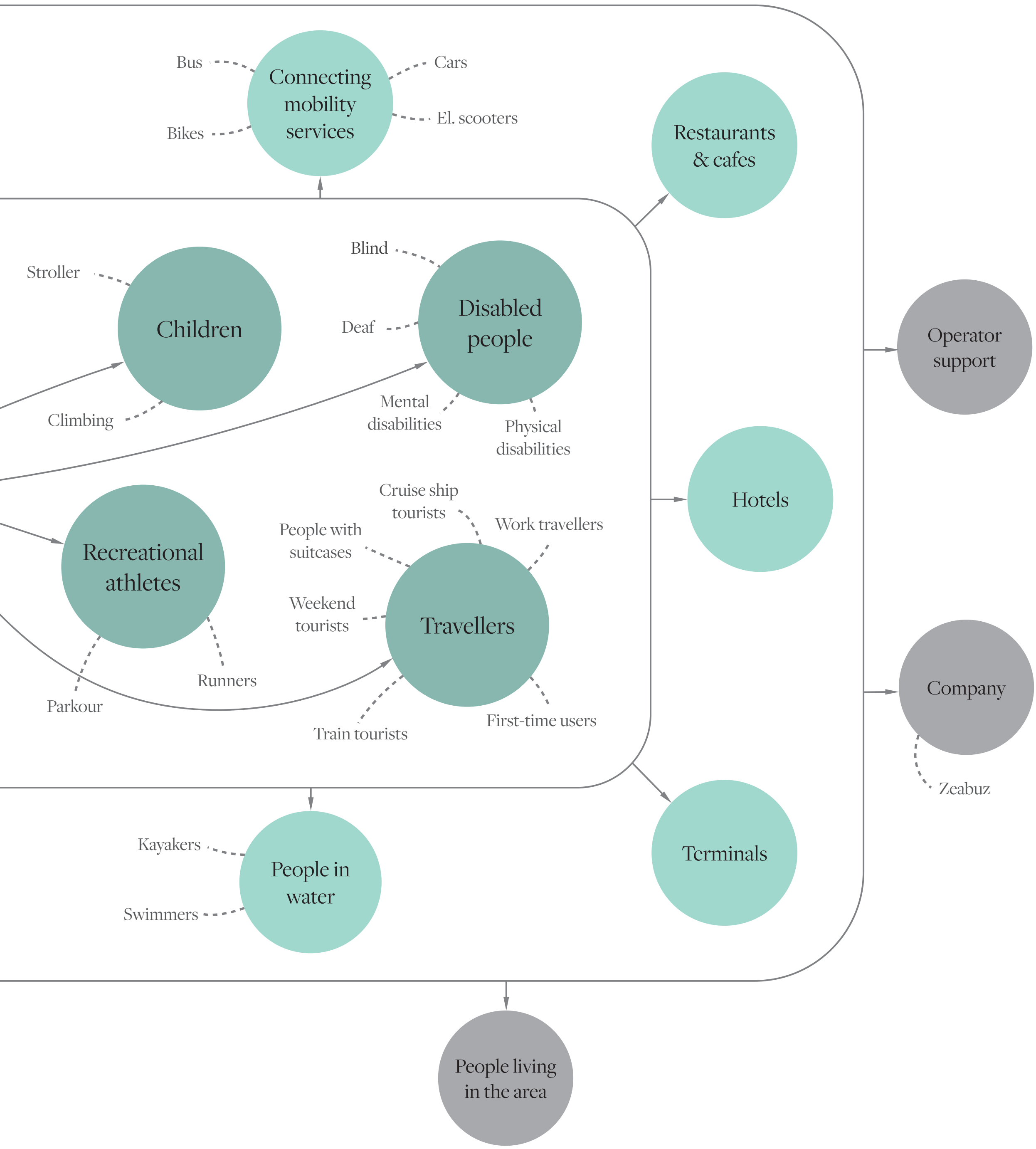
The stakeholders the user encounters directly are other users on the ferry, other connecting transportation services, app/service, boat and dock (physical representation), surrounding areas, operator, other vessels in the water and in severe cases people in the water. All these elements that can affect the users experience of the service. The operator is put as an direct contact because Zeabuz is imagining having an operator on board of the first vessels, and gradually, when people get more familiar with the service move the on shore.

The indirect stakeholders for the user are the company delivering the service (zeabuz), hardware providers (boat, sensors etc.), operator (eventually), support (service and maintenance) and other people living in the operating area.

Doing the user centred stakeholder map made us discover that there are a lot of other factors influencing the user experience. For example how well integrated a city's bus service integrates with the ferry affects flow of a passengers journey. Or if a person falls overboard, the other users on the ferry may need to take action to help.




External stakeholders
Internal indirect stakeholders
Service
Operator
Internal direct stakeholders
Perceptive disabilities
Walking aid
Youth
Hardware manufacturer
Point of boarding/ unboarding
Slow walking
Elderly
User
Physical represent-ations
Electric
Service
Cyclists
Ferry
Commuters
El. scooter users
Support
Ships
Row boats
Headset on
Maintenance
Other vessels
Motor boats
Other autonomous vessels
Jetskis
Other uses of ferry



Bus
Connecting mobility services
Cars
Bikes
El. scooters
Restaurants & cafes
Stroller
Children
Blind
Disabled people
Deaf
Climbing
Mental disabilities
Physical disabilities
Operator support
Hotels
Cruise ship tourists
People with suitcases
Work travellers
Recreational athletes
Weekend tourists
Travellers
Runners
Parkour
Train tourists
First-time users
Company
Zeabuz
Kayakers
People in water
Swimmers
Terminals
People living in the area

DESIGN INSIGHTS

User Groups

While doing the stakeholder map, a need to define the potential user groups of this service arose. We found that we can divide the users into reduced ability users and able users. Within the abled users we had commuters, people using it seldom, people with suitcases, cyclists and e-scooters, tourists, recreational athletes and youth. The reduced ability users we defined as children, elderly, and disabled people. We have tried to look at challenges that might follow some of the user groups. Some of the challenges might be overlapping, and are not exclusively for that group.

Commuters are users that use the service on a daily basis, and therefore probably do not care that much about the service and the technology behind it as long as it works and it takes them from A to B. They will need to learn how the service works the first couple of times using the service but after that, they will be blasé about the information that is presented.

People that rarely use the service will need to learn how the service works every time they use it, and will pay more attention to information provided.

People with suitcases or carrying other heavy or inconvenient cargo will need a smooth passage from standing on shore, through the dock and on board the vessel. The suitcase or cargo need additional space on board and through entrances.

Cyclists, e-cyclists and e-scooters are users that demand more space through the whole journey. They also probably want to have a place to put their bike during the ride. If the crossing takes some time, battery charging is a service the vessel could provide.

Tourists is a user group that probably haven't had previous experience with autonomous vessels. They will use it as an experience and a way of discovering the city they are visiting. We defined three different types of tourists that may have different needs and expectations. Cruise ship tourists are familiar with entering ships, and often come in large groups led by a guide. Weekend tourists and backpackers are more often in smaller groups and have to navigate the city on their own.

Recreational athletes such as joggers, cyclists, parkour and roller-bladers are users that want to continue their activity as soon as possible, and would like the pause in their workout to be as short as possible.

Young users such as youth and young adults can be difficult to reach with information as they may be distracted by other channels such as smartphones and headphones. Many young people have been exposed to technology and therefore trust new technology such as autonomy more.



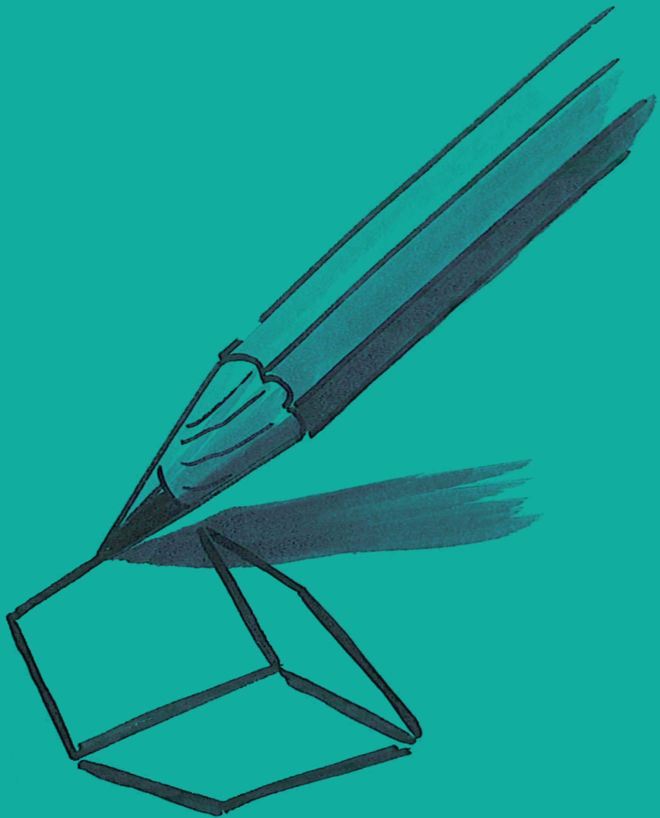
Children have different challenges connected to them depending on their age. Being dependent on a trolley, their parents demand space to manoeuvre the trolley on the dock and on board. The transition dock to vessel needs to be smooth and safe for the trolley. Older children might be able to climb over/under fences and fall overboard.

Elderly users might not be familiar with technology and have a mistrust to an autonomous ferry. Some elderly can have reduced walking abilities and need walking aids. The need for places to sit down in areas where they'll need to wait is also apparent. People that move slowly with or without walking aid will need enough time to board and unboard the ferry. Having a patient ferry that lets users take their time is therefore preferred. With age, your senses might get reduced, having reduced hearing and vision. Therefore communication with this user group might be more difficult. Making communication as clear and precise as possible is therefore crucial.

People with reduced vision, hearing, mobility or mental disabilities are defining the disabled users. This is the user group that demands the most of our services' ability to be user friendly and universally designed. This means that it needs to be intuitive and good to use, also for people that use wheelchairs or have Downs Syndrome. Some of these users might also have a person following them and can help them.

Defining these user groups and imagining what their difficulties might be, helped us to create a better picture of what is demanded of the service we have set out to design. It is important to stress that empathic imagination of what users need only comes so far, and user involvement and testing will give a much clearer understanding of what exactly the different users actually need.

chapter 2



ideation

When planning the project, we decided that ideation should be conducted through all project stages, as our creativity will get inflicted by the amount of insights we have. Different ideation techniques lead to different ideas. Thus, we had a goal of switching up the tools often. Sketching, digital sketching, rapid paper prototyping, working with the materials of the finished product, 3D- modelling, 3D-printing and VR-sketching were some of the tools we switched between using. Another interesting aspect of the project is how we worked on each other's ideas to boost ideation. Further on, we defined five ideas that we believed had the potential to become great solutions for our project.

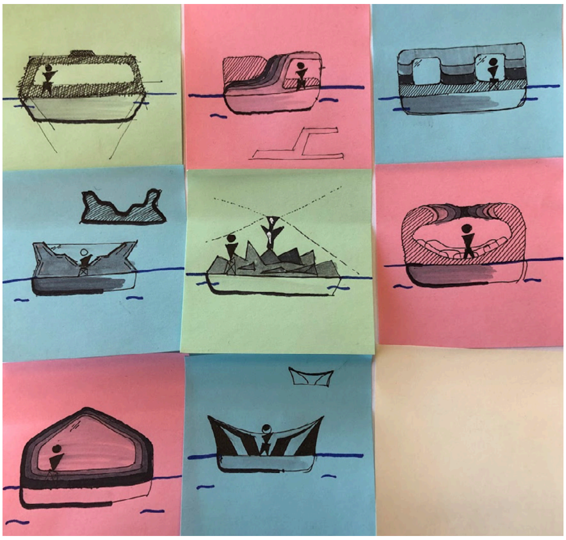
These five ideas were narrowed down to three ideas, through evaluating each idea to a set of criteria.

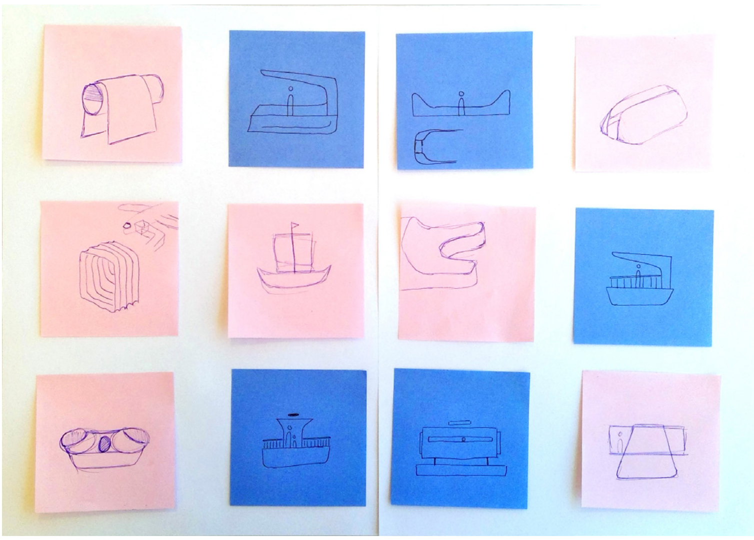
IDEATION

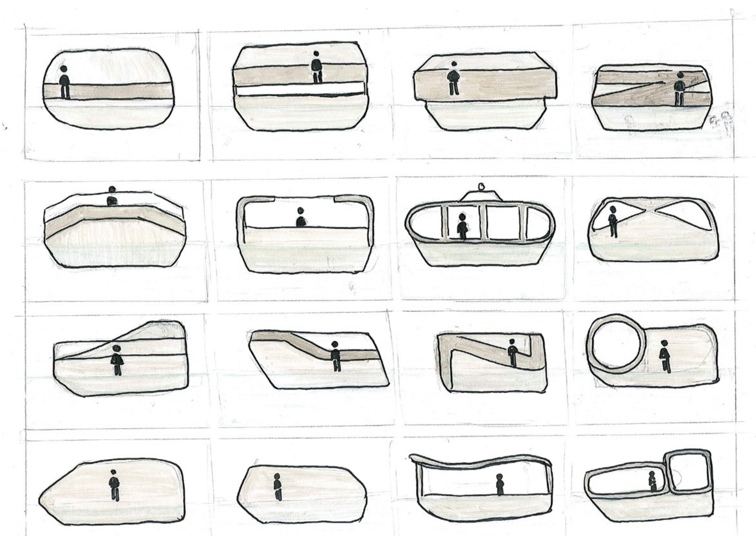
INITIAL IDEAS

The first together sketching session took place in week two of the project. We had gathered some inspiration through making vibe boards, looking at other projects and making some initial storyboards and job analysis. We decided we should sketch whatever we felt like for one hour, and then discuss the ideas together. We learnt that it was nice to capture the early stage ideas, and the discussion was good to inspire each other. The other initial sketching sessions took place whenever we had ideas, both individually or together. Every group session started with showing the ideas we had sketched on our own. Whenever we felt tired of doing research, the ideating helped us in gaining new excitement and engagement for the project.

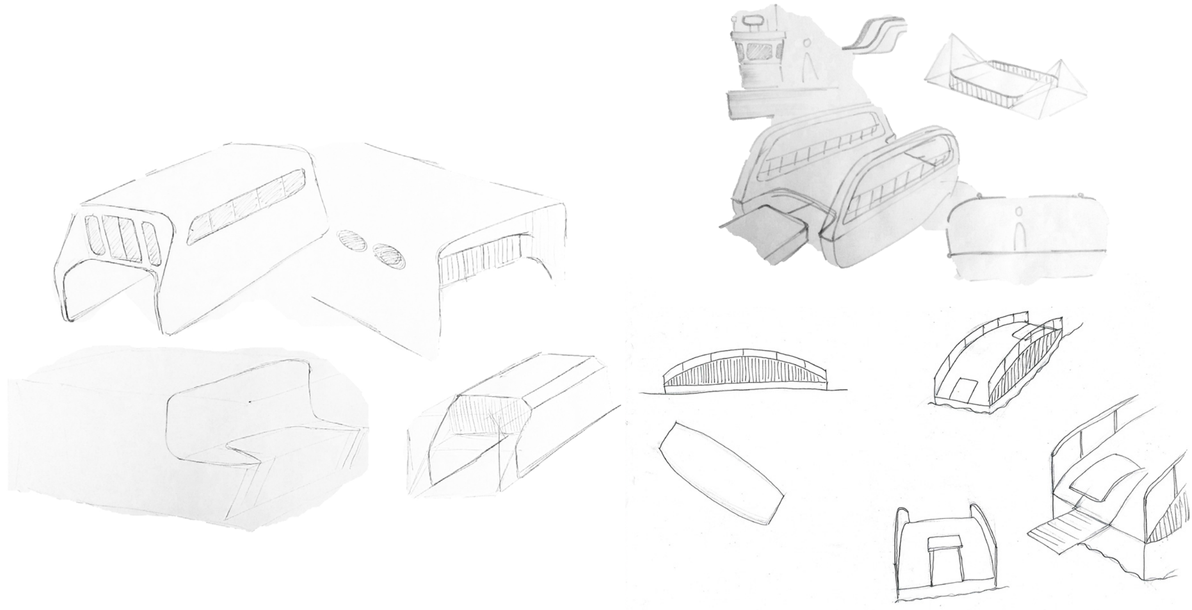
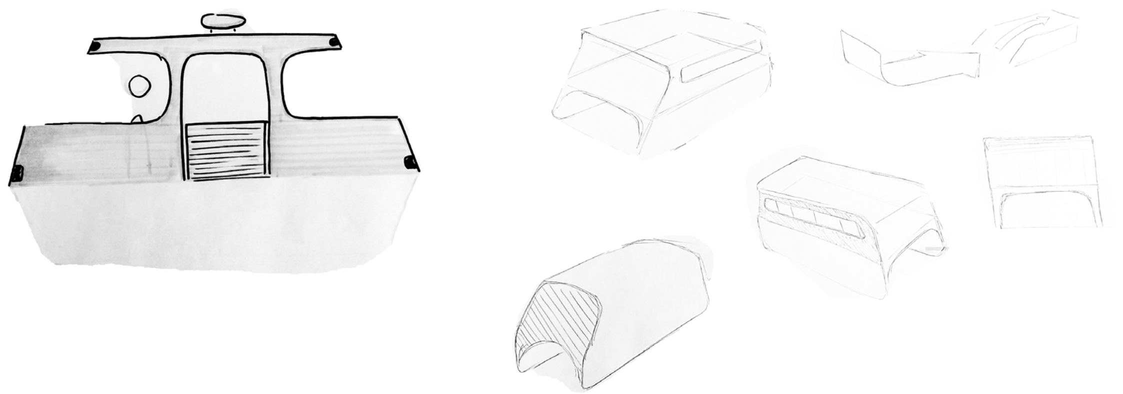
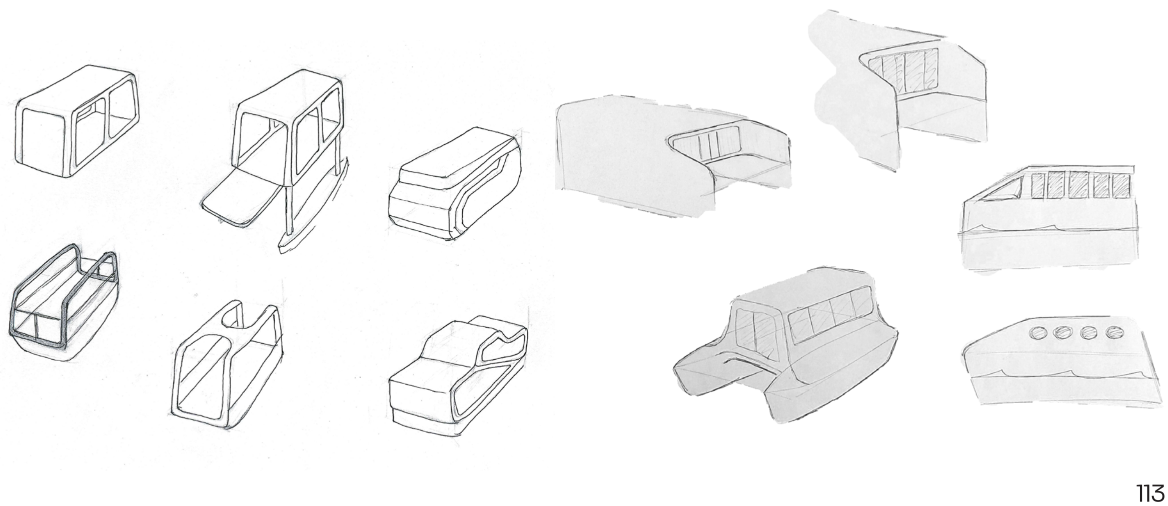
The first sketches were quick thumbnail sketches, scrambled on post-its and paper.

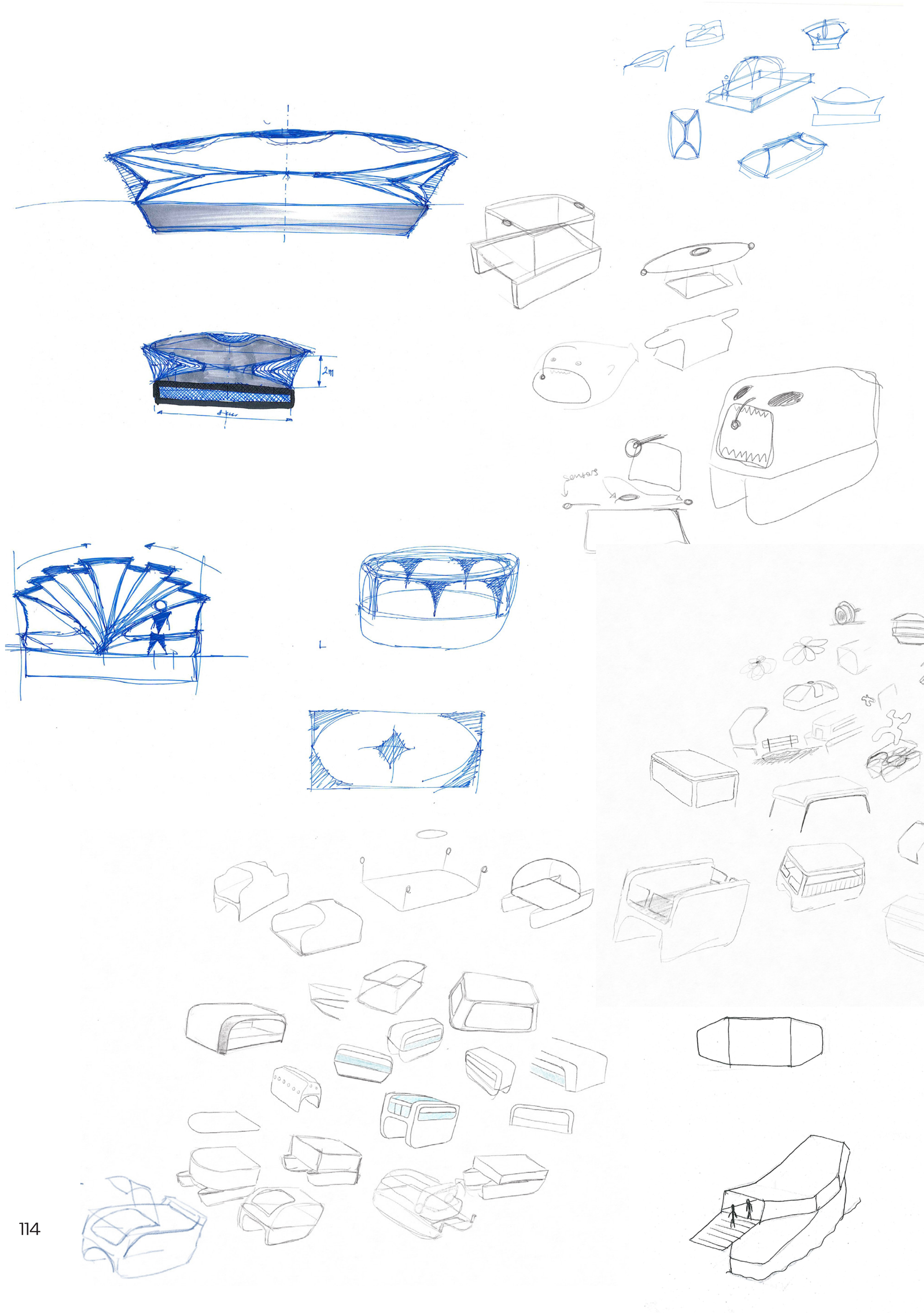


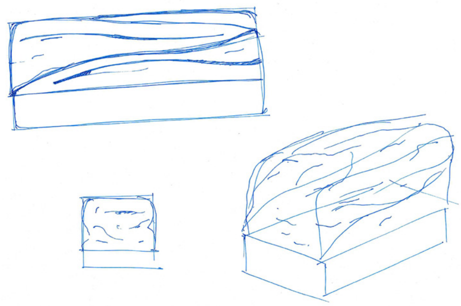


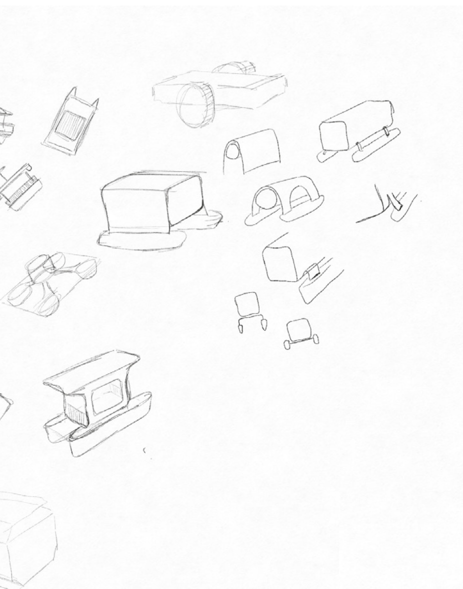


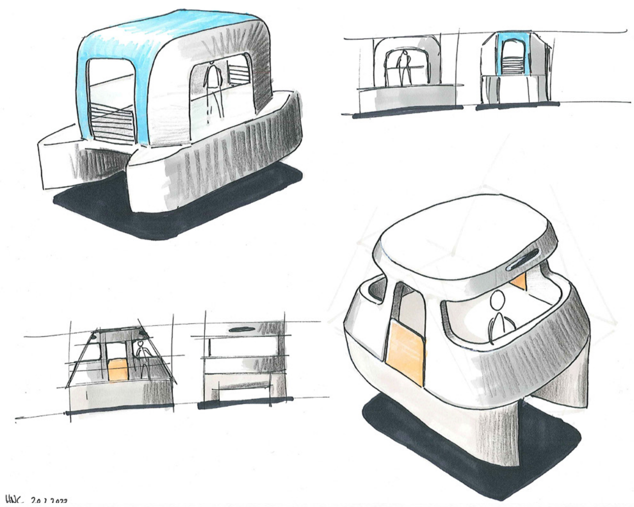
We started working with perspective sketches, just shapes or ferry-like ideas based on the thumbnail sketches and other inspirations. When going through the sketches and explaining the ideas to each other we at the same time placed dots to highlight the ones we liked.

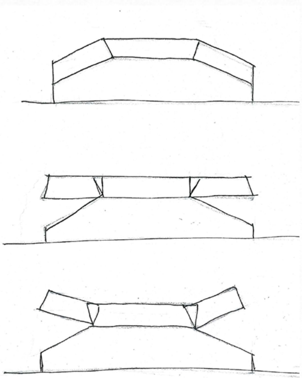




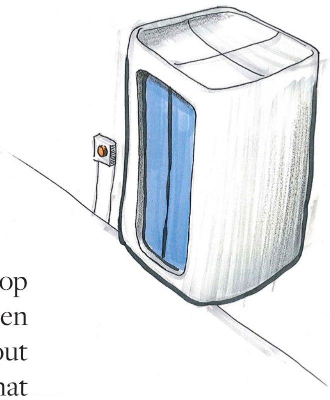

2m
sensors





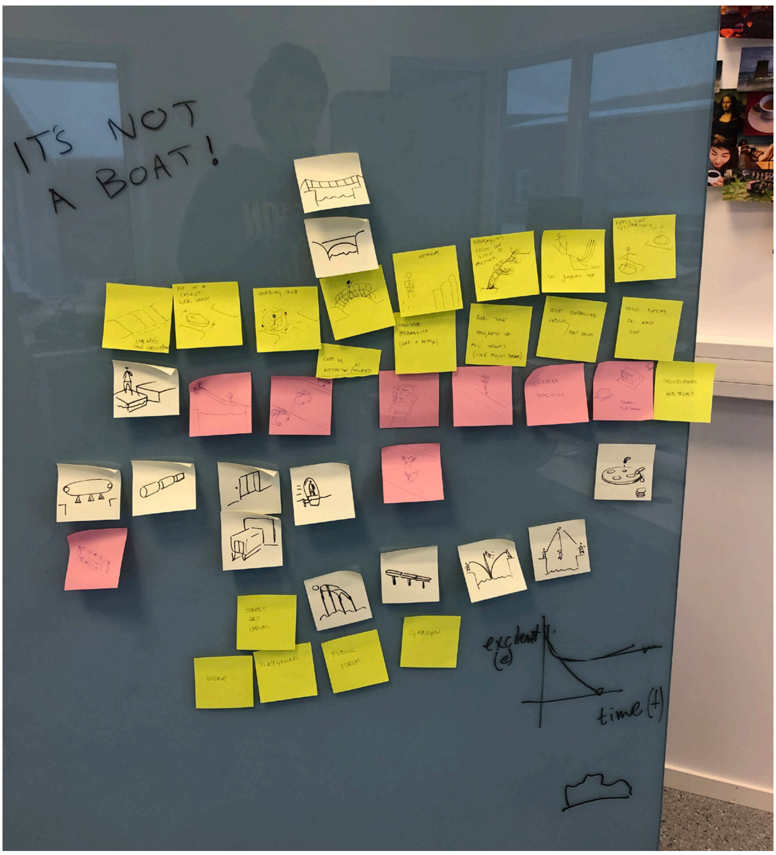


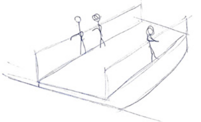




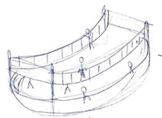
IDEATION
SERVICE IDEATION

A comment that was repeated within the team and also at the workshop with Zeabuz was "It's not a boat". This inspired us to have an open minded brainstorming session of what the service could be, without having ferry in mind. We learnt that this led to many fun ideas that could be included in the final concept as an add-on to the experience. At the end of the day, the goal is to cross a body of water in urban areas, and a floating vessel gives the most flexible solution of the ideas we discovered.

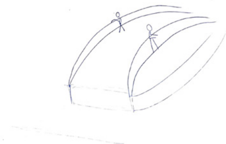


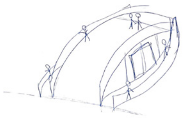


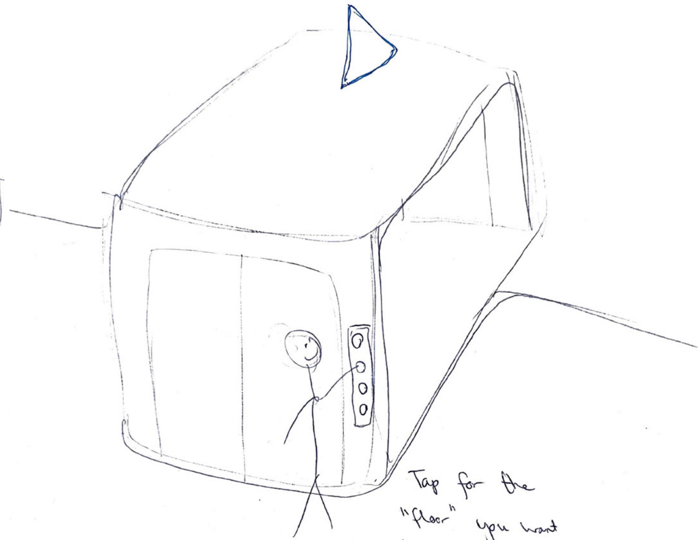
Flat bridge



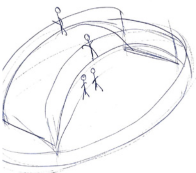
"Hengebru"



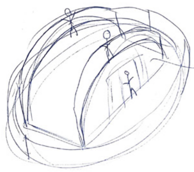




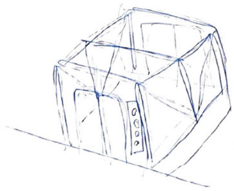
Tap for the "floor" you want to go to



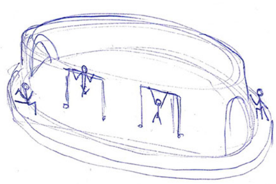
Summer



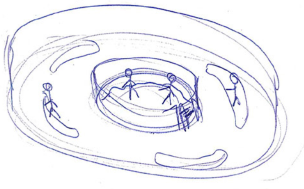
Winter



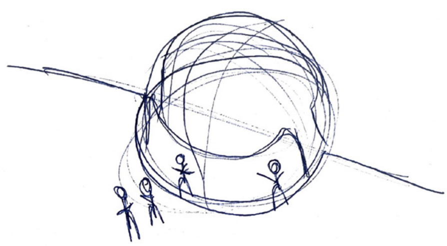
Glass elevator w/ aluminium structure

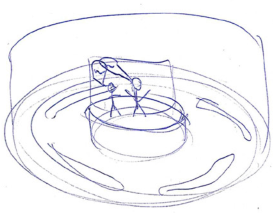


Gym



Moonpool Swimming pool



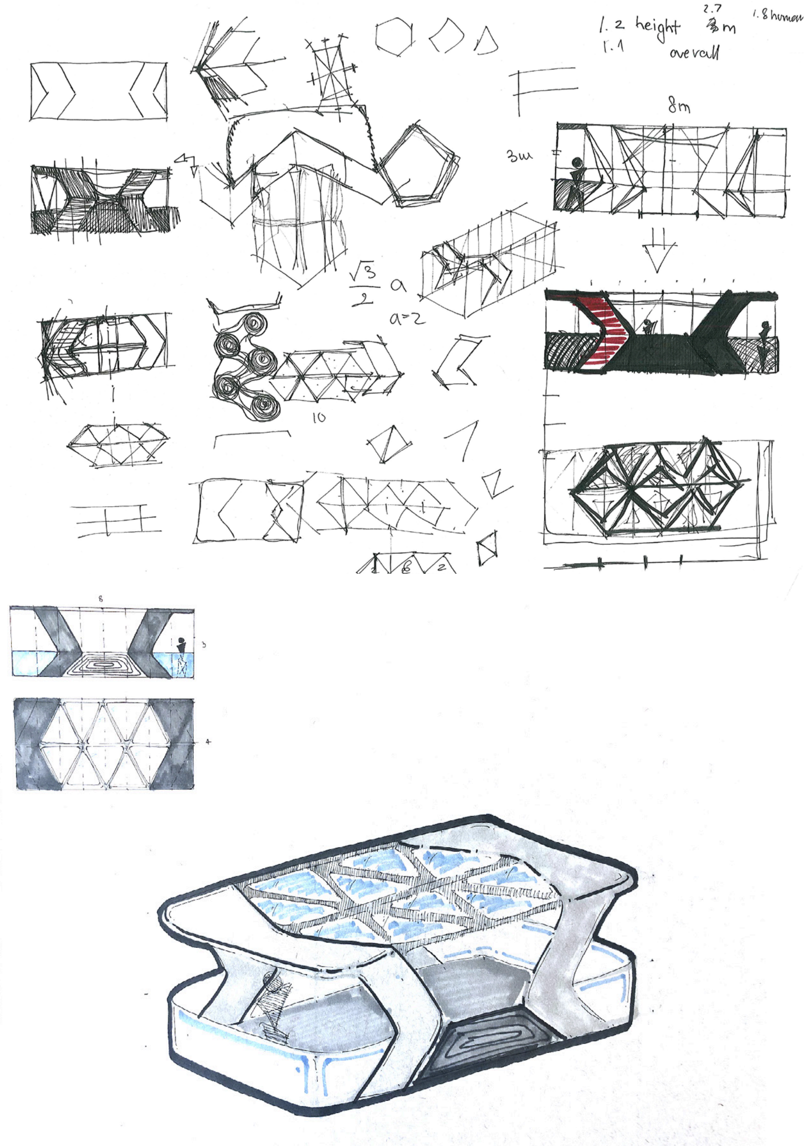


Theather / Concert

IDEATION

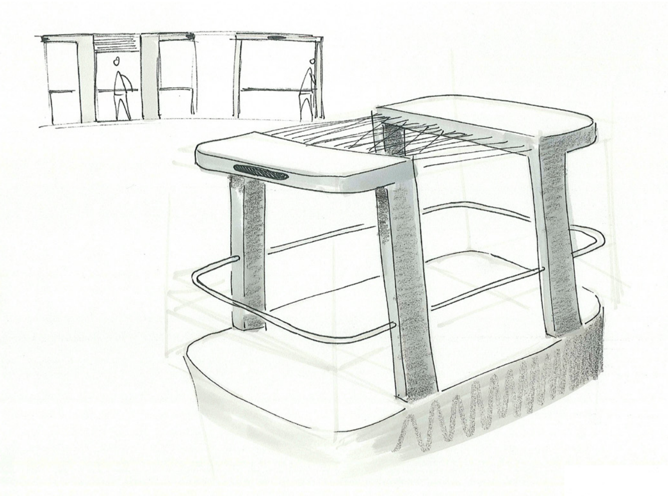
WORKING ON EACH OTHER'S IDEAS

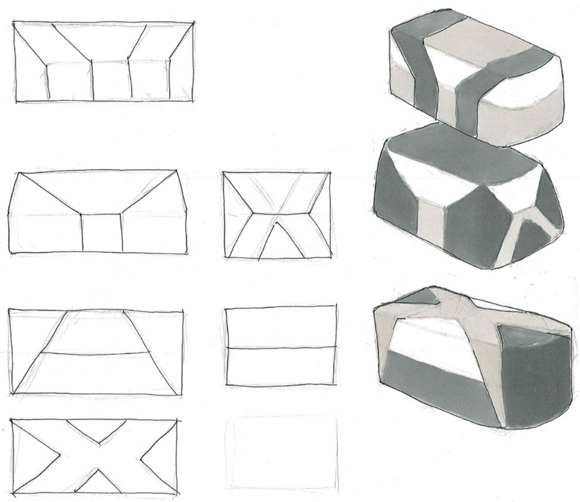
A method we came up with for ideation was to build on each other's ideas. We decided everyone should sketch a realistic, early stage concept before our group session. We had a round of discussing the ideas together. Afterwards, we used 30 minutes to sketch on each of the other ideas. The method worked well for boosting ideation, and also to get more invested in each other's ideas. We recommend other designers working in groups to try it out, as we believe it can strengthen the engagement and feeling of ownership within the group.

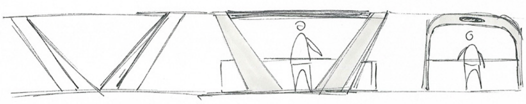


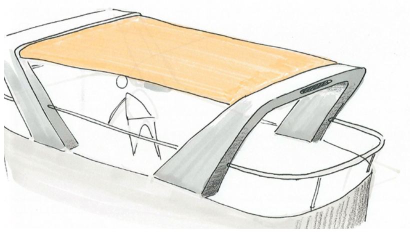
Vedran's start

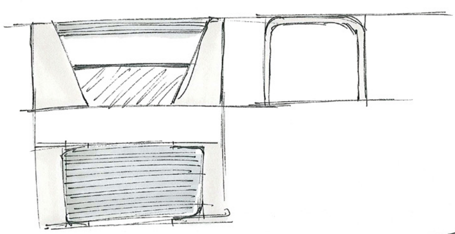
The idea behind this superstructure was that it had elements that gave it direction. Two structural parts on each side connect a removable roof, making it possible to adapt to the different seasons.

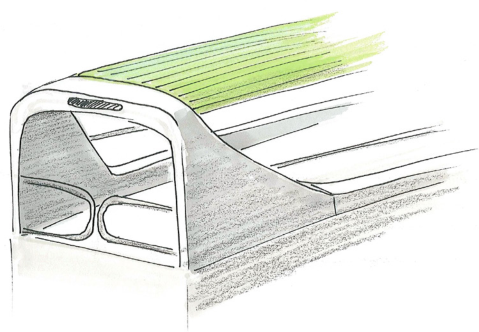




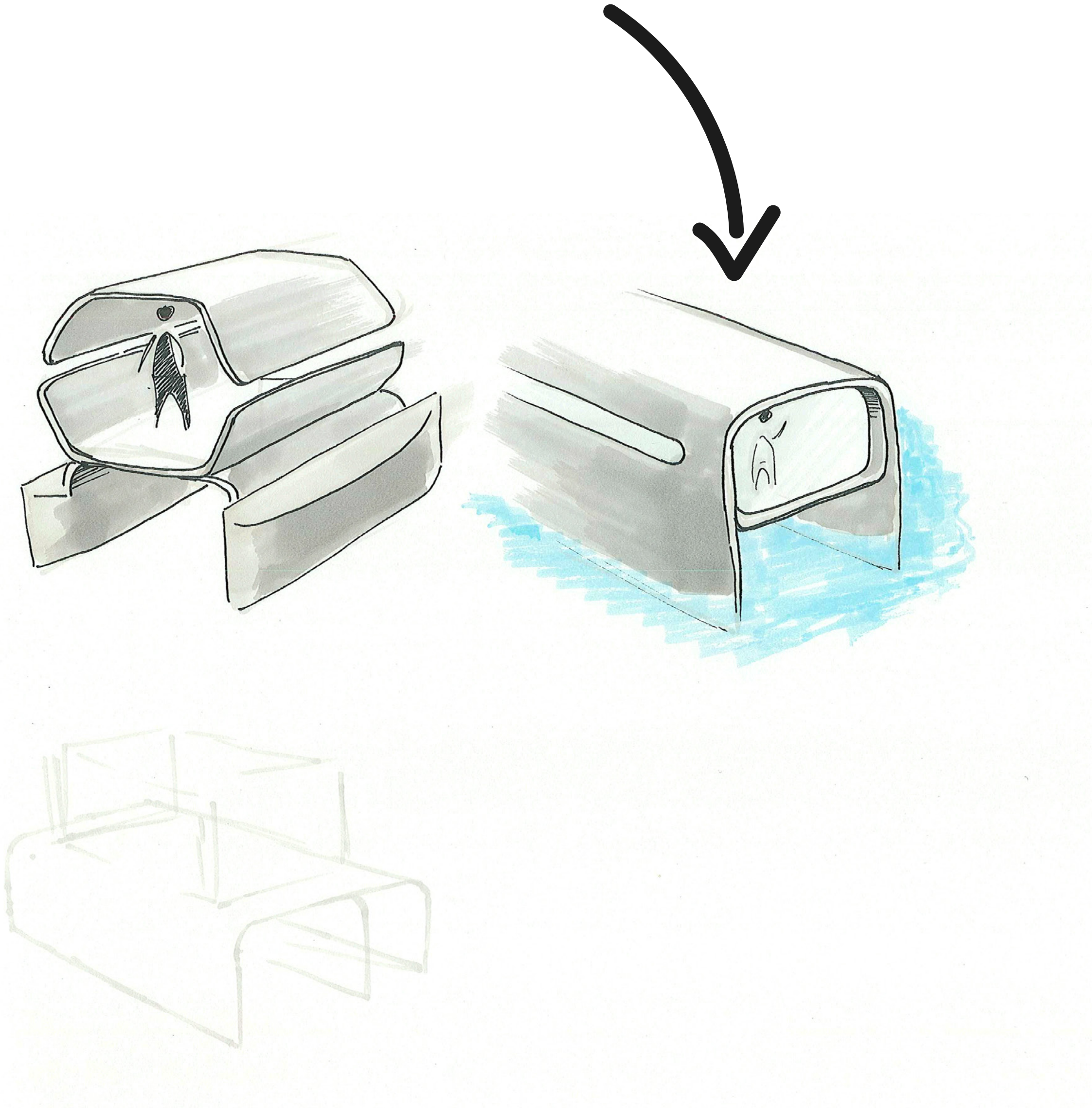






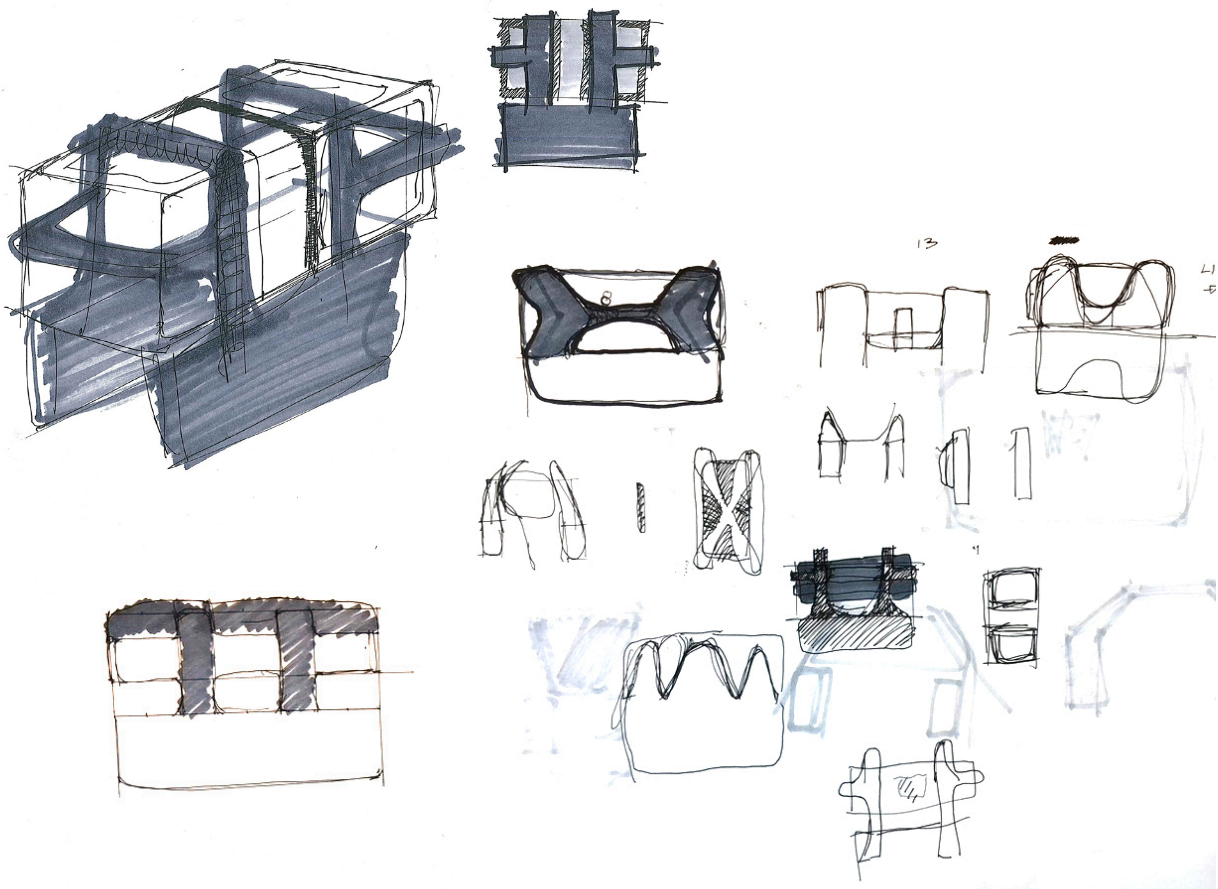


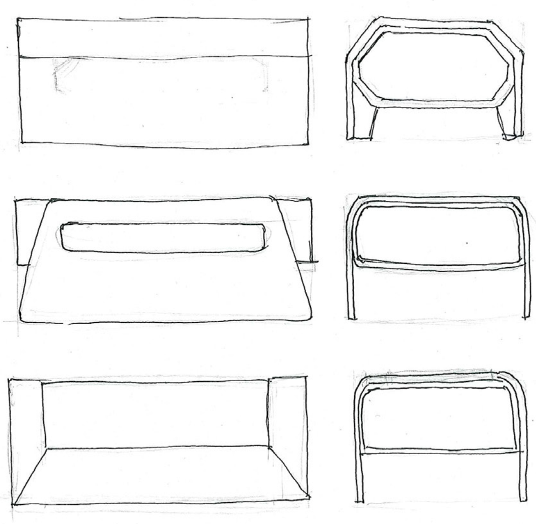
Hilmar's and Malene's reaction

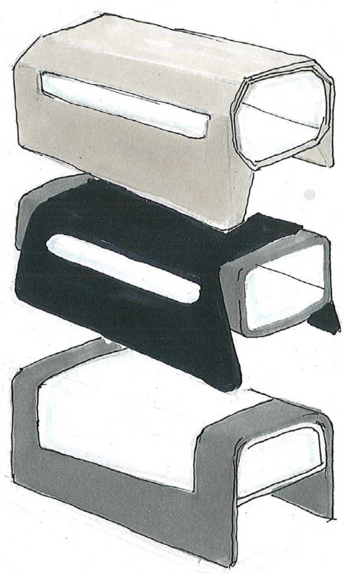


Hilmar's start

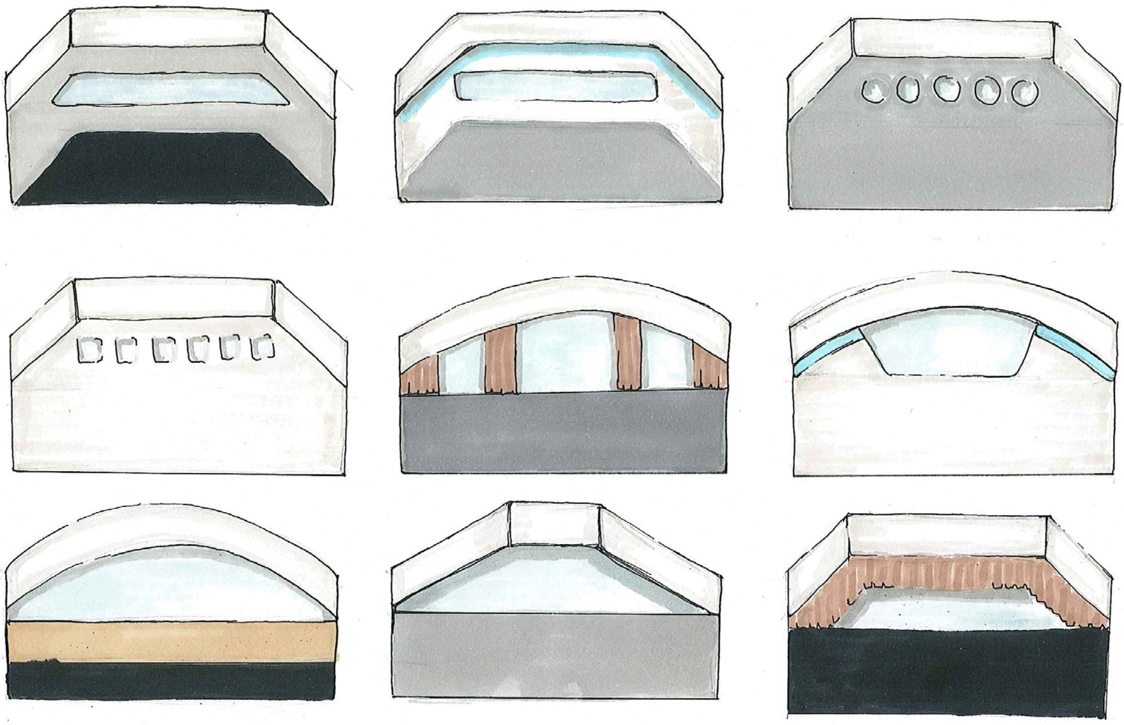
120 A continuous sheet of material bent over the passenger compartment it's carrying, made the superstructure and the hull connect in a nice way.





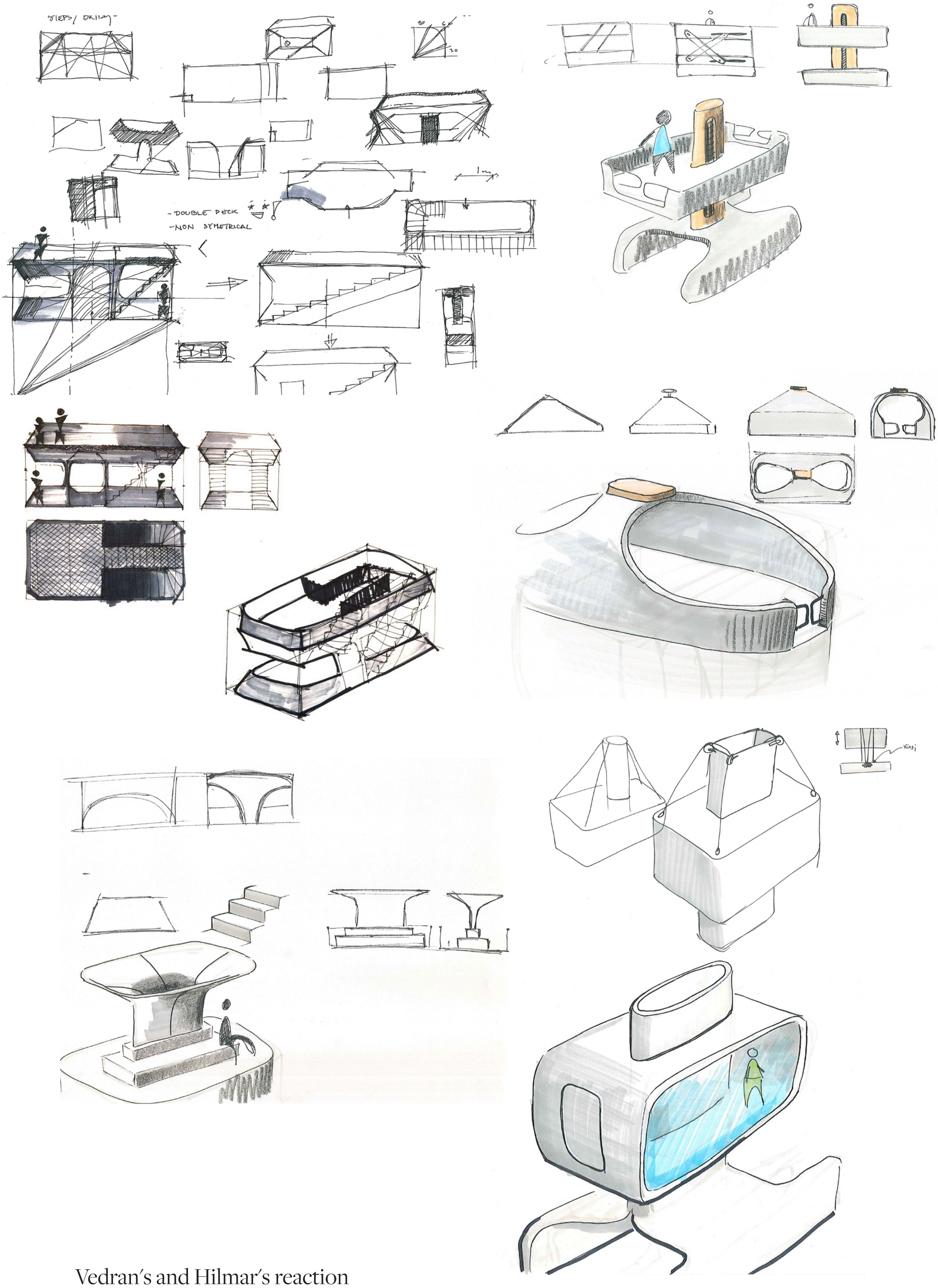


Vedran's and Malen'se reaction



Malene's start

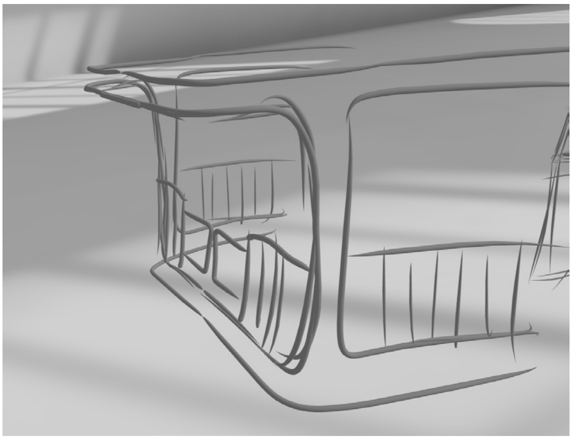
 To adapt to the elements and be familiar to users, the idea for this superstructure was to mimic bridges. You either can walk on the roof or go inside for weather protection.

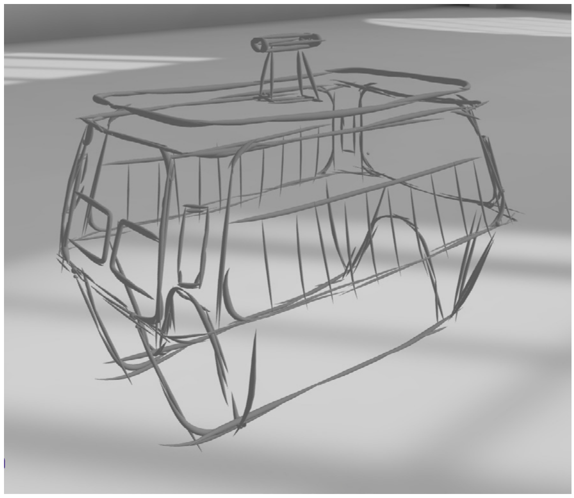

- DOUBLE DECK
- NON SYMETRICAL

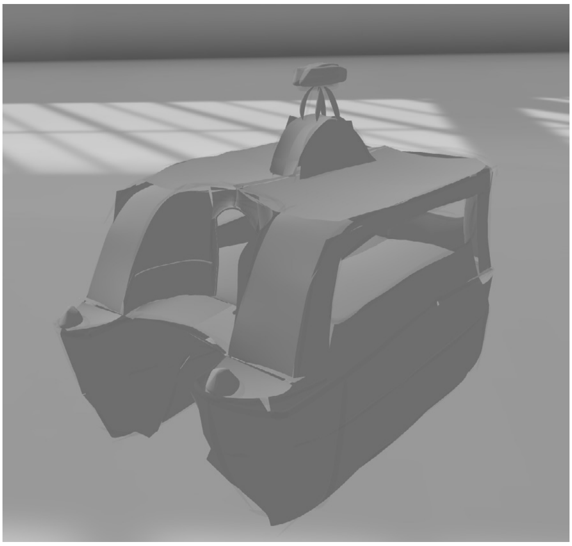
IDEATION
DESIGN IN VR

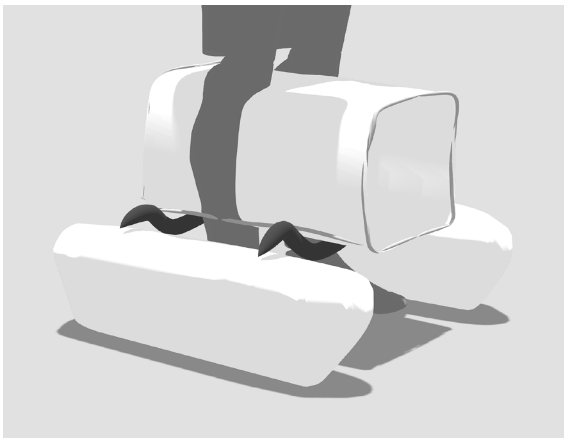
From the start of the project, we were very keen on working in virtual reality (VR) and using it for spatial sketches and an immersive experience while ideating. Thankfully, we have been lent a pair of Oculus Quest 2s VR goggles that support the ability to install Gravity Sketch, the most popular VR sketching app available. It is often used by automotive designers to not only quickly ideate on ideas to get a feeling for them in a virtual space, but also to assess their final designs without the need to manufacture body panels or create a time consuming clay model in 1:1 scale. This technology is truly amazing and it undeniably beats staring at a 2d screen while modelling in a traditional CAD program. Because of this, we have used it in the starting phase when sketching initial ideas.

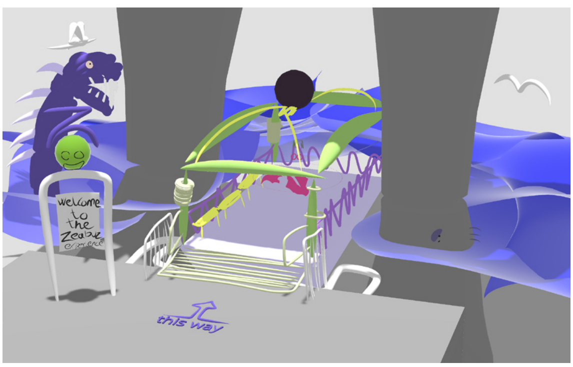
What is more, during the process of creation in virtual reality, we have discovered an opportunity to scale up the model we have been working on and instead of only creating the exterior of the vessel, actually experience the interior as if it was in its true size and we were the passenger on board. We have learned that it is a powerful tool that can be used multiple ways and decided to also use it later in the process when evaluating the experience of being inside the finished design.











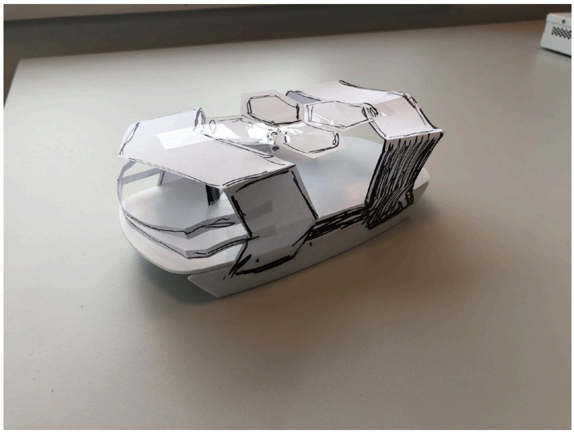
When we discovered that Gravity Sketch had the ability to work collaboratively, we couldn't resist making our dream ferry and putting it in an environment.

IDEATION

SMALL SCALE PROTOTYPES

When we started prototyping we thought it would be relevant to have a hull to structure the prototype on. Jarle Kramer, Senior System Engineer at Zeabuz sent a unidirectional catamaran hull that Zeabuz has been working with. This hull was 3D printed in scale 1:50. To not be biassed and limited by the model we got from Zeabuz, we modelled some unidirectional and bidirectional hulls that we also printed. Øyvind Smogeli emphasised that we could make hulls of our own if we wanted to. On these hulls we worked with paper and cardboard to create the superstructure. Paper and cardboard behave in bending in a similar way sheet aluminium does, as it only allows for bending in one direction.

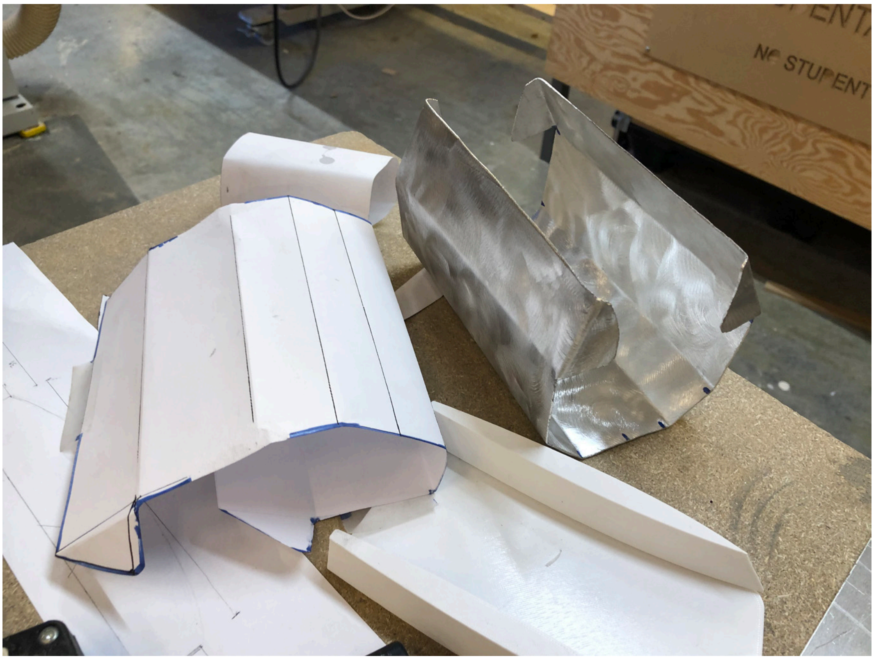
Having a hull as a reference to build the superstructure on top of, made it easier to get a sense of the scale of the superstructure. Although, when making a scaled person to fit into the superstructure, we quickly discovered that most of the roofs were made too low. As the paper is rather weak, but gains strength when bent, working with paper models gave an indication on how strong the structure was and where it needed to be stronger.



IDEATION
SMALL SCALE PROTOTYPES

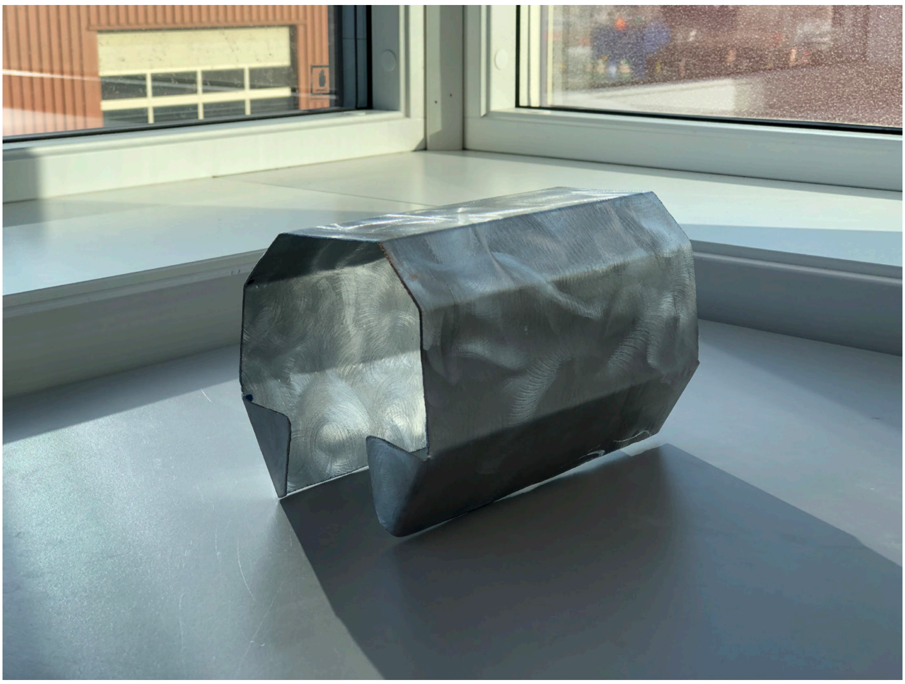
The scale we worked with was 1:50. This scale was sufficient because it made it easy to fit the models on the printbed of the 3D printer at the institute. It also was big enough to test its floating abilities and to get a general impression of the appearance. The 1:50 scale was something we stuck to during our whole process.

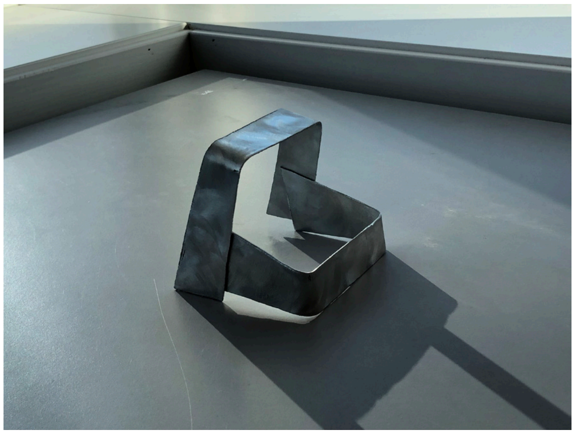
To get a better impression of how aluminium behaved and looked we made some of the ideas we were currently working on in thin sheet aluminium. We drew the shape on paper, cut it out and transferred it to the aluminium sheet. We then cut it on the band saw and cleaned the edge with a rotational sander. By bending the sheet aluminium over steel pipes, we got the desired radius. The models were then glued or melted into the plastic hulls.



IDEATION
SMALL SCALE PROTOTYPES

These aluminium models provided us with insight on how the material is to work with and how it's affected by cutting, bending, and sanding. It was harder to cut than expected and we identified the importance of surface treatment, as it varies greatly depending on how it is handled. Starting with a flat surface, and from that creating a continuous shape we think is an interesting way of making a design.





IDEATION

DEVELOPING THE IDEAS

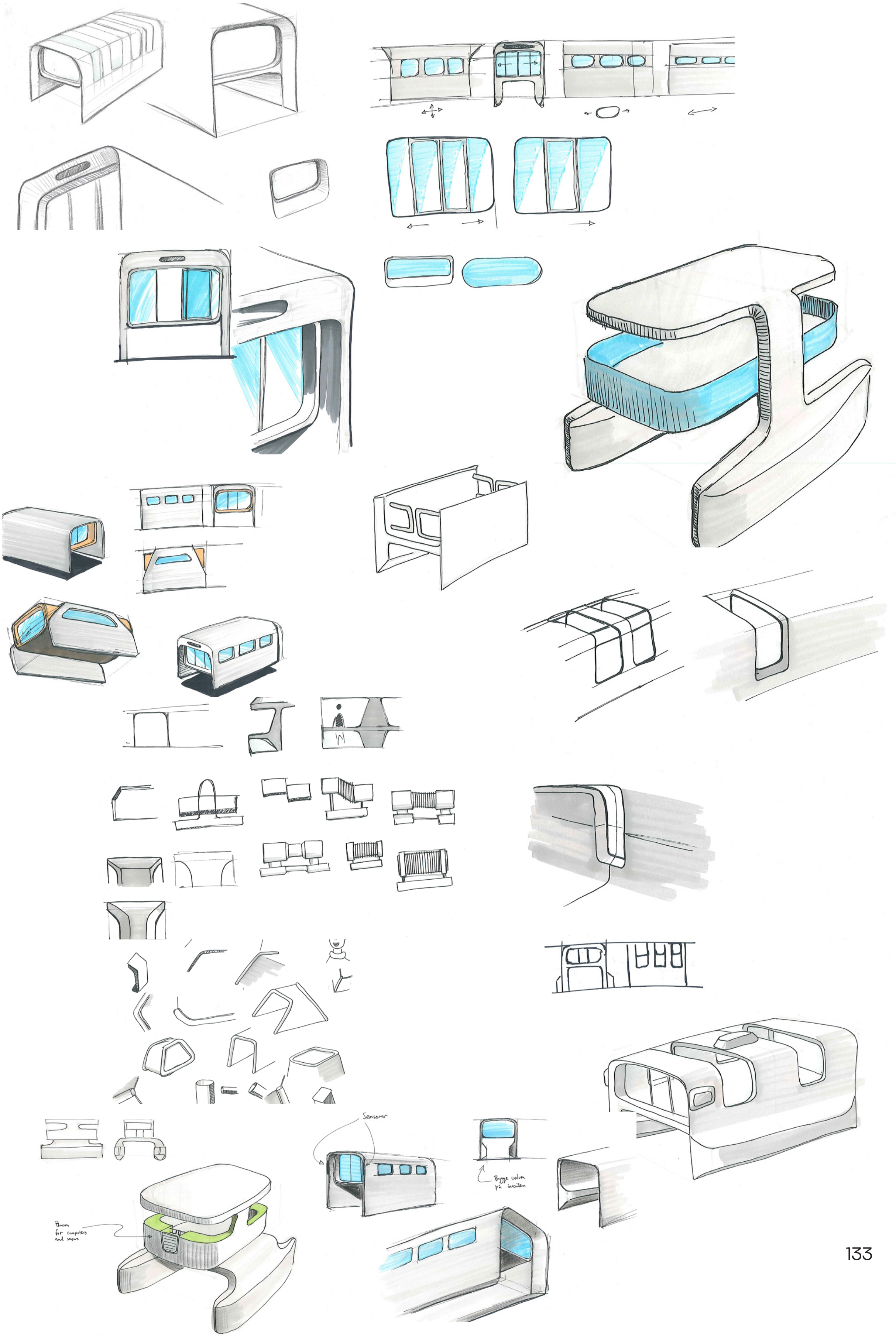
In further development of the ideas, in addition to sketching, we also involved 3D modelling to get a better impression of the ideas. Some ideas consisted of unifying both hull and superstructure, while other ideas involved having an on board elevator.

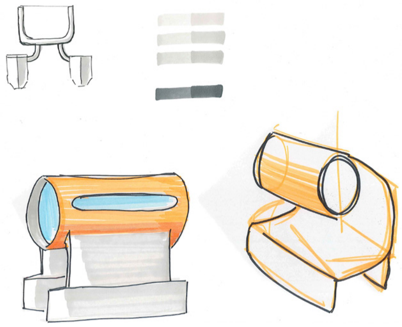
Einar Hareide was very positive to the use of design expressions from other fields, like architecture, music, art, etc. We learnt that getting inspiration from other fields can lead to innovative designs for the field we are designing for. Analogies we used for inspiration were elevator, bridge and arrow:

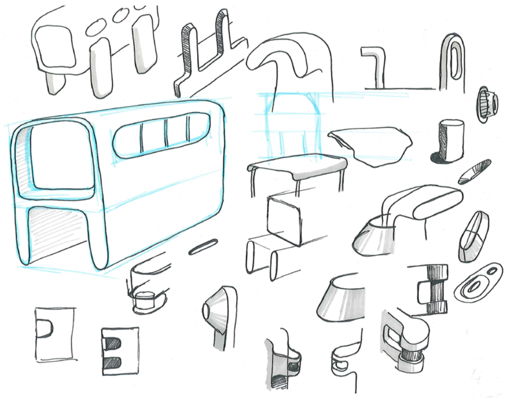
Elevator
The Zeabuz team mentioned on several occasions that taking the Zeabuz ferry should be like taking a horizontal elevator.

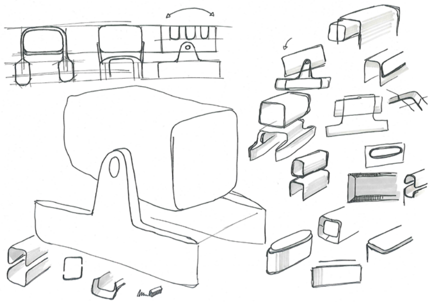
Bridge
As mentioned in the project brief, the goal of the next generation Zeabuz ferry is to be a more sustainable and flexible option for a bridge. This gave us the ideas of bridge-looking structures.

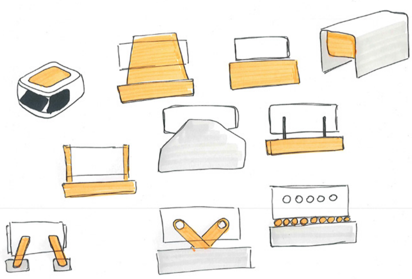
Arrow
The idea of going in a direction, inspired us to sketch ideas with arrow-shapes. The arrows can be used as actual arrows when communicating with the surroundings, or just serve as a shape that stands out from other ferries.

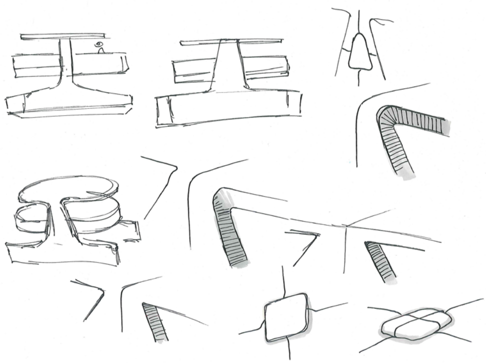

Sensorer
Bygge volum på insiden
for computers and sensors

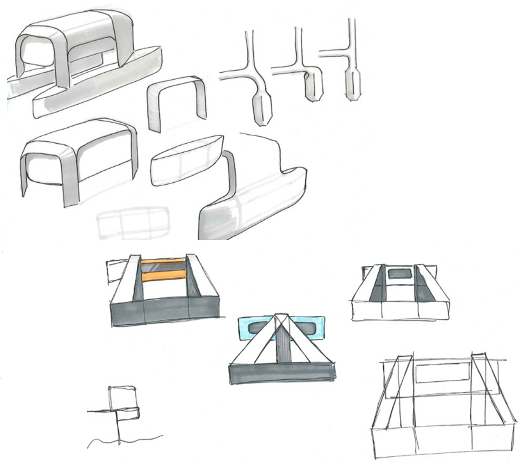


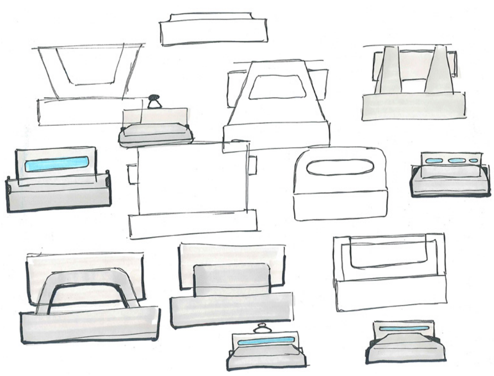


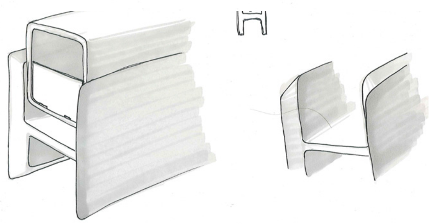


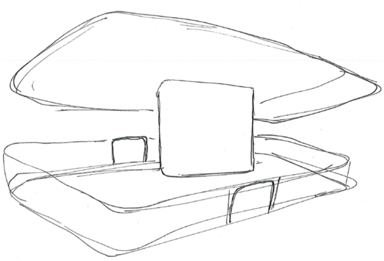


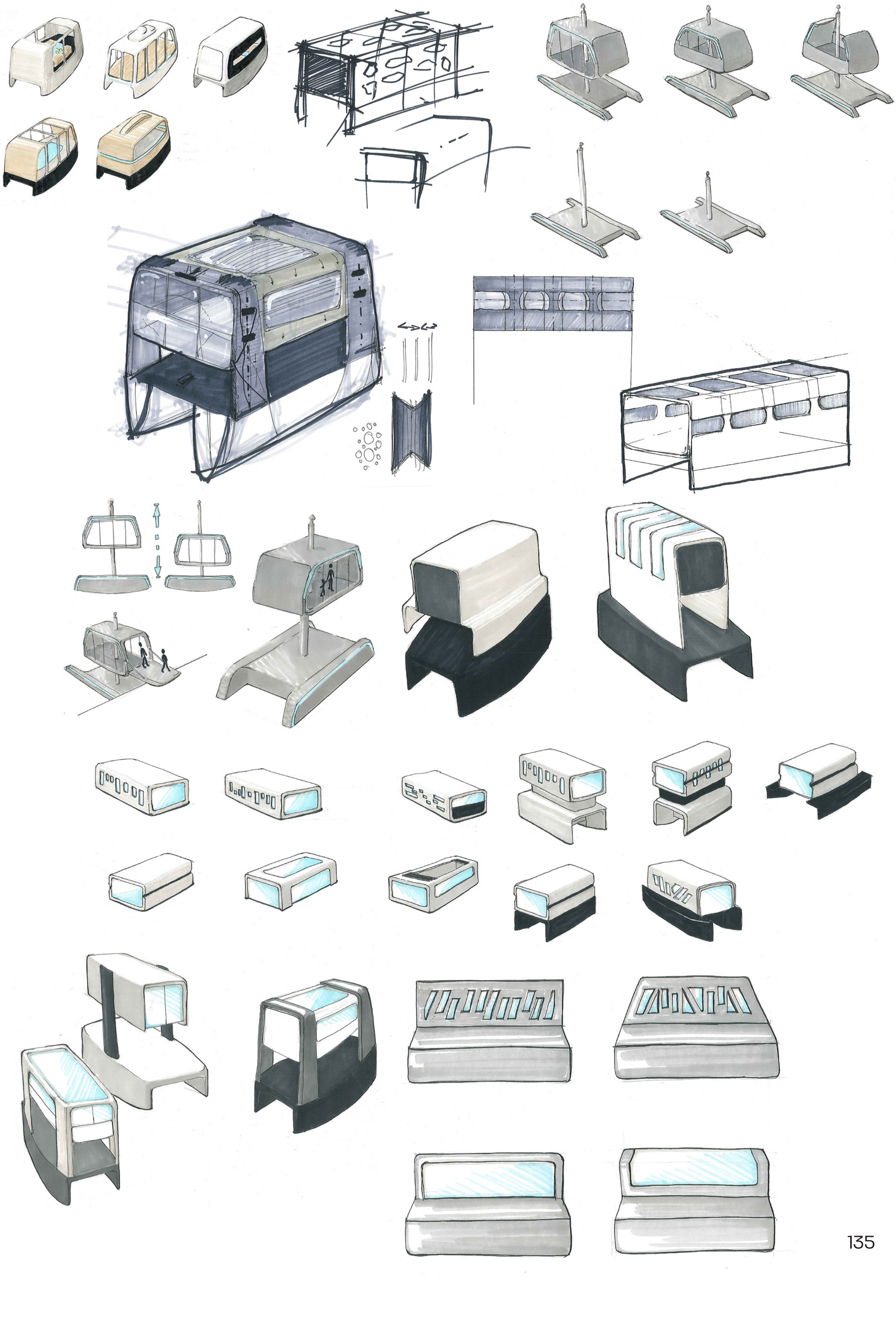


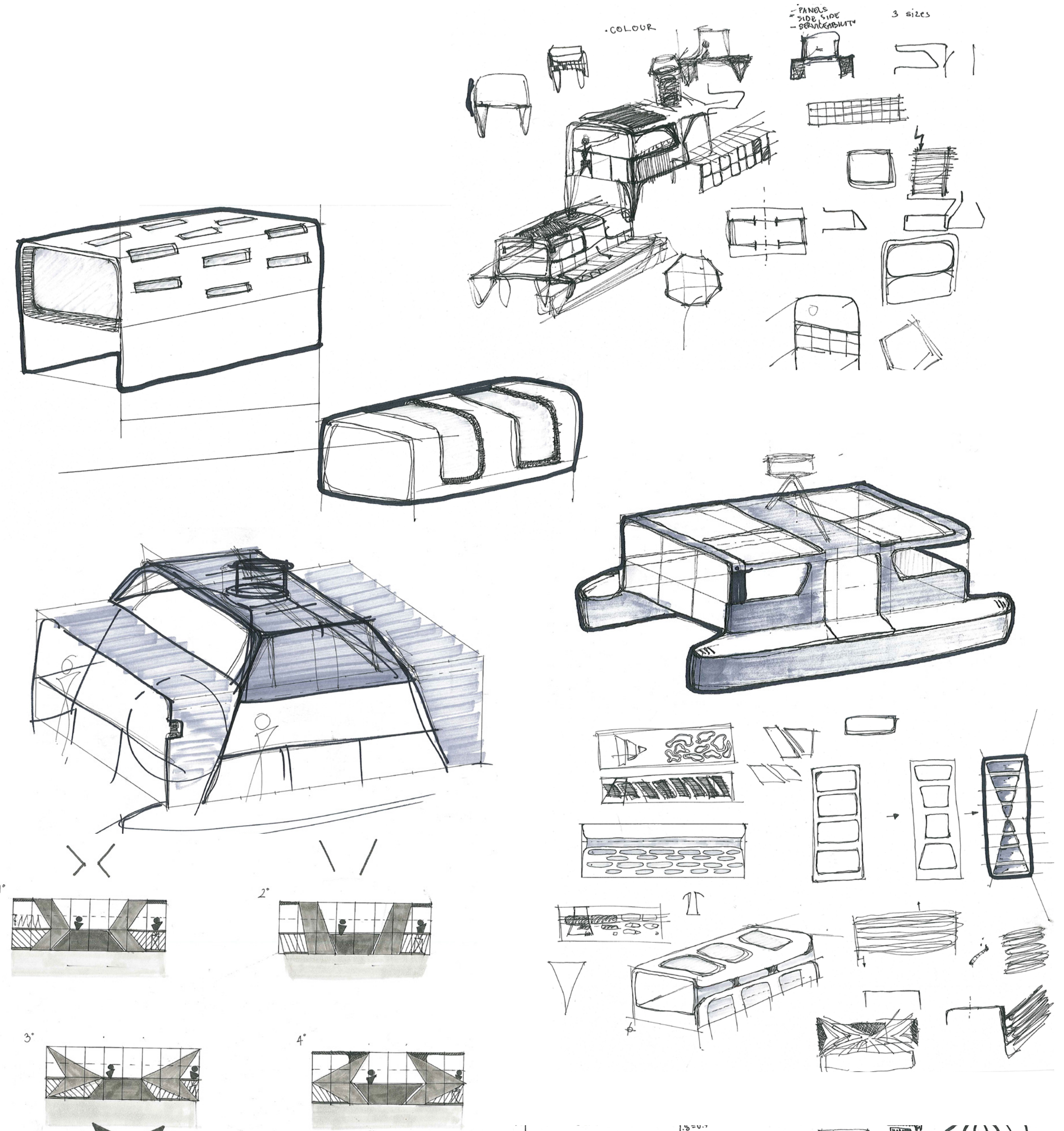


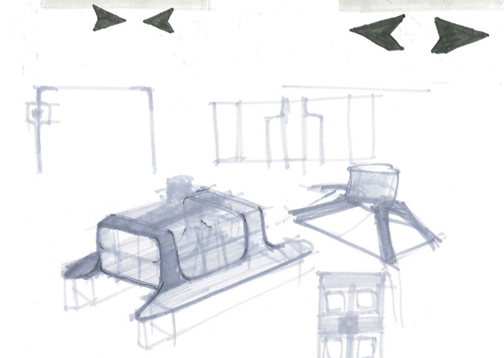


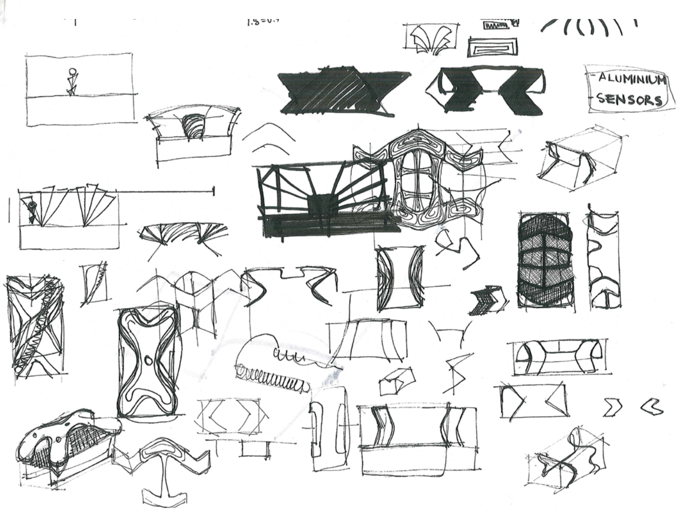


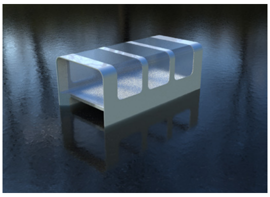
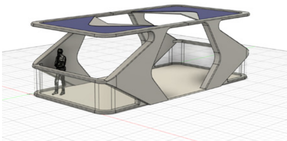


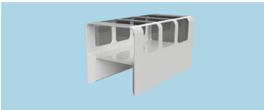
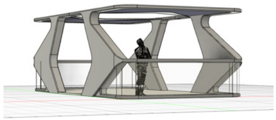
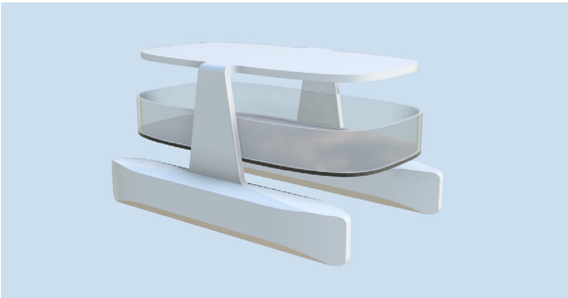
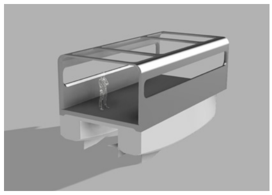
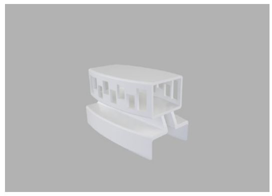
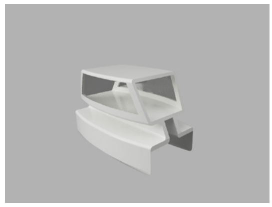
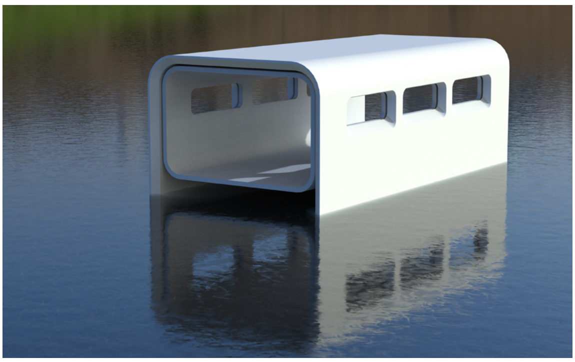



·COLOUR
3 sizes
1°
2°
3°
4°




ALUMINIUM
SENSORS

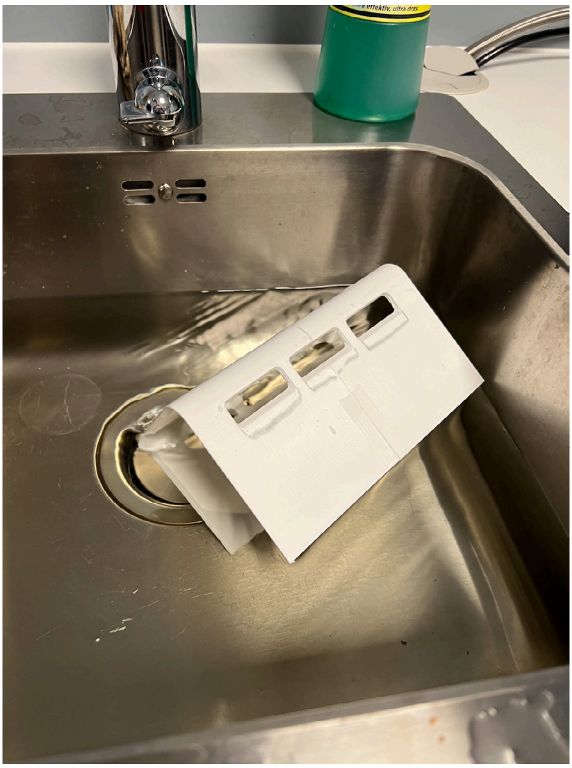




IDEATION

DEVELOPING THE IDEAS

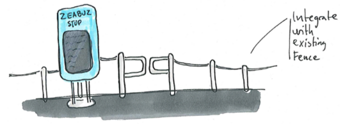
We 3D printed some of the models and tested it on water. This gave us quick feedback on its floating ability. It occurred to us that we are not naval architects, therefore not trained in designing ship hulls. Nevertheless, a convincing design should also have a reasonable hull.



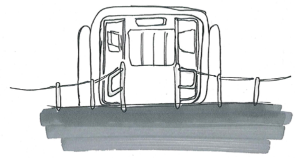

Suma
Renax
ULTRA

Ideation on parts of system

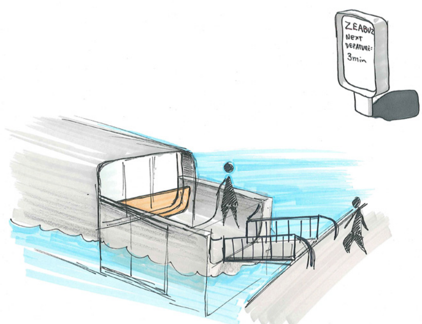
As part of developing the ideas, we also looked into the different parts of the service and ferry.

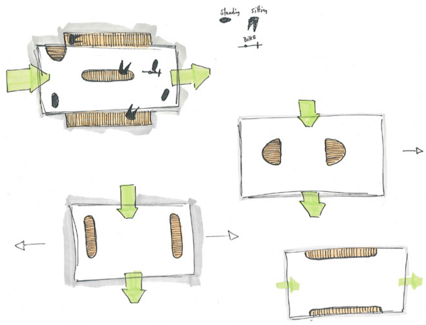


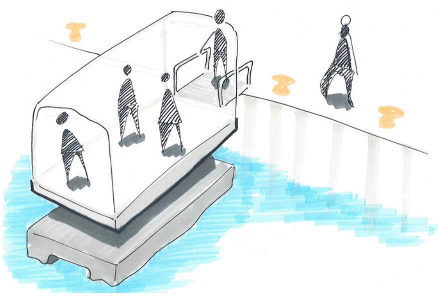
Dock and passenger flow

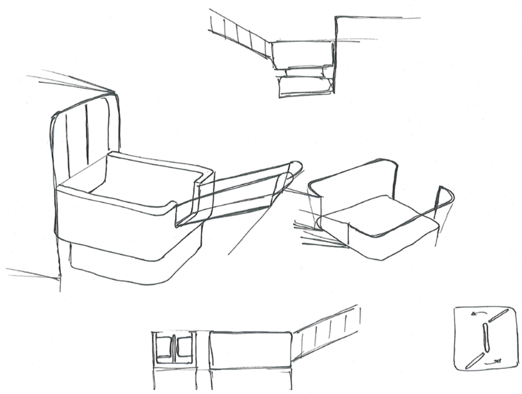


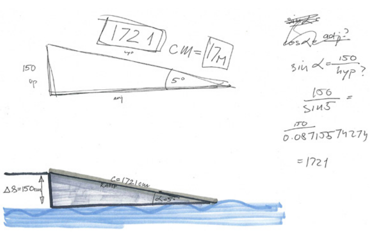
A major challenge with the user journey when taking the ferry, is how to provide smooth docking and passenger flow. With large differences in quay height and tide water, it is difficult to make a design that fits in wherever. A land-based dock is expensive to install, and may limit the number of possible docking spots. Having a flexible on board docking system integrated into the design would possibly solve some of these issues. We made some idea sketches based on these.

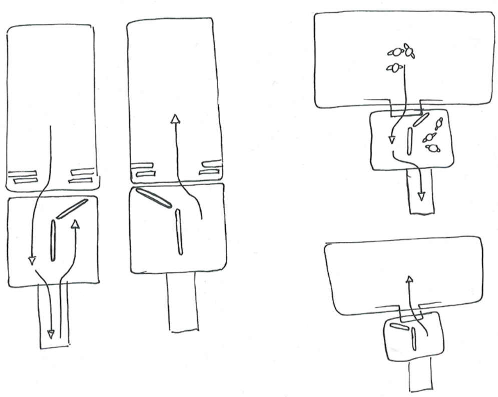


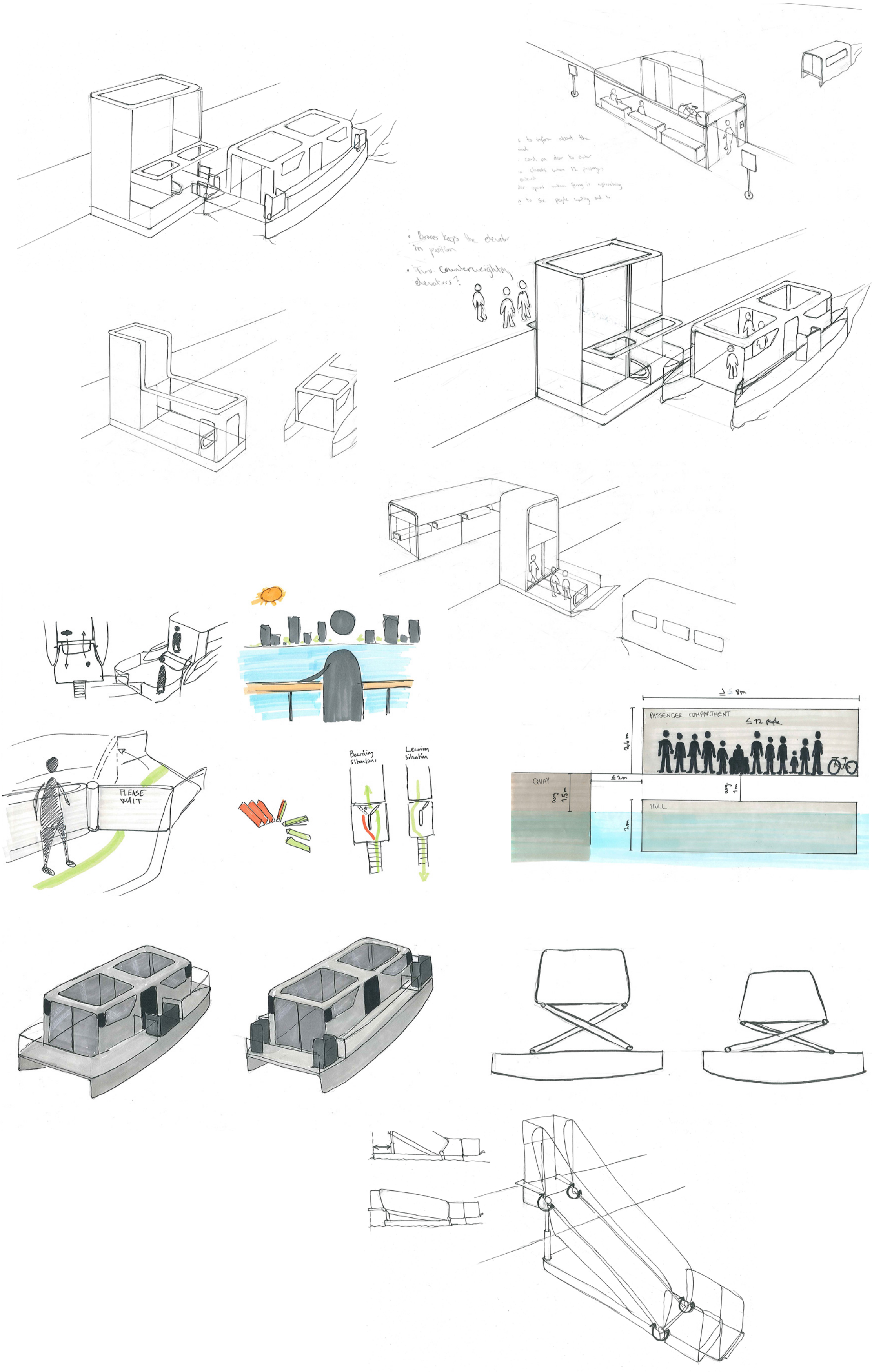








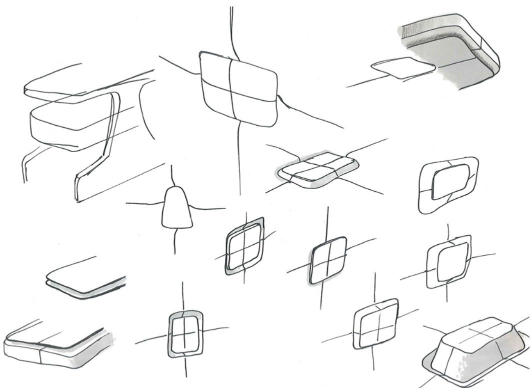


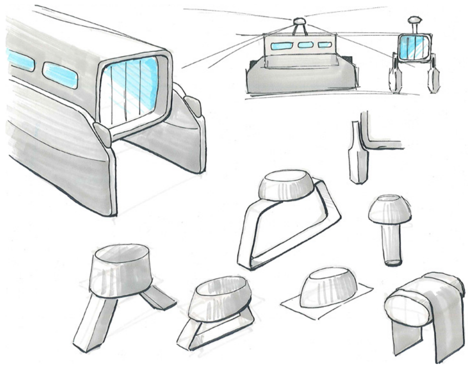


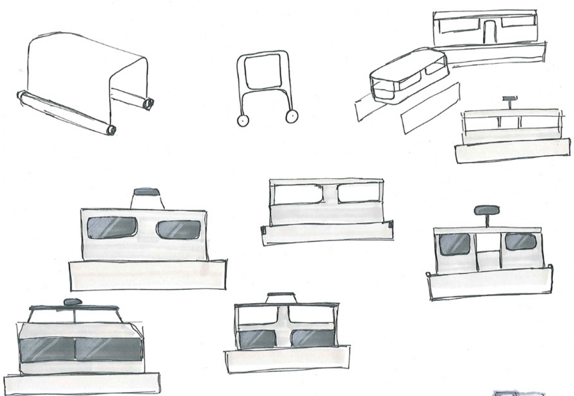
• Brakes keeps the elevator in position
• Two counterweighting elevators?
PLEASE WAIT
Boarding situation
Leaving situation
PASSENGER COMPARTMENT
≤ 12 people
QUAY
HULL

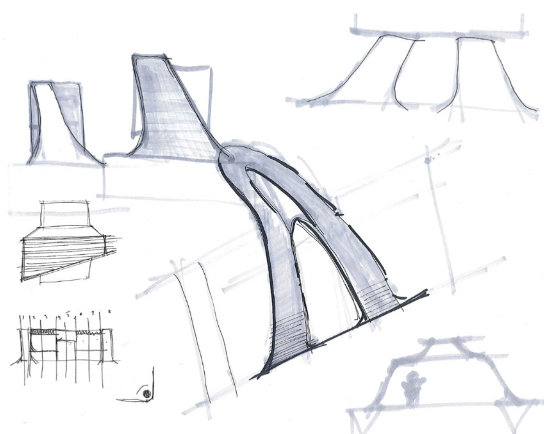
Sensors and antennas

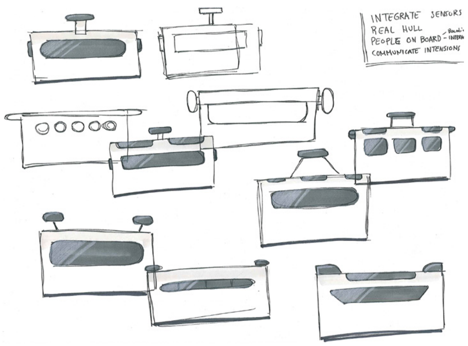
We ideated on how the sensors and antennas could be integrated with the superstructure. By exploring different shapes for covering the sensors, some of these shapes derived new ideas for the superstructure.

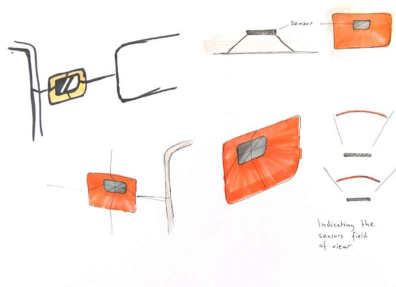


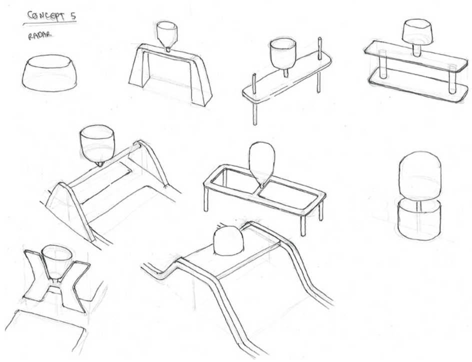


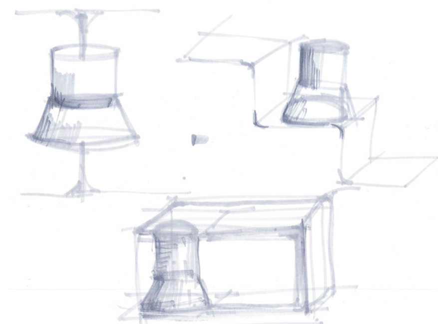


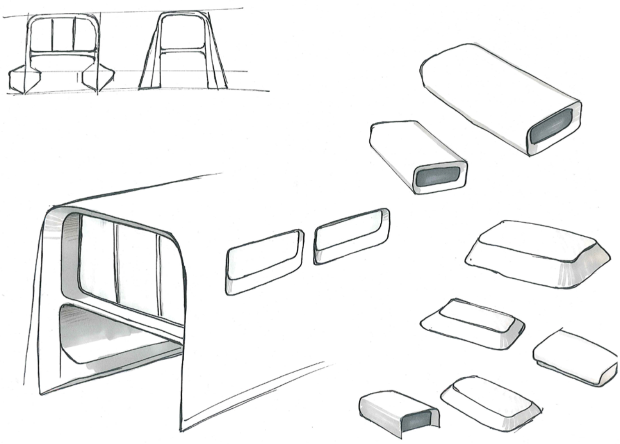


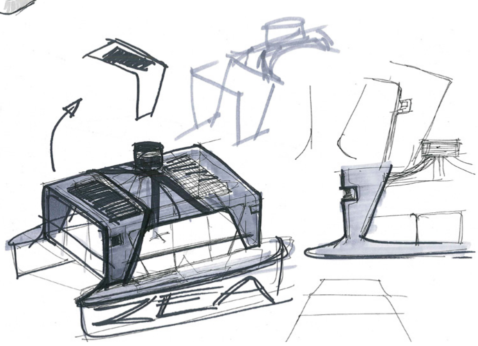

INTEGRATE SENSORS
REAL HULL
PEOPLE ON BOARD
COMMUNICATE INTENSIONS


Sensor
Indicating the sensors field of view


CONCEPT 5
RADAR



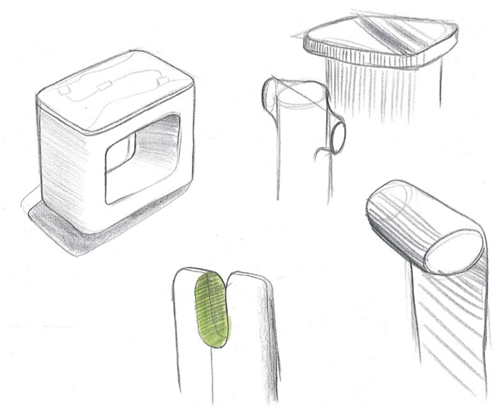


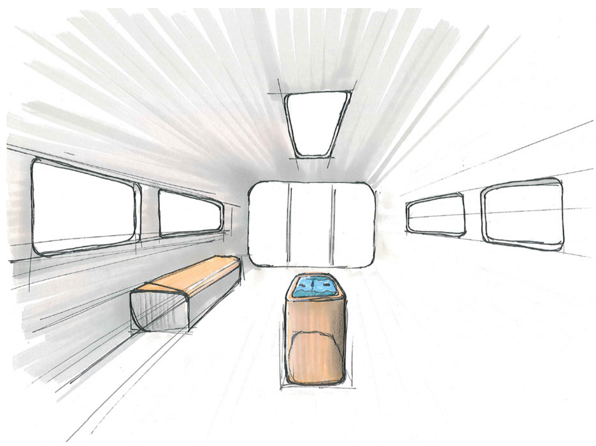


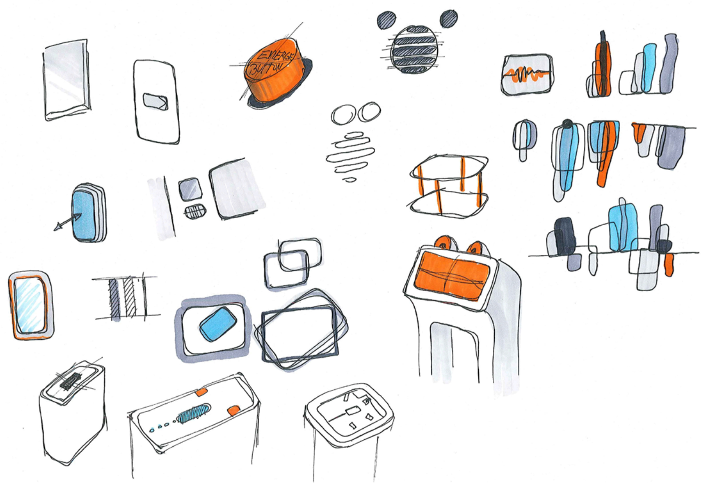
DEVELOPING THE IDEAS

Passenger interaction and on-board operator

Since we wanted our design to communicate with the passengers, showing the ferry's perception of the surroundings and its intentions, we considered ways of achieving this. One of the ideas we had consisted of a table screen presenting a birds view of the ferry and its environment. This table could, when coupled with a joystick, become an on-board operator station.





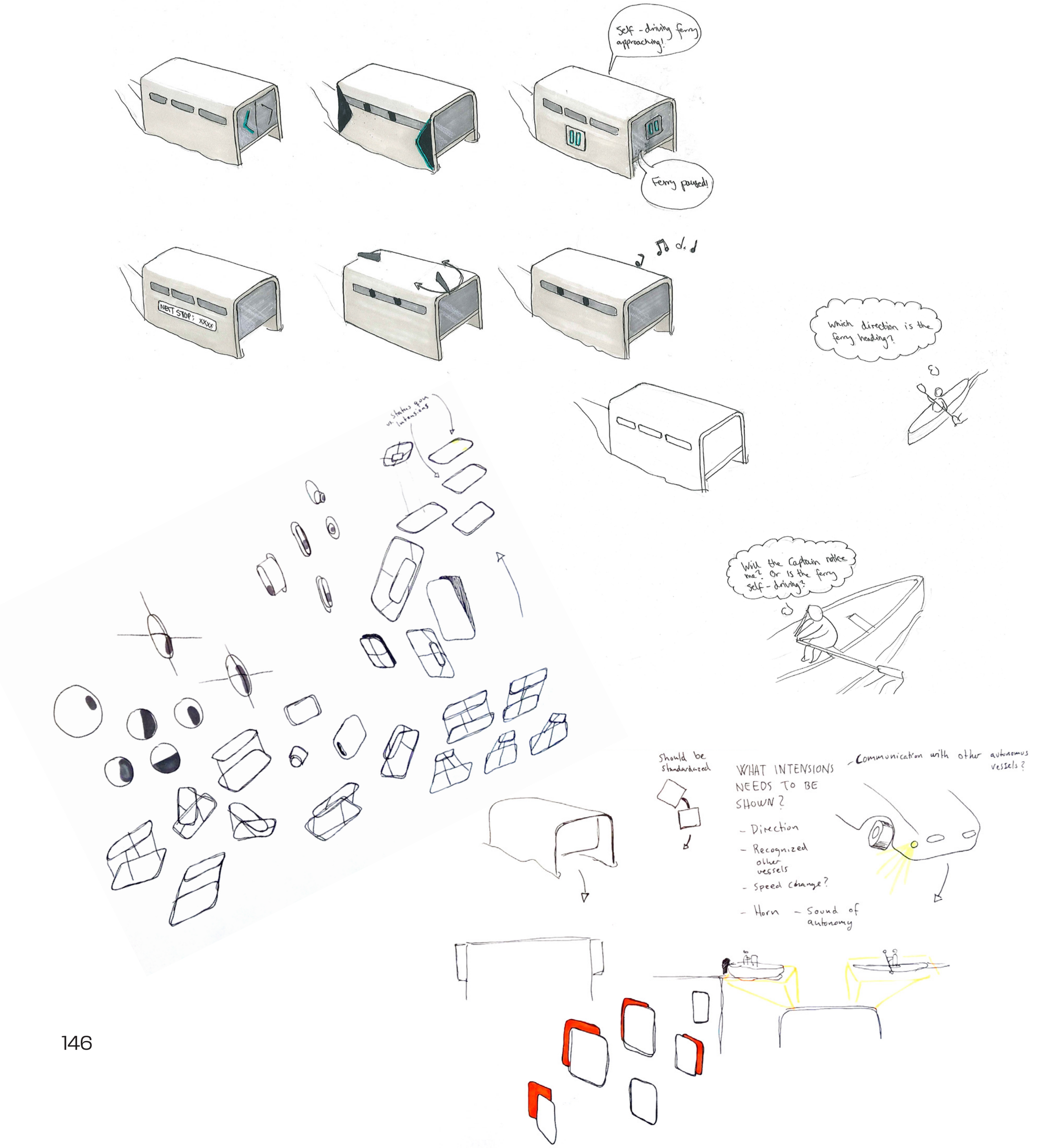


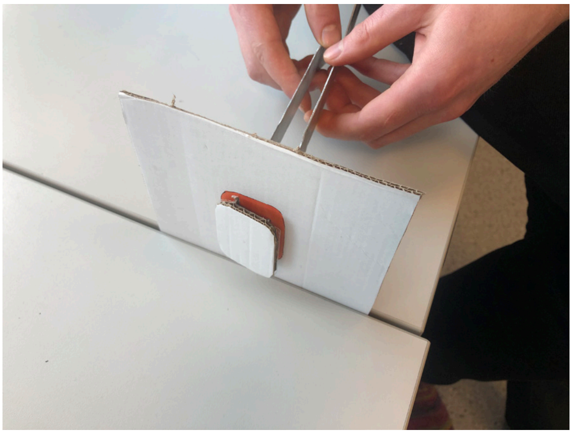
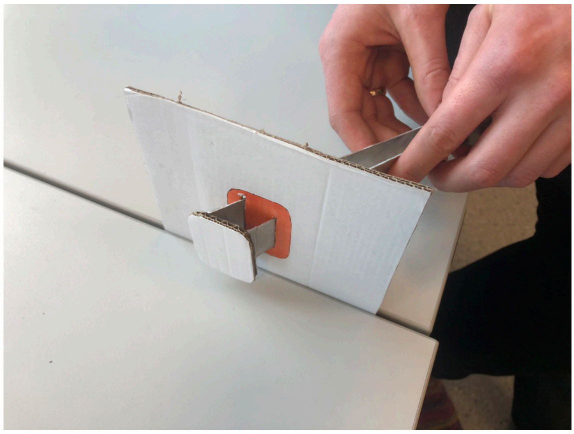
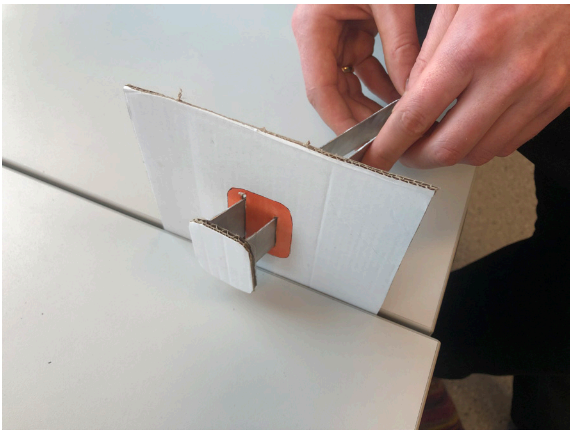
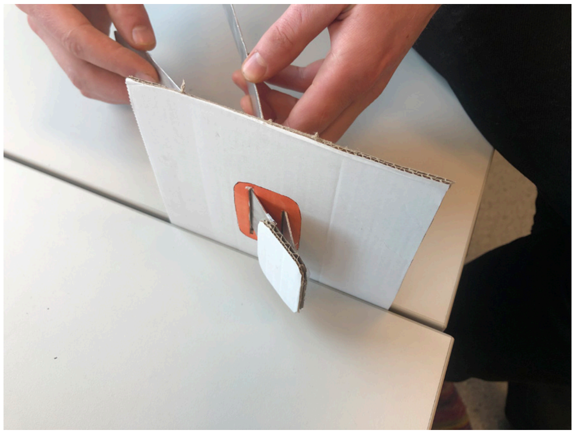
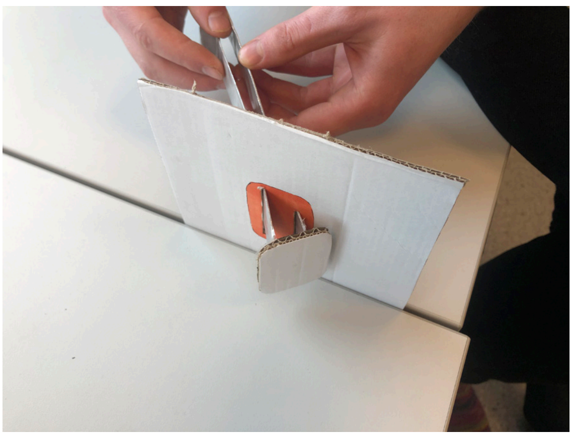
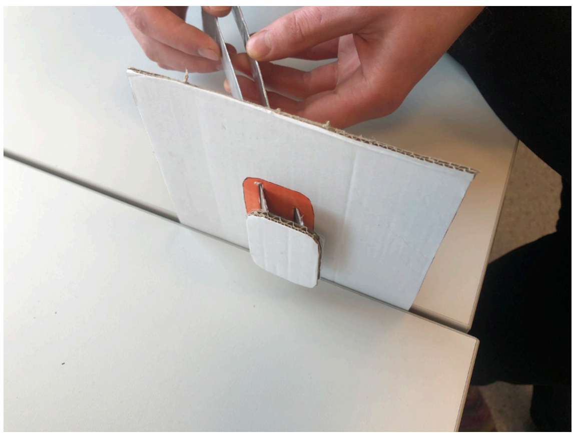

NEXT STOP: XXXXX

DEVELOPING THE IDEAS

External communication

Making a ferry autonomous ferry, we thought that it would be interesting to explore how the ferry could communicate to other vessels and its surroundings. An idea we had was that something on the outside of the ferry could move in relation to the ferry, to show its intended driving direction.

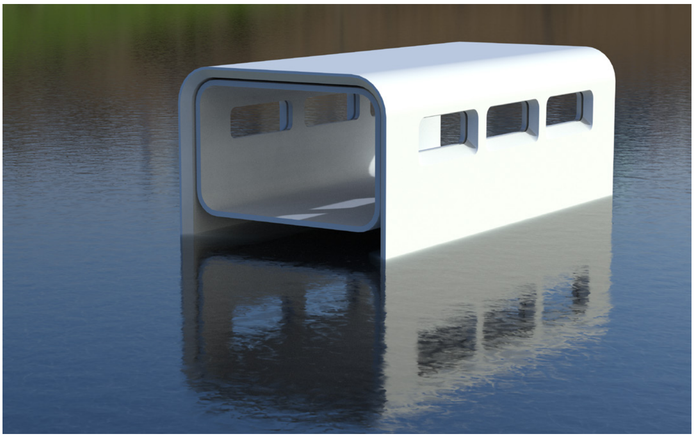


IDEATION

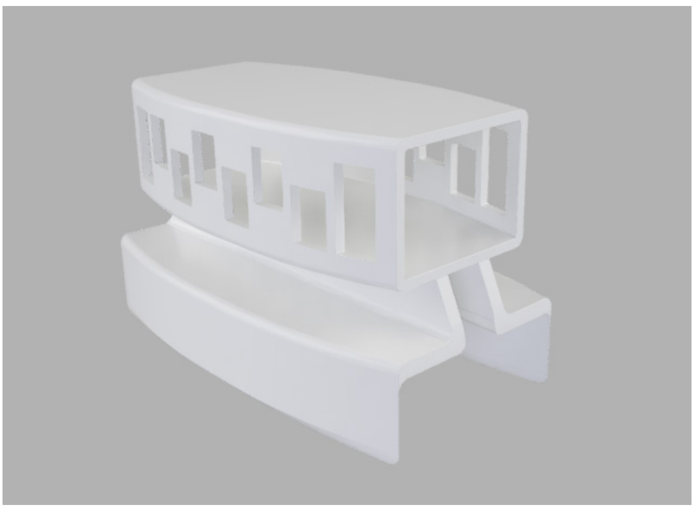
DESCRIPTION OF THE 5 IDEAS

At this point, we identified that we had five main ideas that we all liked and could develop further. The ideas had been developed to different stages, some only being on paper, others taken into 3D.



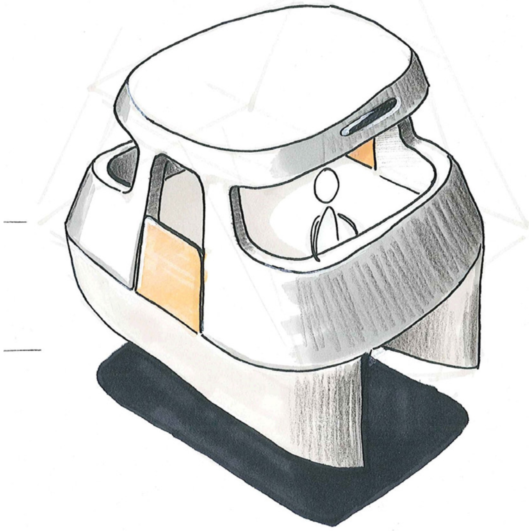
Idea 1

- The hull is hidden under water
- Front/back entrance with sliding doors
- Fixed passenger compartment
- Closed compartment



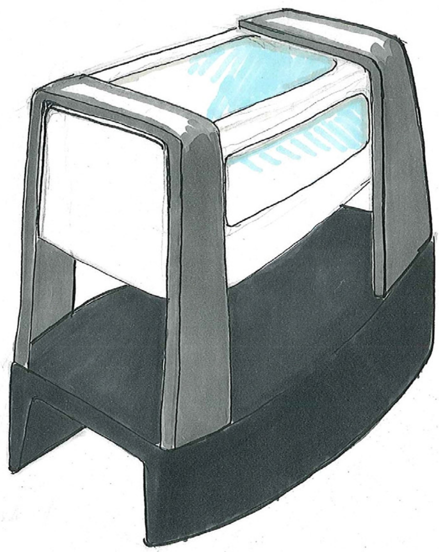
Idea 2

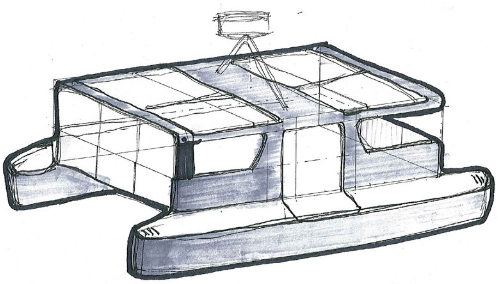
- Raised fixed passenger compartment
- Front/back entrance with docking hatch
- Window art
- Easy access to hull for maintenance



Idea 3
- Side entrance
- Fixed passenger compartment
- Sufficient viewing angles for sensors
- Access to hull through passenger compartment

Idea 4
- Front/back entrance with docking hatch
- Integrated elevator of passenger compartmen
- Side and roof windows
- Easy access to hull for maintenance





Idea 5
- Front/back or side entrance
- Fixed passenger compartment
- Easy access to hull for maintenance
- Roof windows
- Extended hulls for increased stability

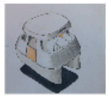
IDEATION

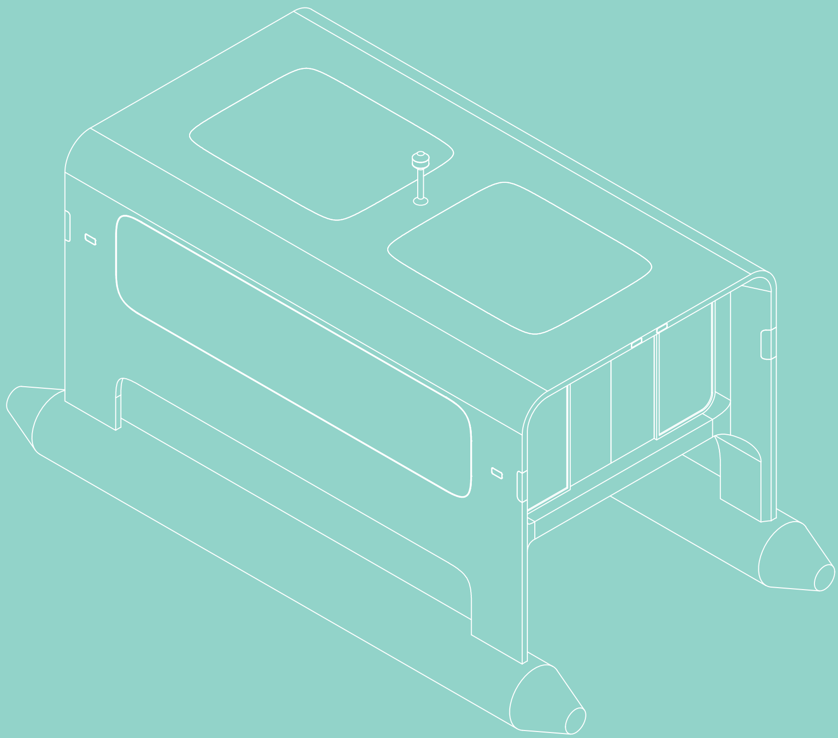
VOTING FOR IDEAS

To decide which ideas to continue with into the process we wanted to narrow down the number of them from 5 to 3. Furthermore, to make the process less of an informal discussion and more quantifiable we decided to set a number criteria to vote on individually. Those criteria included the values that have been set with the client (4 functional, 3 aesthetic, 3 emotional) and others we deemed important: serviceability, weather protection, adapting to different environments, providing view and finally gut feeling, which was something recommended by our supervisor, prof. Hareide as an aspect that is truly important when choosing a direction to go on with.

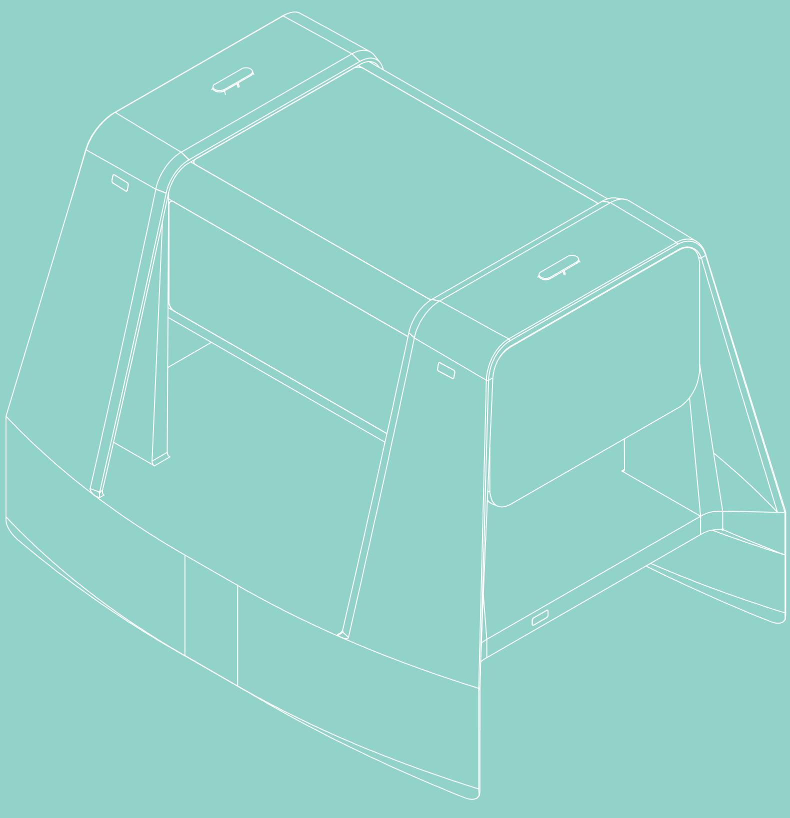
Each team member rated each category from 1 to 10 after which the average was calculated, and added to the final score for the overall idea. We recognize that this method means every category is deemed equally important. This was decided upon to make the process as simple as possible rather than getting caught up in the process of deciding upon the weighing of each category.

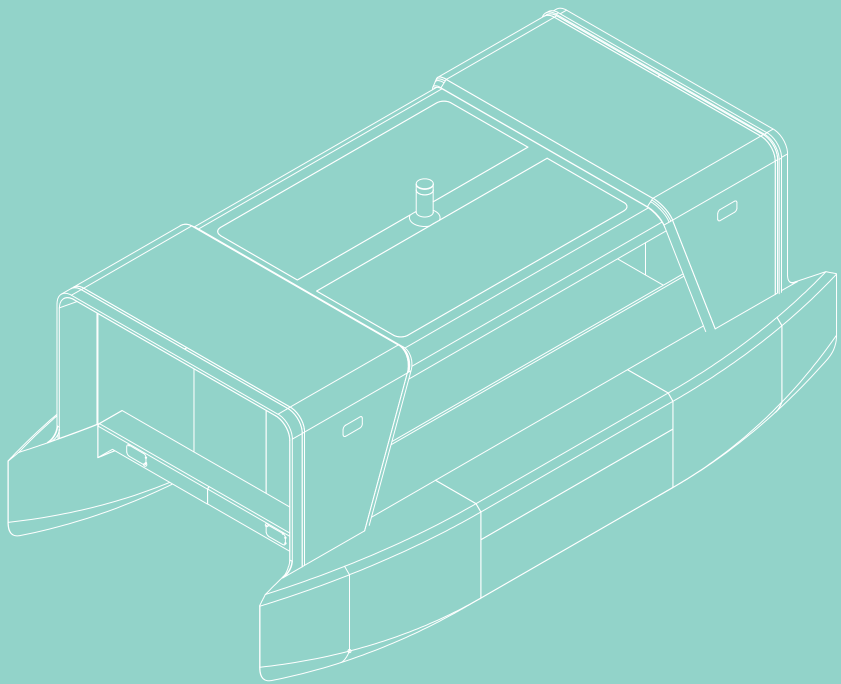
The results showed that we have shared similar opinions about similar ideas. However, only the top 3 ideas by the number of points were chosen. Those were idea 1, idea 4 and idea 5 with 107.62, 109.94 and 109,94 points respectively.

	CRITERIA	CONCEPT 1	CONCEPT 2	CONCEPT 3	CONCEPT 4	CONCEPT 5
		 - Front/back enter - Fixed position passenger compartment 	 - Front/back enter - On board docking hatch - Window art - Fixed position passenger compartment - Outside hatches on top of hull for service	 - Side enter - Fixed position passenger compartment - Hatches for service inside passenger compartment	 - Front/back enter - On board docking hatch - Elevator - Roof and side windows - Hatches on top of hull for service	 - Front/back OR side/side enter - Fixed position passenger compartment -hulls on side for serviceability -glass on top
emotional	Smooth 	7 8 8 7,66	6 7 7 6,66	7 6 7 6,66	9 9 8 8,66	8 7 8 7,66
	 Trust worthy	6 9 7 7,33	5 6 6 5,66	8 7 8 7,66	5 6 5 5,33	8 8 7 7,66
	Feels sustainable 	8 6 5 6,33	6 6 7 6,33	6 6 8 6,66	5 6 5 5,33	7 6 7 6,66
aesthetic	 Functional	8 8 7 7,66	5 6 6 5,66	7 8 8 7,66	9 8 8 8,33	8 8 8 8
	Simplistic (nothing unnecessary) 	10 9 8 9,00	5 6 6 5,66	8 8 9 8,33	8 7 8 7,66	7 8 8 7,66
	 Characteristic (easy to identify)	8 8 7 7,66	7 7 7 7	7 7 8 7,33	9 10 8 9,00	6 7 7 6,66
functional	Scalable (different markets) 	7 7 4 6,00	6 7 7 6,66	5 4 6 5,00	9 6 8 7,66	6 6 6 5,66
	 Seamless	7 6 8 7,00	6 6 7 6,33	4 5 6 5,00	9 8 9 8,66	7 7 7 7
	Sustainable 	9 7 7 7,66	5 6 6 5,66	7 6 5 6,00	5 7 5 5,66	6 7 7 6,66
	 Safe	10 9 8 9,00	4 4 5 4,33	8 8 7 7,66	7 7 5 6,33	9 7 7 7,66
	Serviceability	3 3 2 2,66	5 5 8 6	7 4 7 6,00	8 5 7 6,66	10 9 8 9
	provides weather protection	9 10 9 9,33	9 9 9 9	8 7 7 7,33	9 9 9 9,00	8 8 8 8
	adapt to different environments	6 4 5 5,00	4 5 7 5,33	6 4 5 5,00	10 8 8 8,66	7 7 6 6,66
	provide view	7 6 8 7,00	5 6 7 6	8 5 7 6,66	8 8 8 8,00	8 8 8 8
	GUT FEELING	8 8 9 8,33	5 5 6 5,33	6 7 7 6,66	7 4 4 5,00	7 8 6 7
	TOTAL NUMBER OF POINTS	107,62	91,61	99,61	109,94	109,94



chapter 3



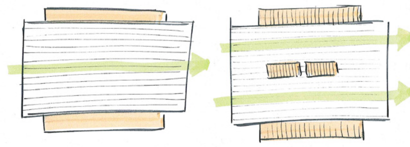


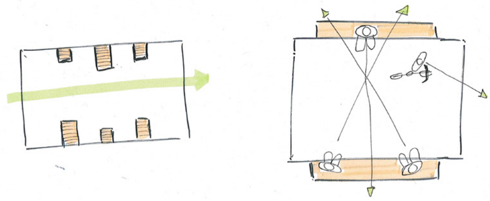
conceptualization

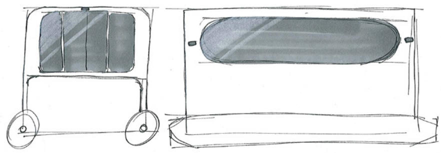
Going further with the three ideas and developing them into concepts, we worked with 3D-modelling and sketching to make them more detailed and to get a better impression of how it would look. We looked into how the different concepts would dock and how the sensors should be integrated with superstructure. Visuals and physical models of the concepts were made and presented for the client. From the client we got valuable feedback which was taken into account when we had to choose one of the concepts. We then decided upon one concept to be our chosen design direction.

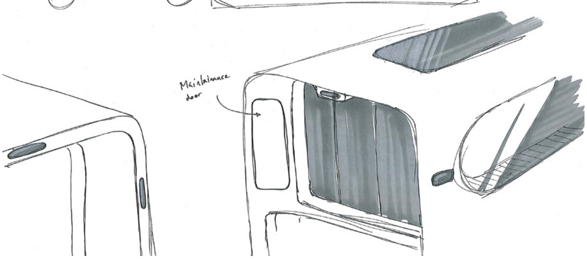
CONCEPTUALIZATION
DEVELOPMENT OF THE 3 CONCEPTS

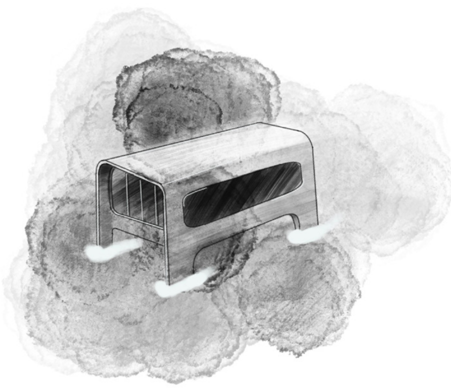
Firstly, some additional sketches were made to try and mature a concept.

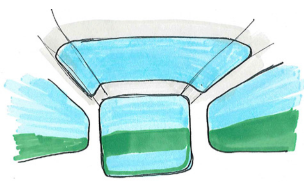


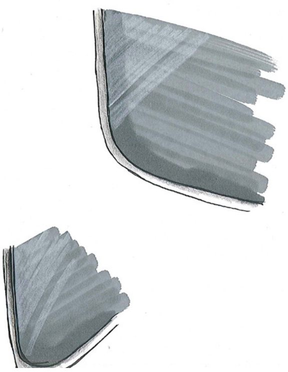


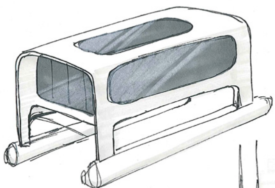


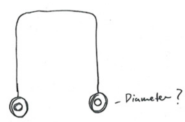


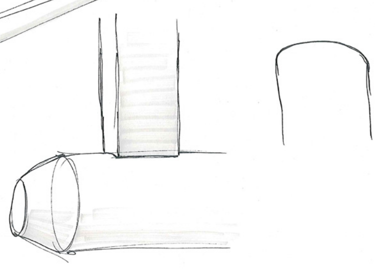


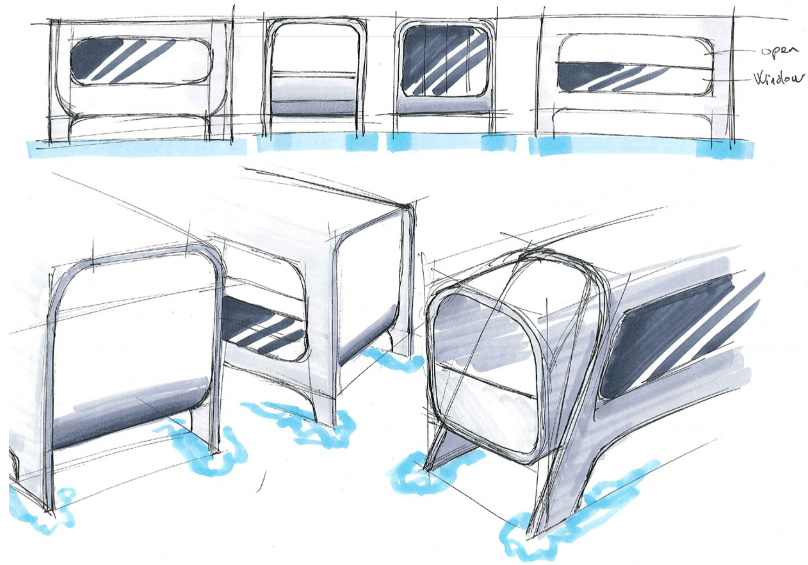


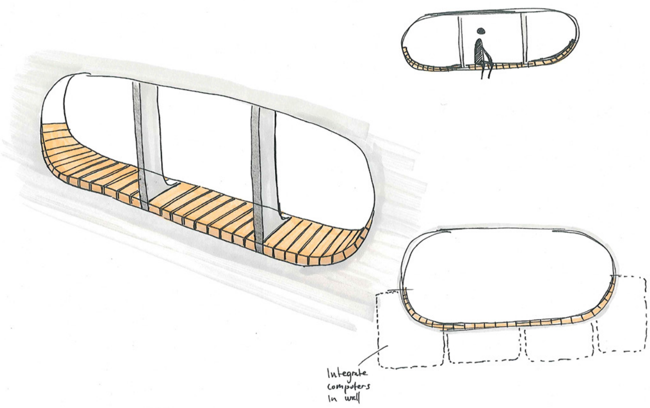


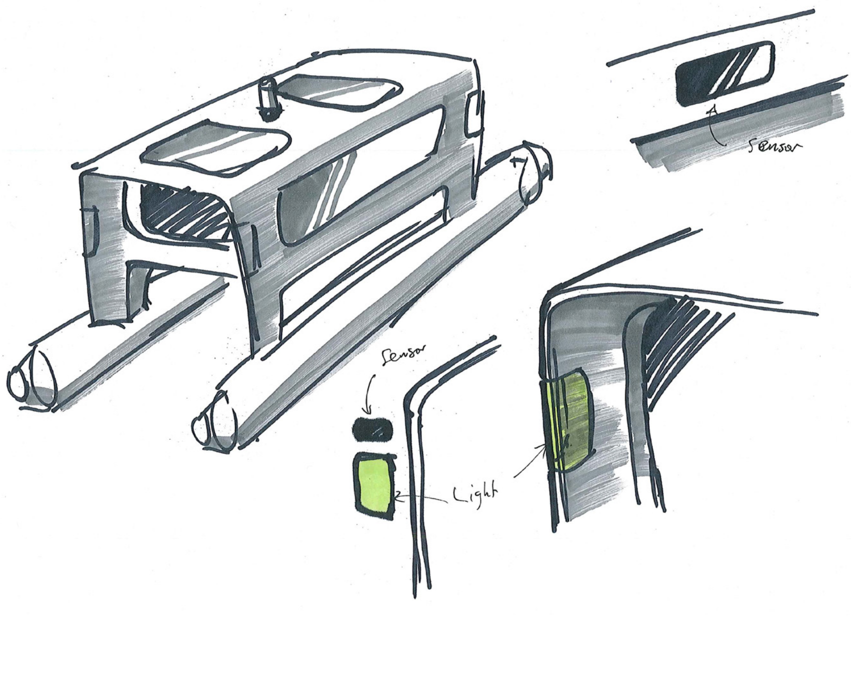







open
Window


Integrate computers in wall

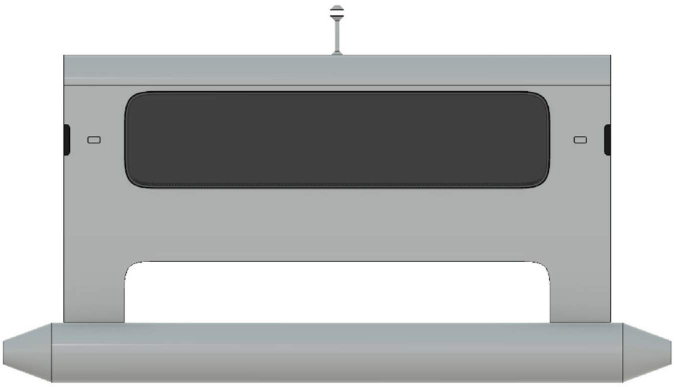

Sensor
Sensor
Light

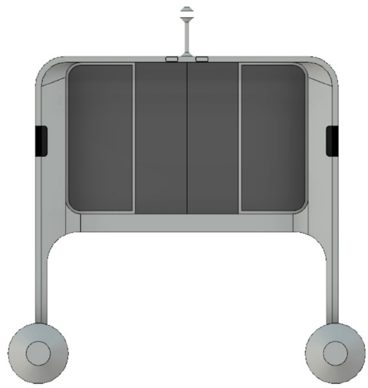
3D-models with functioning hulls and realistic dimensions

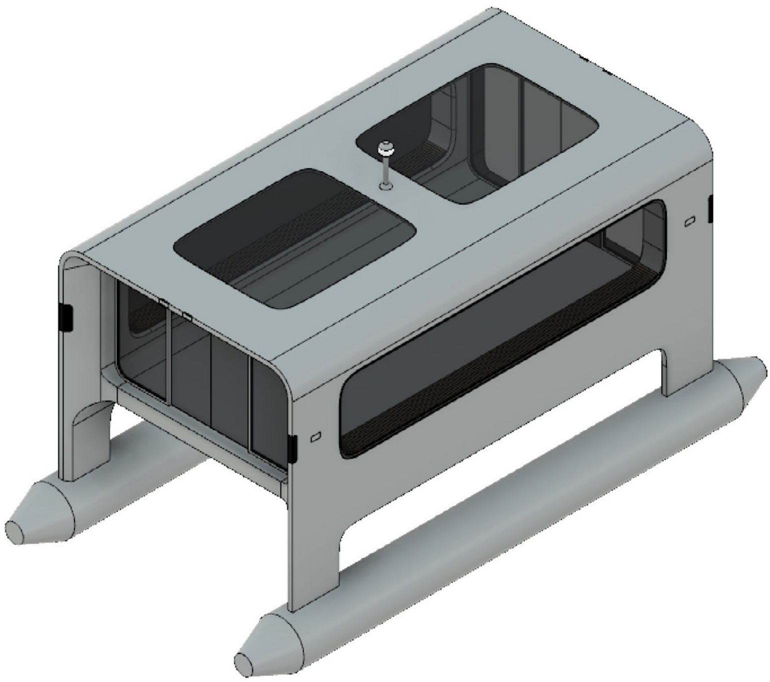
The three chosen ideas were developed further with more detail oriented 3D-modelling. We based the dimensions on the minimum requirements from Zeabuz, which was at least 8 meters long. In the workshop with Zeabuz concerns about claustrophobia were mentioned. Thus, we decided to have a high ceiling of at least 2,5 meters. Several of the earlier hulls we designed did not float. Thus, we made adjustments on the hulls to increase stability. Windows, entrance/exit, rooftop lanterns were modelled as well. By doing the digital model, we got pushed to take a stand with respect to details that often get ignored when only doing sketches.

Concept 1 – "Swath"

Concept 1 was adjusted to fit a swath hull. This hull is known from crew transport vessels at wind farms, and has great stability abilities. In addition, the torpedo-looking hulls can be filled with ballast water for elevating the hull. The elevation function could solve some of the challenges with quay- and tidewater differences that Zeabuz is facing. To give a more "open" feeling to the concept, a window in the ceiling was added. The earlier 3D-models had bad manoeuvring and stability features. A cut-out in the lower hull was made to try to solve these issues.





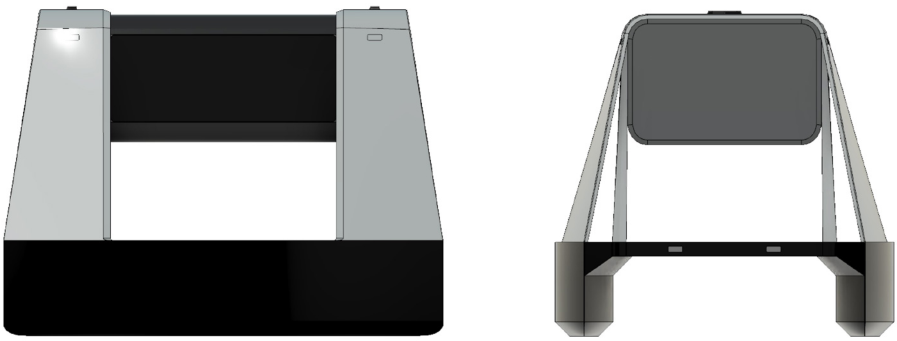


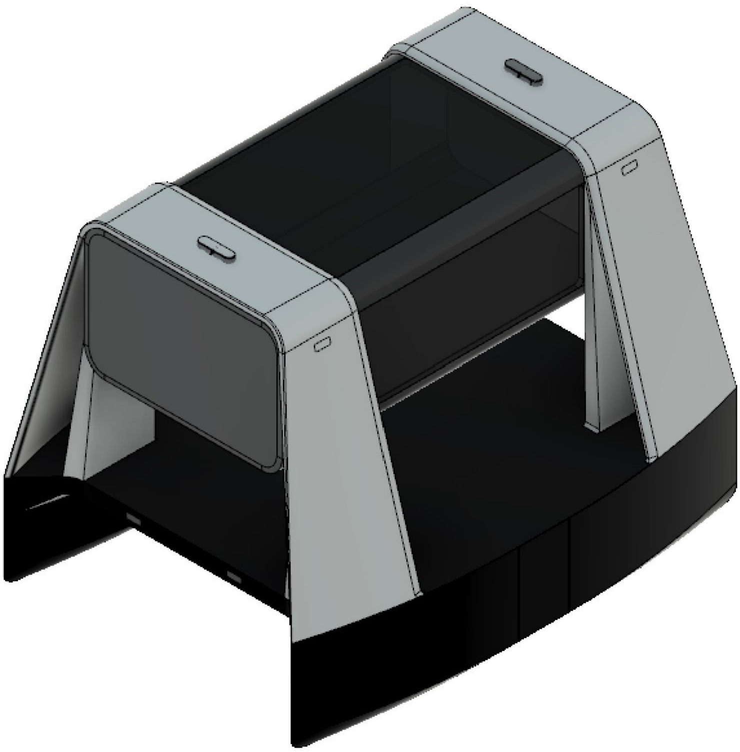
CONCEPTUALIZATION

DEVELOPMENT OF THE 3 CONCEPTS

Concept 2 – "Elevator"

The crucial part of Concept 2 was to give satisfyingly stability features when the passenger compartment is at its top level. It was decided to model the elevation at a range of 2 metres, as this is sufficient for most cities that were investigated. The size of the passenger compartment and the 2 metre height above the hull was the set point for the 3D-model. Then the remaining structures and hull were modelled based on the specifications of the passenger compartment, as they needed to be a lot wider for good stability. The hull was based on the catamaran hull from Zeabuz.



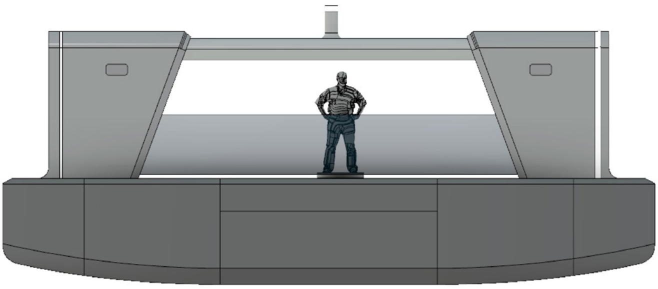


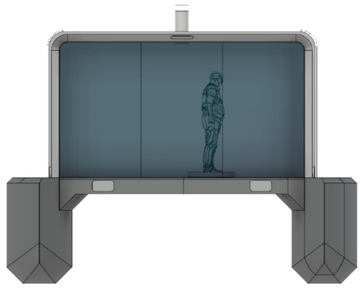
CONCEPTUALIZATION

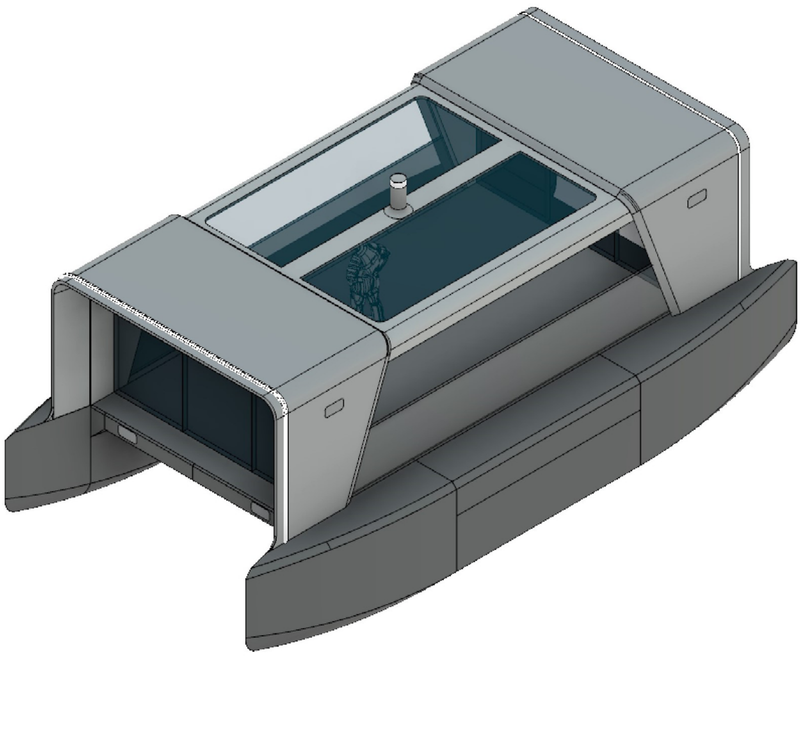
DEVELOPMENT OF THE 3 CONCEPTS

Concept 3 - “Wide”

Like Concept 2, the Concept 3 were modelled to fit the catamaran hull from Zeabuz. The hull was made wider and longer for increased stability. The superstructure was changed to a cleaner, more Scandinavic looking shape. For giving a feeling of openness, glass was only added to the front and back. The sides got more simplistic lines and openness by adding see-through railing and removing the side-windows.



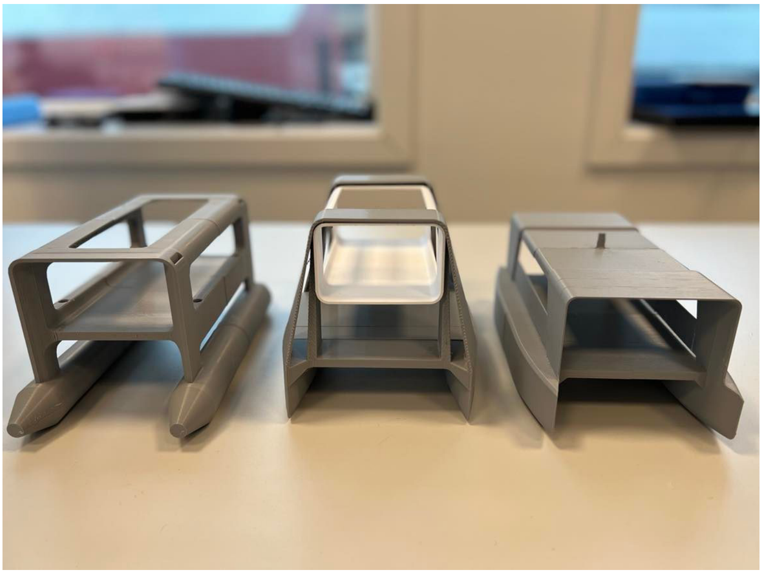


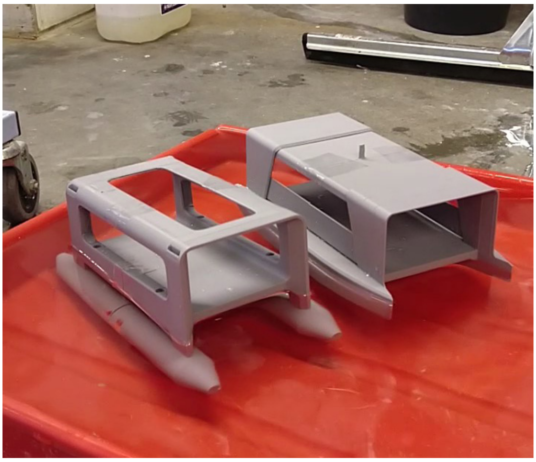


Printed models

The three developed concepts were 3D-printed and tested in water. The stability and hydrodynamic features seemed much improved compared to earlier 3D-prints. The printed models were used in the concept presentation for Zeabuz, in supervision and stayed on our desk for the rest of the project. In discussions, the models were a great addition when explaining and communicating thoughts.

The “Swath” model was made with inlets for filling the swaths with water. This was included to test if it was possible to adjust the height and stability with added ballast in the swaths.





CONCEPTUALIZATION

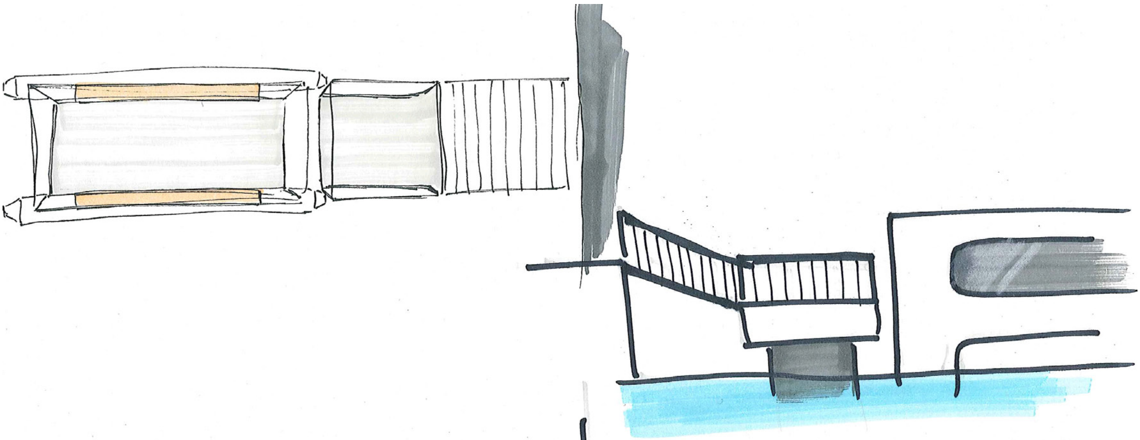
DEVELOPMENT OF THE 3 CONCEPTS

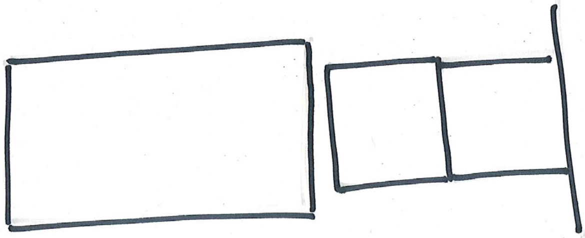
Ideas for Docking

For all three concepts, we looked at how the docking situation could be solved and how this would affect the passenger flow.

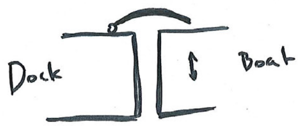
Concept 1

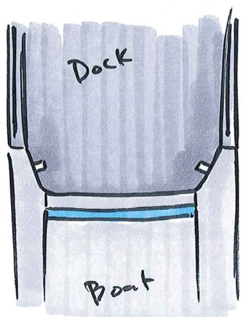
Docking for concept 1 requires a land-based dock. The entrance/exit is at front/back, which gives good passenger flow for the bidirectional ferry when going back and forth from destination A to B. The ramp must be fitted within the inside of the hull to safely transport passengers on board/off board. In addition, the dock and ramp must have railings to keep the passengers safe.

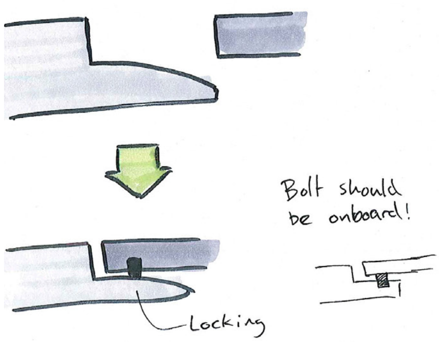





Mechanicly
activated
hatch


Dock
Boat


Dock
Boat

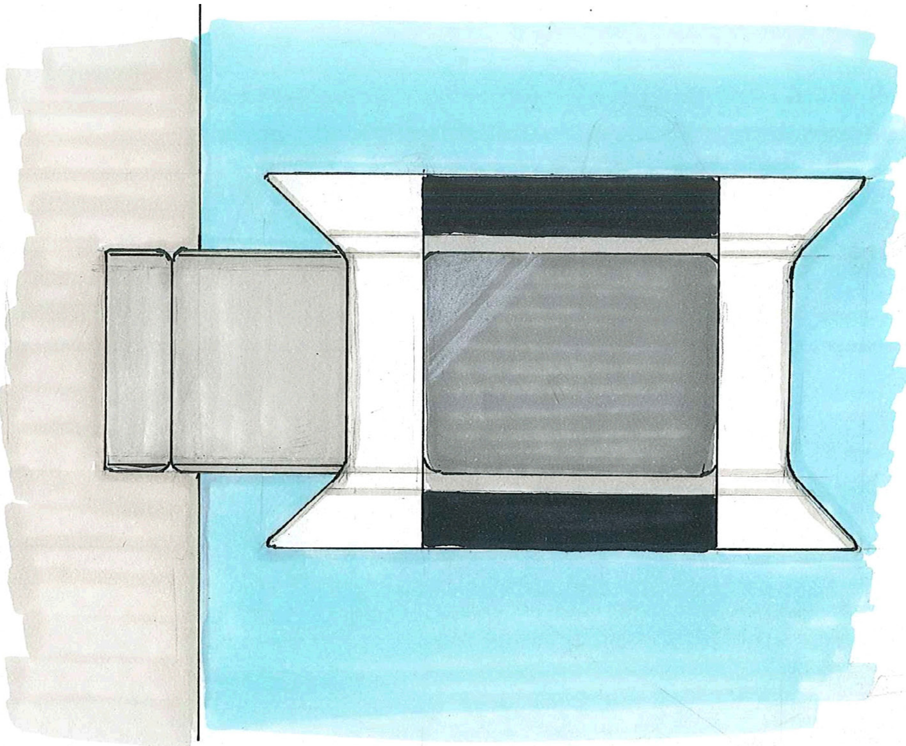

Bolt should
be onboard!
Locking

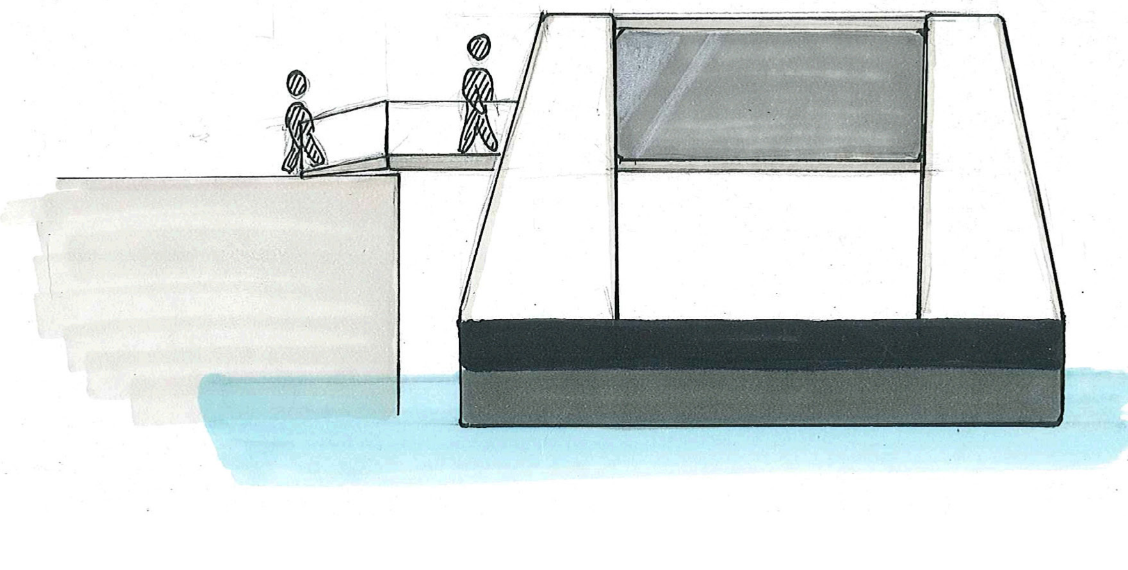
CONCEPTUALIZATION

DEVELOPMENT OF THE 3 CONCEPTS

Concept 2

The main feature of Concept 2 is the built-in docking system. The passenger compartment is lifted to the level of the quay. A front/back hatch opens, and bridges the gap between the shore and the ferry. Front/back entrance/exit gives good passenger flow for this directional concept. The docking hatch should have railings to keep the passengers safe. There must be some land-based installations for this concept as well, to let the passengers know where to board. Gates/barriers are also needed on shore and on board to keep passengers safe when docking/undocking. Some mechanical connection must be installed to attach the ferry to shore when docking.

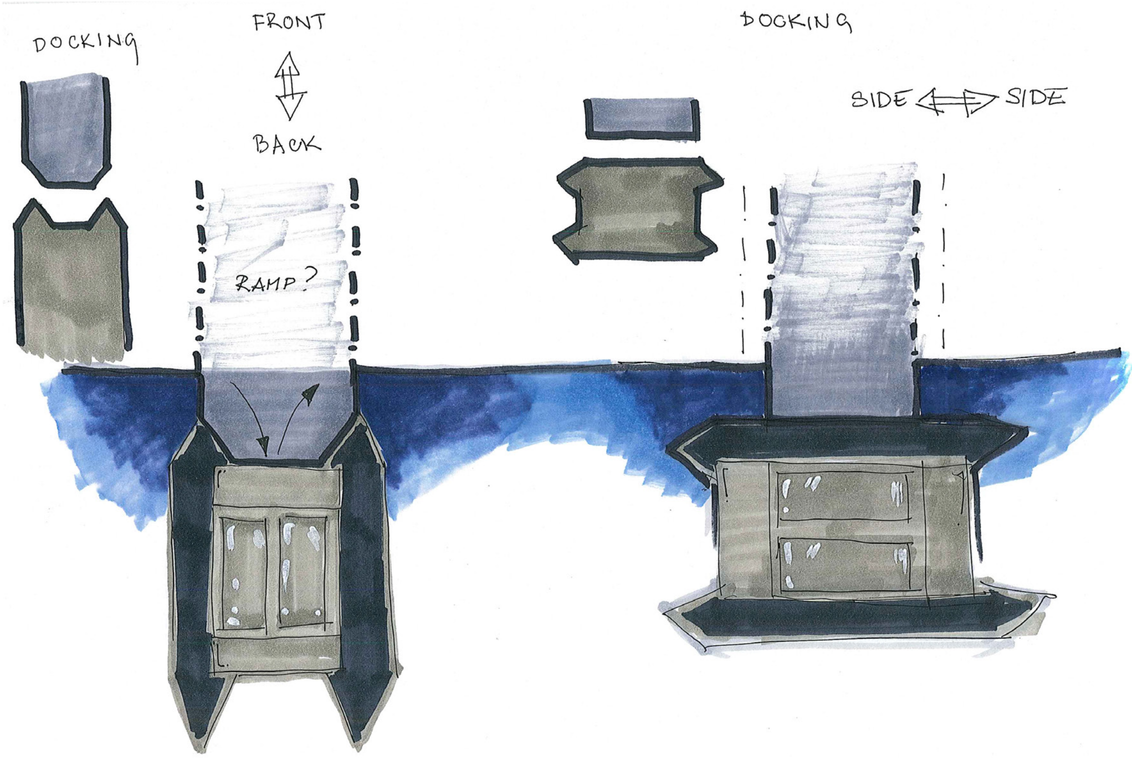




DEVELOPMENT OF THE 3 CONCEPTS

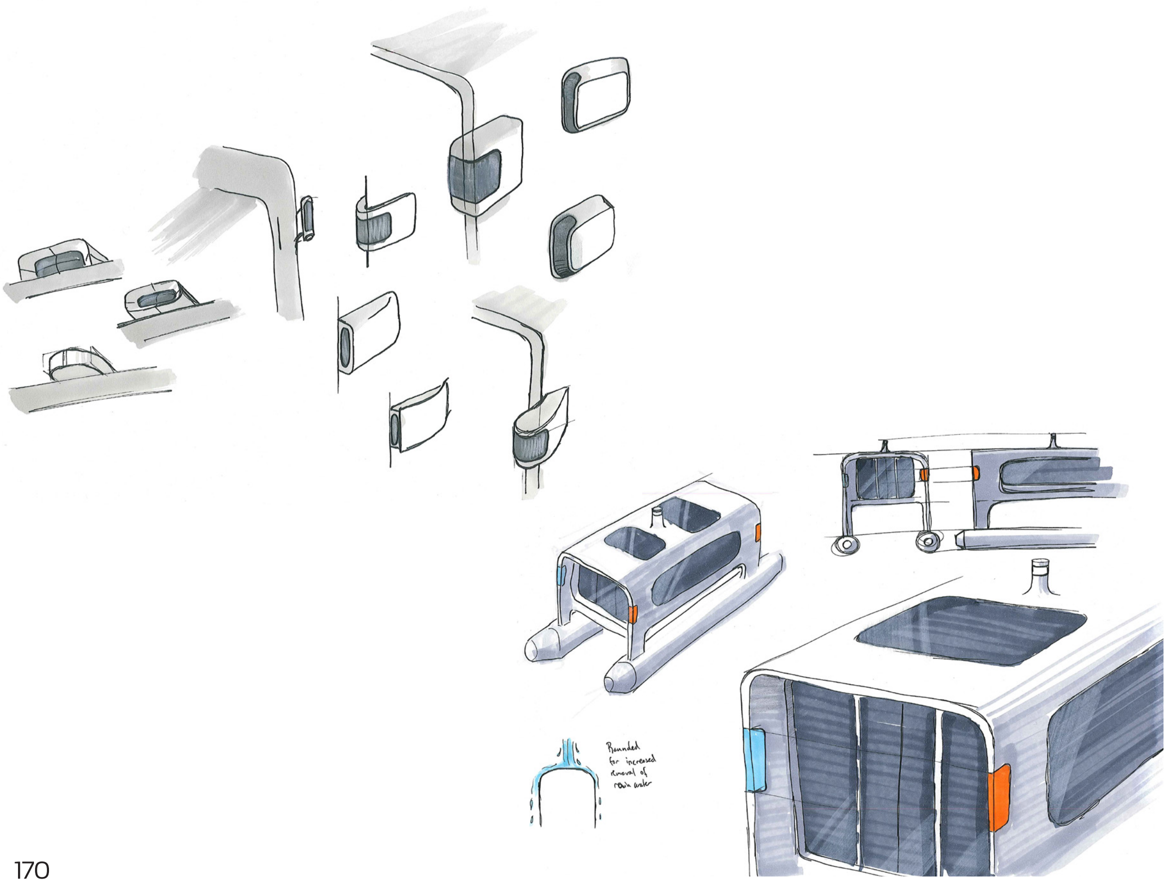
Concept 3

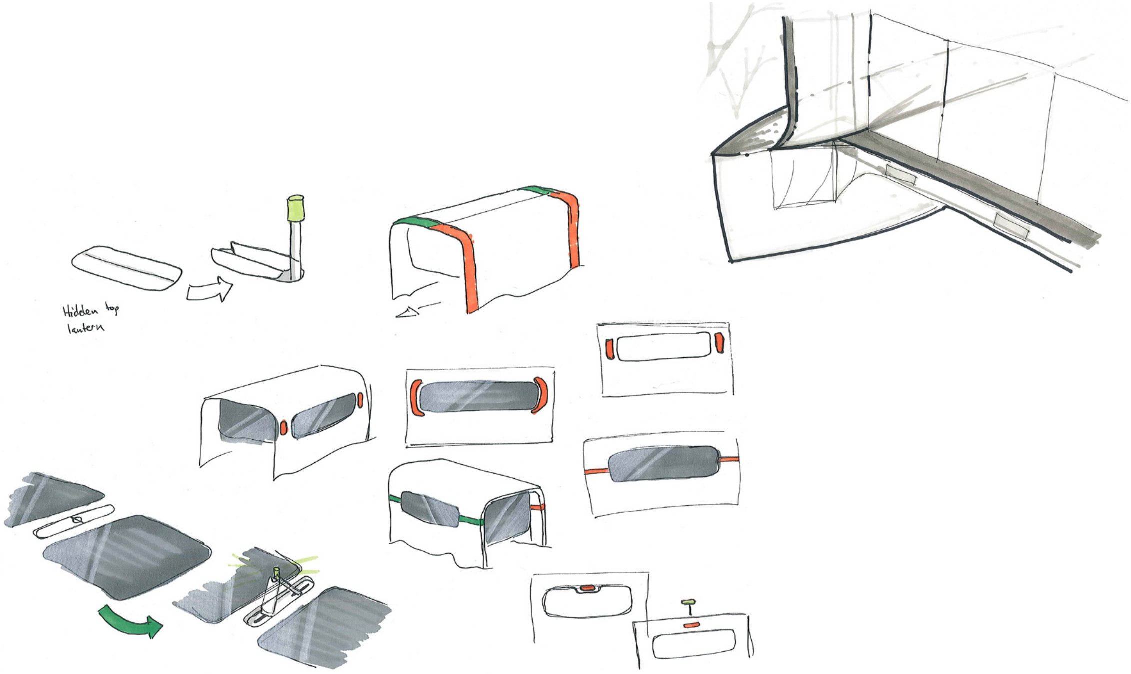
The advantage of concept 3 is the possibility to have exit/entrance at both sides and front/back. This will make a very adaptable design that can make docking easy for routes with both pendulum sailing and routes with many stops (for example along a river). The concept requires a land-based docking system with a ramp. The ramp must be fitted to the ferry for front/back docking, as with concept 1. For side-docking, there is more flexibility in the size of the ramp. For safe docking, it is necessary to install a mechanical connection to attach the ferry to shore. The on board part must be installed at front, back and the sides.

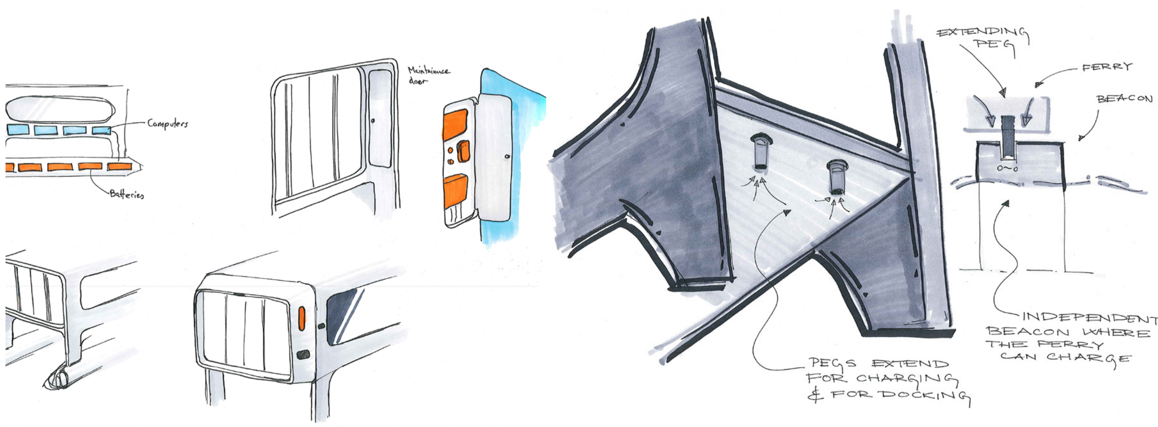

DOCKING
FRONT
BACK
RAMP?
DOCKING
SIDE
SIDE

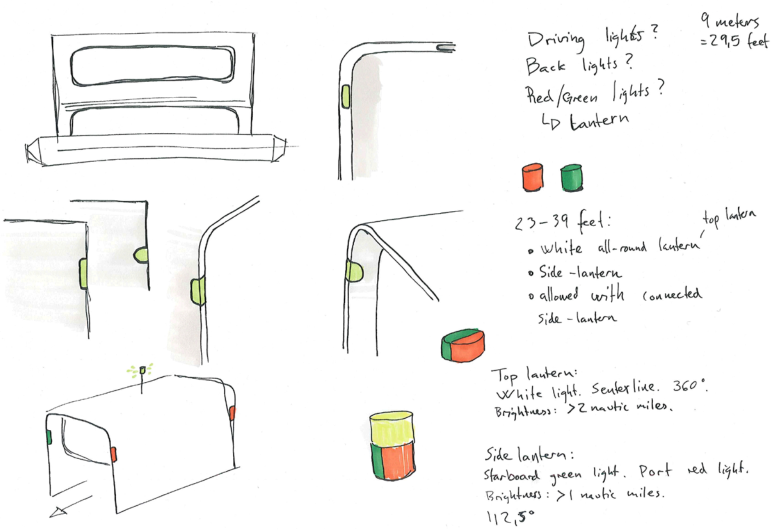
Integrating required equipment

Our supervisor prof.. Hareide kindly reminded us, when developing the concepts, that the placement and looks of required equipment such as sensors, lights and batteries could affect the overall impression of the superstructure. Hence, we ideated on how these elements could be an integrated part of the exterior design. Where it couldn't be an integrated part, but attached to the superstructure, it should reflect the design of the superstructure. Having a chat with Erik Wilthil about sensors, we learned that newly developed sensors can be integrated into the hull and thus become flush with the surface. This meant that the sensors could be integrated without being a visual disruption.




Hidden top
lantern


Computers
Batteries
Maintenance
door
EXTENDING
PEG
FERRY
BEACON
INDEPENDENT
BEACON WHERE
THE FERRY
CAN CHARGE
PEGS EXTEND
FOR CHARGING
& FOR DOCKING

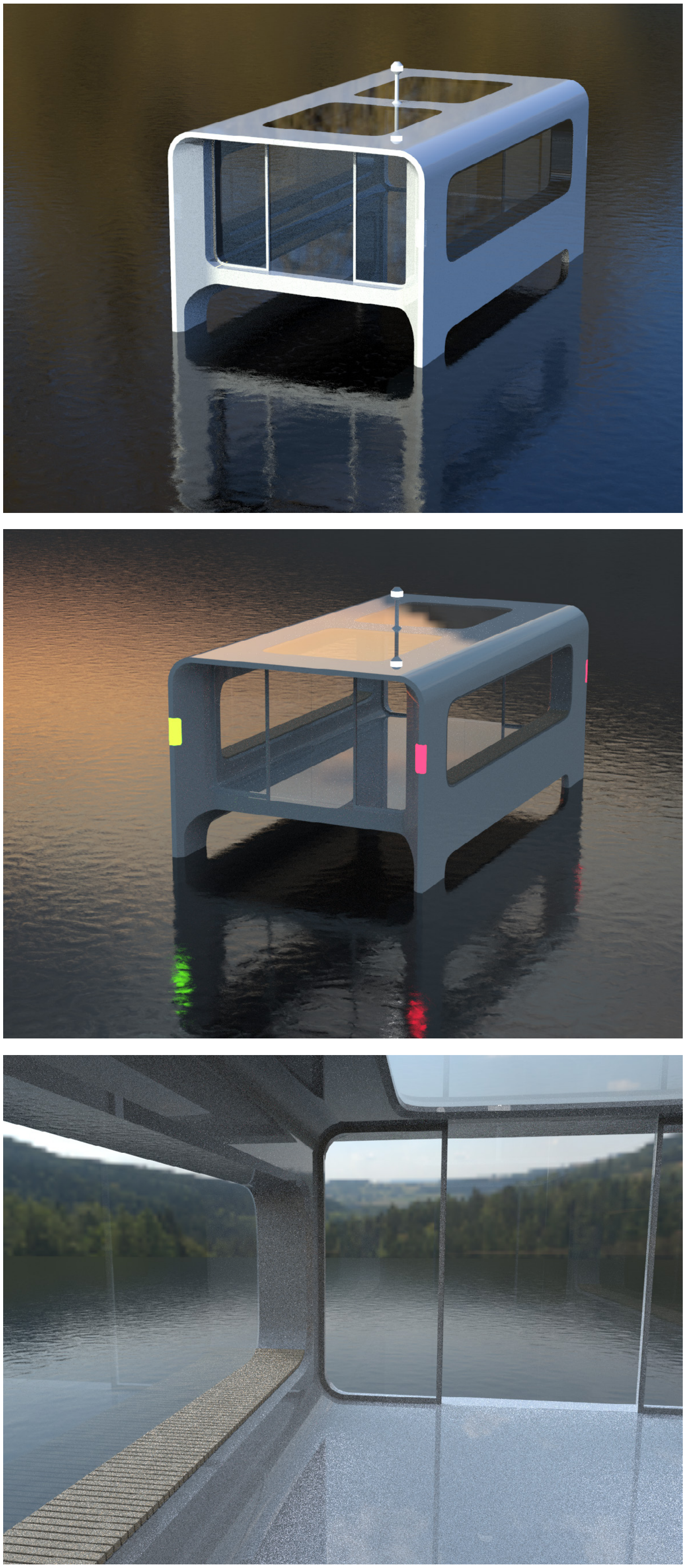

Driving lights?
Back lights?
Red/Green lights?
↳ Lantern
9 meters
=29,5 feet
23–39 feet:
• White all-round lantern
top lantern
• Side-lantern
• allowed with connected
side-lantern
Top lantern:
White light. Senterline. 360°.
Brightness: >2 nautic miles.
Side lantern:
Starboard green light. Port red light.
Brightness: >1 nautic miles.
112,5°

CONCEPTUALIZATION

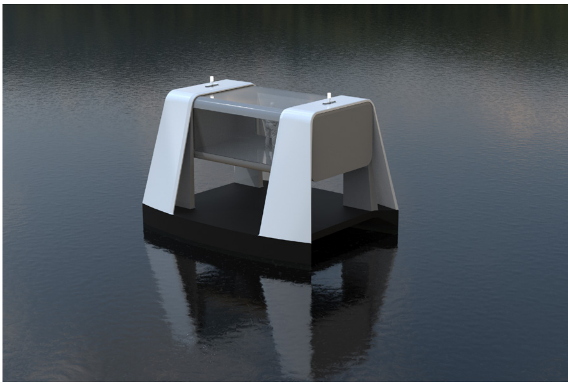
DEVELOPMENT OF THE 3 CONCEPTS

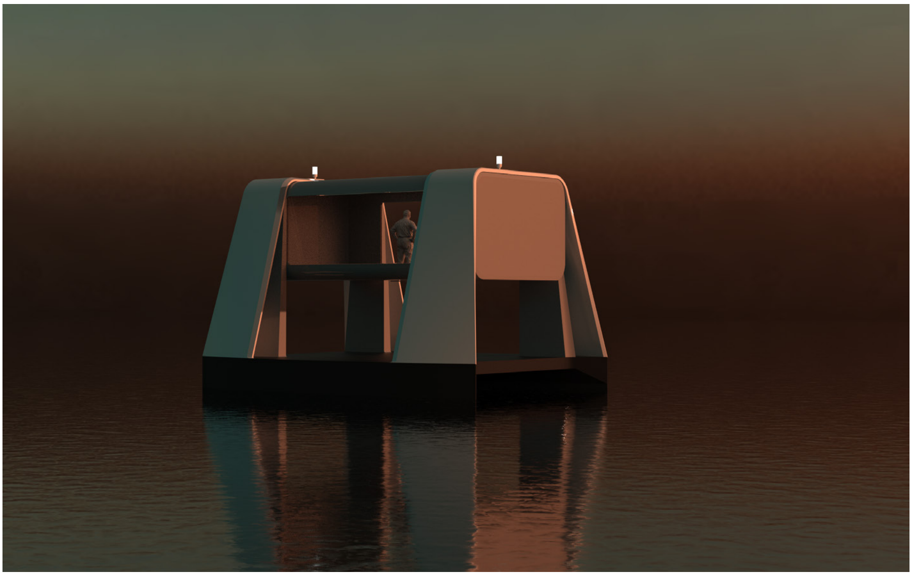
Visuals

To have an equal basis to evaluate the three different concepts we made similar visualisations of the concepts in Keyshot, showing them float on water both in daytime and night-time and a view from the inside. These visualisations were used to present for our supervisors, our client and for the Paris Olympic committee.

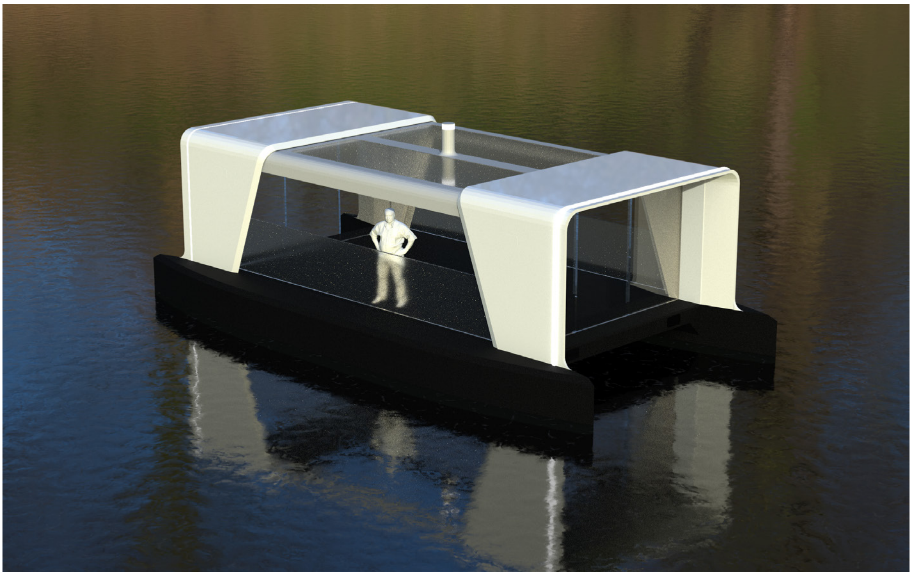


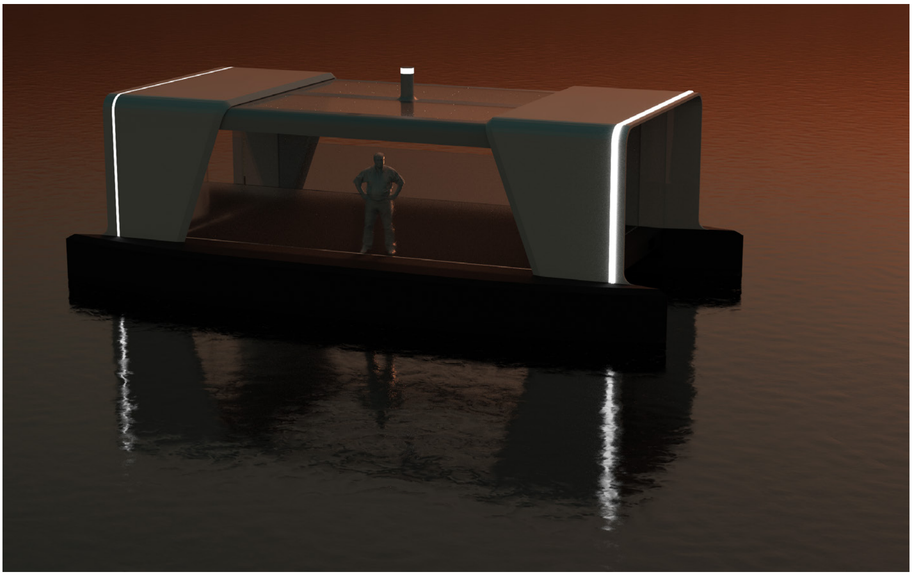
Concept 1





Concept 2





Concept 3

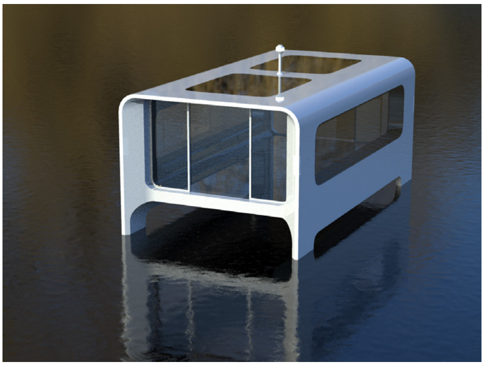
CONCEPTUALIZATION

CONCEPT PRESENTATION FOR CLIENT

The three concepts were presented for the client. Several of the attendants at the workshop were present. The goal was to get feedback on what they liked/disliked on each concept, and to get other valuable feedback. Overall concepts, sensor placement, lanterns and docking were explained. The 3D-printed models were brought to the presentation. The Zeabuz team got to have a look at the models, before we discussed advantages and disadvantages of each project.


DISCUSSIONS

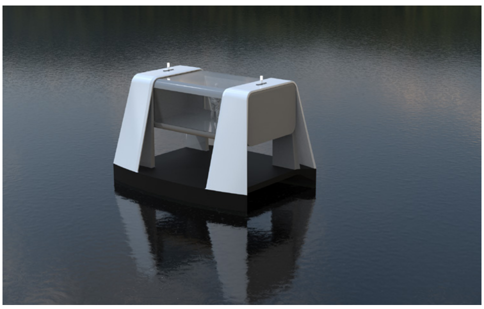
Feedback from the Client



Concept 1

+ Swath hull can go pretty fast up and down with a big ballast pump
+ Adjustments can be made while crossing
+ Swath hull gives a very comfortable ride with less motion than a regular ferry.
+ Looks simplistic but different

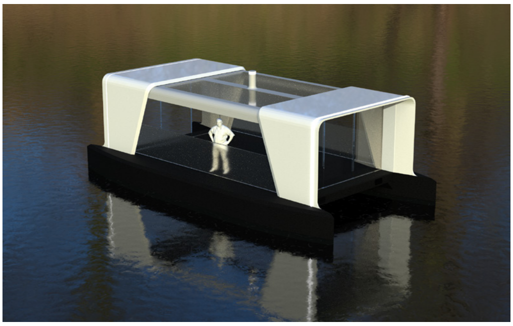
– Must do pumping while passengers boards/unboards
– Has a coffin feeling inside, should have more open space
– Bad serviceability for swath hulls



Concept 2

+ Great idea if its cheap
+ Could be tailored to different places
+ Good passenger flow
+ Good serviceability

– Bad if its expensive
– Looks grotesque and big



Concept 3

+ Most feasible design
+ The inverted shape is simple and nice, but still characteristic
+ Nicer deck inside the passenger compartment with hatches outside
+ Good serviceability
– No way to adjust the height

Other comments

- What about having the superstructure of concept 3 on the hull of concept 1?
- Everyone uses floating piers. Maybe it is because that is the best solution?
- It is OK to integrate sensors in a subtle way into the design
- The design must be for everyone
- Zeabuz is unsure what is most expensive of having an elevator on board, or having a dock that is a big construction
- Ensure safe and good passenger handling
- Zeabuz wants us to decide what to do further work on

CONCEPTUALIZATION

CHOOSING ONE CONCEPT

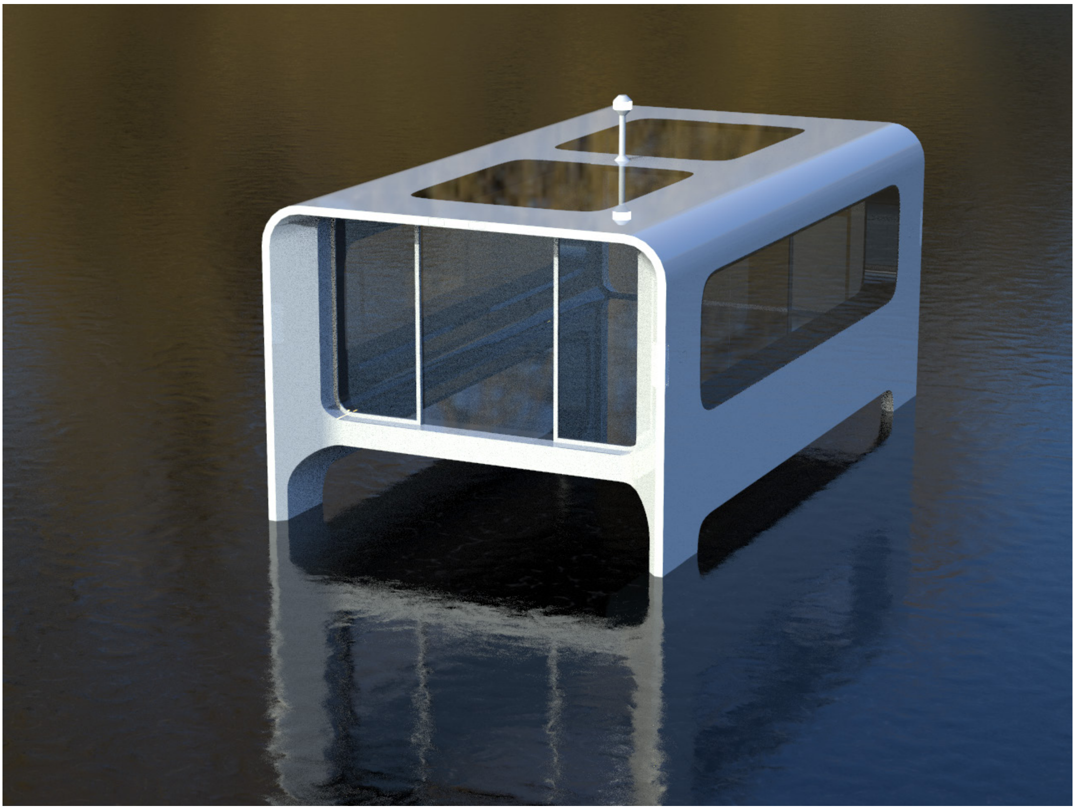
To move ahead with the process, we decided to choose one concept to go forward with. This proved to be harder than expected since all of the concepts had their strengths and weaknesses. The decision was made based on discussions within the team, weighing the different qualities up against each other. Gut feeling also played a role here, considering which concept we believe to both create the most value for the client, but also being the most exciting concept to continue working with.

Concept 2 seemed to be too far into the future. Integrating an elevator on a ferry would involve complications that could affect the design after we submitted it.

Concept 3 felt too safe, thus not pushing the boundaries of what urban mobilities on waterways can become. We also thought this was a project that didn't showed "what is the best we can do".

We decided to go on with concept 1, codenamed 'Swath'. This concept is introducing groundbreaking ideas into the marine section, being such a small swath vessel with an original design. The concept fits Zeabuz' vision about being a disruptive urban mobility provider. Being a swath hull, its distinctive design makes it characteristic, thus differentiating itself from other waterborne vessels and catches attention. The swath hull also has many advantages, as it can adjust the height by adding ballast.

This decision has been made exclusively by the team, as the client and our supervisor, Einar Hareide agreed that it should be a decision based on our own deductions.



Chosen concept

chapter 4

individual parts

As previously discussed, this Master Thesis is combined work of the group of 3 students. This Chapter of the thesis includes individual parts we have worked on, that have been divided between the group's members. Those are the topics we have personally decided to dive into deeper, and give more attention to. They have been selected as a combination of both personal preference/interest and as a subject matter that we deemed important for the development of the overall experience. We divided the parts into "Communication with the environment", " Passenger journey" and "Interior", where Vedran, Malene and Hilmar respectively had the responsibility.

Introduction

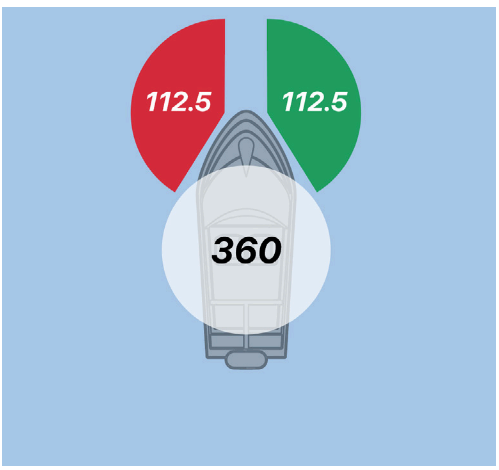
Communication with the environment is a topic that has been discussed for Milliampere 2 previously. The idea is that an autonomous vessel needs a way to communicate with other vessels on water and somehow show that it understands the situation it is in. As there is no captain on board or a person in charge of controlling the vehicle, those users unfamiliar with maritime rules and regulations need an effective way to come to recognize what is to happen.

Additionally, creating an interface for communication means the ferry can get a new dimension to its existence, one that goes deeper than just being a machine transporting passengers. Communication with the environment has been selected as one of the individual parts of work because the group recognized the importance of this subject matter as something highly valuable for future development of autonomous vessels. Undoubtedly, with the steady development of technology, autonomous systems become an important factor. Hence, this rather unexplored topic of communication between an autonomous vessel and the environment must be addressed at one point or another.

I, Vedran Simic, have predominantly been working on this section of the project alone, so in the coming text of this chapter I will mostly use the pronoun 'I'. This decision was made so the reader of this thesis can better understand the division of the group's work and execution.

Insight
Research review

To start, an understanding of the current maritime regulations is needed. Depending on the size of the vessel, lights in specific colours need to be put in place on the ship's superstructure. Since the ferry is under 12 metres long, it falls under the category with less requirements. These navigation lights include an all around white light that can be seen from 360 degrees. Additionally, there needs to be a bi-colour light, or 2 separate side lights, in the colour green (starboard side) and red (port side) shining from dead ahead to 112.5 degrees on each side, respectively. These are the required lights for a vessel of this size.



Maritime regulations include COLREGS or the Convention on the International Regulations for Preventing Collisions at Sea. These regulations apply to everyone on sea, regardless of size. COLREGS addresses crossing situations by stating: "When two power-driven vessels are crossing so as to involve risk of collision, the vessel which has the other on her own starboard side shall keep out of the way and shall, if the circumstances of the case admit, avoid crossing ahead of the other vessel." (International Maritime, 2003).

A problem with following COLREGS instructions in these situations is connected to the users encountering the autonomous ferry. Many of those travelling in kayaks or other leisure vehicles are not familiar with the procedure that should be followed when coming across another vessel (Porathe, 2021). Those users have very little knowledge and nautical experience to act by the convention. In addition, even when the user encountering the autonomous ferry is aware and knowledgeable on the subject of using COLREGS to address a crossing situation, it might not be sure if the autonomous vessel follows those regulations too. How might one know if the boat will act according to the rules or

do something completely unexpected that might need an additional reaction? Research also suggests that an autonomous vessel should act very passive, and not be aggressive with its behaviour and movement in any way. It should also not force control over the situation, even if it breaks the maritime rules, meaning it should behave in an adaptable way (Dey et al., 2020).
To start, an autonomous vehicle is a machine that is capable of moving completely on its own, without any human input. It is important to understand the difference between an autonomous vehicle, or a driverless vehicle and an automated vehicle. Automated vehicles (AV) are those which are capable of moving by themselves but still require human input in certain instances (Wang et al., 2021). There is a large number of research papers available on the topic of external human-machine interfaces (eHMIs) and automated vehicles, however they are fairly limited to the car industry, or at least vehicles on shore. Despite this, it is a valuable resource to take inspiration from and gather information as to some extent it can be compared to the maritime domain.

Cyan, turquoise or blue-green colour has been identified to be as the most promising colour to be used for communicating intent of an autonomous vehicle. It results in having the least misunderstandings in research done so far. Additionally, in a research paper by Werner (2019) the colour turquoise has been pinpointed as the most suitable for communication as it is unique and salient. Green and red colours have also been tested in some cases (Dey et al., 2020), as they are deeply rooted in traffic systems with the connotations of go or stop, but it has been shown that they cause confusion as they are associated with explicit commands.

A number of articles talk about different ways of displaying information through eHMI's for self driving vehicles. They observe that there are some common solutions used for communicating intent. Text, symbols and lights have been used to display some information that could help users discern what is the intent of the autonomous vehicle (Carmona et al. 2021). Text is most effective, even though it possesses a critical concern in everyday traffic - the language barrier. Even though it can easily be used to express a vehicle's intentions, if the targeted person does not understand the language, all communication is lost. Additionally, if a vehicle only relies on text it means the vessel will not have any communication with large groups like children or visually impaired. Symbols take the second place as the most effective in communicating intent. They exceed the language barrier and are effective across cultures. They are also most accurate and legible from a distance, but require learning. Least effective for communications are lights, that are an abstract way of communication. They can be made fairly simple however, but require learning which imposes a learning curve on the users involved. Still, there is one even more effective way of communicating intent - behaviour. An article by Dey et al. (2020) points out that users always try to confirm the alleged information coming through some communication channel with the actual movement of the object-vehicle-vessel. This article's research was based on Maritime Autonomous Surface Ships (MASS). These are larger vessels that mostly operate in open waters, meaning their size and distance of communication is much larger than the given case of an urban passenger ferry. It is also said that the movement of the vessel needs to be gentle, controlled and uniform. To conclude, if the intent of a vessel is uncertain to a user, the behaviour of an autonomous ship needs to clearly communicate what is to happen.

To quantify some of these ideas, speculation and proposals, researchers usually recreate a real life scenario in a controlled environment. A large amount of these papers currently available in academia have been conducted for automated and autonomous vehicles on road - cars. These normally take one of two approaches: a controlled test in real life on a closed road with simulated conditions, where a driver of the vehicle is camouflaged to not be seen by the crossing pedestrian (Moore et al., 2019), or a virtual reality VR test that mimics the same situation without the need for a physical model (Deb et al., 2018). In these tests pedestrians are to cross a street that is approached by a driverless vehicle and need to make a decision to cross or not. To quantify this, most papers look into time needed for a participant to take action into crossing a street, while others ask participants to evaluate if it is safe to cross at all. Reaction times for the first case are collected and compared between different eHMI's to rate effectiveness. A study done by Dey et al. (2020) asks participants to rate the intuitiveness of a given design, rating it on a scale from 1 to 5.

Standardisation in autonomous vehicles is also an option some experts see developed in the future as it would mean people would not need to learn a new eHMI system for every autonomous vehicle manufacturer. It would also mean that there is less change for confusion between cultures. Still, some social groups might interpret the same signage in a completely different way.

INDIVIDUAL PARTS

COMMUNICATION WITH THE ENVIRONMENT

Sound is also a very interesting way of capturing someone's attention. An article by Alsos et al. describes ways of communication in the maritime domain. One of the many mentioned ways is shouting, which is effective for very close verbal communication. Sounds like a voice of a loudspeaker have been argued by Porathe (2021) to most likely disturb the quietness and peace of nearby residents. Directed sound could also be used, as a tool that only communicates a signal to a single group of people or a person. This method is already used in the maritime industry to send audio signals to vessels at around 500 metres. It could be an effective solution that also solves the global loudness of playing sounds or voices.

Radio communication of very high frequency or VHF, is a tool most of the bigger vessels on water have, however most of the smaller ones do not. Nonetheless, it can be used to call in the operator on shore to communicate if there is a possible lack of understanding of the ferry's intent.

In an article by Veitch and Alsos (2021), users that interact with an autonomous ship are categorised. They are split into 3 groups; developers, primary users and secondary users. Secondary users, important for this section of the report include sailboats, leisure boats, kayaks and bystanders. This group also includes fishing boats, ferries, cruise ships and all other marine traffic. In addition, the research paper outlines the needs users have from the explainable artificial intelligence, or XAI. Secondary users need confirmation that the autonomous surface vehicle (ASV) sees them or acknowledges them, to avoid situations that are potentially dangerous and to avoid collisions.

Furthermore, clear information on the ASV's intentions is needed to keep the flow of traffic smooth and to avoid deadlocks, situations where no progress between two sides can be made.

Death by GPS is a phenomenon that describes deaths in people which resulted by trusting and following GPS systems. (Lin et al., 2017). This directly reflects the design of the vessel's eHMI as it is important users understand what they are dealing with. If, for example, the ferry's communication system is designed in a way that is too friendly, people might not realise that it is also a machine that can hurt them if they approach it too close. Because of this, it is important that the design of the eHMI, together with the design of the overall exterior does not come off as too approachable or too innocent.

In an ideal setting the signals these designs make should be unambiguous, meaning they are not open to more than one interpretation. Because of this, it is crucial that the boat's way of communicating with the outside world and with other participants in the water is clear and understandable.

Comparable Cases

The comparable solution with the most research is definitely the automotive industry, where full autonomy is expected to be just around the corner. Car manufacturing giants like Mercedes-Benz and Audi have been working on developing some sort of external HMIs and displaying them in concept vehicles, but none of the solutions have hit the mainstream market. With a lot of companies working on autonomous technology it is not a surprise that it is the industry with the most available resources on eHMIs.

When looking at car traffic and vehicles with wheels in general, there are a lot of factors one can pay attention to, to see the projected path of a moving vehicle. For example, if the vehicle is turning, its wheels change direction which can clearly be seen in most situations. Additionally, a moving vehicle's wheels turn clockwise or counter-clockwise, depending on the direction, another thing that can be seen by traffic onlookers. The wheels are in a way a reflection of what the vehicle is about to do, available even if there is no driver in the seat. On road, users can assume the projected vehicle path by following the road's curvature (or lack thereof).

Photo credits: Auto123.com, Photographer Lesley Wimbush

A similar principle on water would be a boat rudder, which in a way shows the direction of the boat in the very near future. One thing a rudder lacks compared to a wheel is the speed of the vessel, which cannot be assessed just by looking at it.

Photo credits: pbo.co.uk

Nominal Conditions

Nominal conditions are the situations that can happen in an environment where an autonomous vessel is active.

The nominal conditions for this project were selected by assessing the important situations that might occur on water, when the ferry is passing in busy waters. These are placed in a list below.

1 The ferry is in autonomous mode.	**STATUS**
2 The ferry is in manual mode.	
3 The ferry is docking.	
4 The ferry is in panic mode.	
5 The ferry is attracting attention to itself.	
6 The ferry is performing a turn.	**PROJECTED MOVEMENT**
7 The ferry is speeding up.	
8 The ferry is slowing down.	
9 The ferry is performing an emergency stop.	
10 The ferry is showing its direction of movement.	
11 The ferry perceives a secondary user.	**PERCEPTION**
12 The ferry goes first, while the secondary user has to wait.	**DIRECT COMMUNICATION**
13 The secondary user goes first, while the ferry waits for them to pass.	

Usually, literature categorises these conditions in 3 different sections - perception, driving mode and intent (Faas et al., 2020). Autonomous vehicle perception means that the machine shows to the environment that it has detected or seen something of importance, a human, a cyclist, a kayaker... Driving mode speaks for itself, it is used to show how it is currently in control of the vessel, is it in autonomous mode like envisioned, or is it actually being controlled by the shore control operator using manual controls. Lastly, intent stands for understanding the actions that might ensue between an autonomous vehicle and a direct participant. This, of course, needs to be communicated. I have decided to categorise the nominal conditions into 4 sections, however, by status, perception, projected movement and direct communication. These can be seen in the list as well. This was established as the category intent felt like lacking in specificity. There is a difference between the boat's intent as an individual entity on water and intent as a result of encountering a possible secondary user. Communication is key in both but in our opinion it should differ in eHMI execution.

This external communication can be either egocentric or allocentric (Camora et al., 2021). Egocentric communication, from the vehicle's point of view (POV), means that the vehicle is expressing its own intent, for example by displaying the words - I am slowing down, I am stopping, I see you etc. Allocentric communication, from the vehicle's POV, means that the vehicle is instructing others in what they should do. For example, a vehicle can say - please stop, move, or any other form of command. There are a few problems with the allocentric approach from the vehicle's POV. Firstly, if an autonomous vessel meets more than one person in the water, how does it instruct both of them at once. Surely, one command cannot apply to everybody around the vessel, meaning it can cause confusion and uncertainty of the outcome. Possibly, the eHMI design should be scalable in a way that allows for multiple secondary users simultaneously. Secondly, the current research says autonomous vehicles should not give explicit instructions to others (Lee et al., 2019)., as it can be interpreted as an order and if something unexpected happens, who is to blame?

To conclude, the boat should only ever display or show its own intentions, and let the users decide on their course of action on their own.

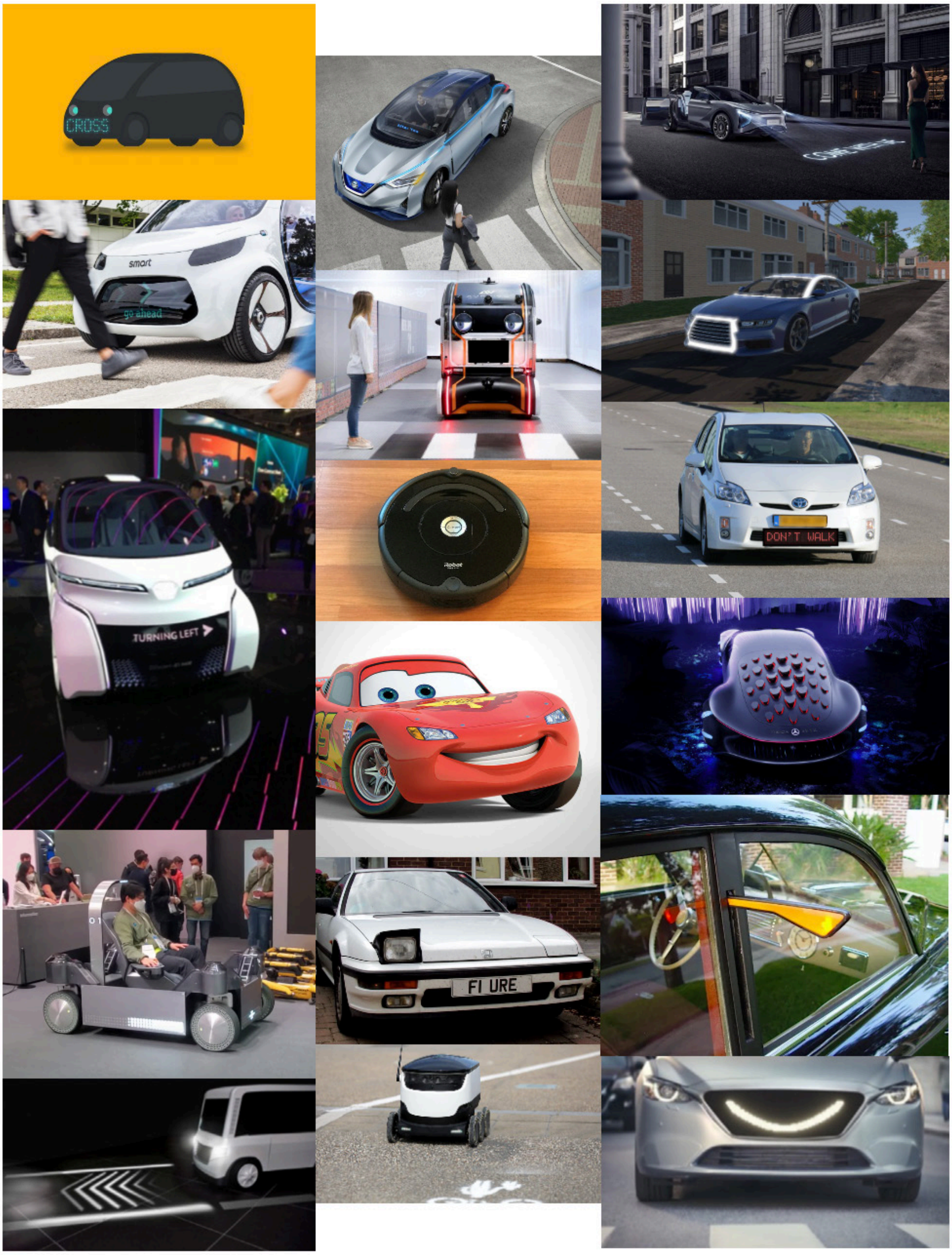
Ideation

Inspiration (moodboard)

The moodboard for this task heavily relied on the ideas developed for the car industry, where among concept vehicles, there are some purely speculative designs which exist to provoke the idea of a fully autonomous vehicle.

As much as autonomous vehicles are a part of the future, there have been some interesting ideas in the past for communicating intent as well. For example, trafficators, or pop up indicators are a way for showing where the car will turn by moving a physical part of the vehicle. This idea uses a dynamic part for communicating intent. It can be argued whether it is more or less effective than in built light indicators, but it is an interesting concept. Same thing applies for pop up headlights, that are a moving chunk of a car that changes its appearance drastically. To start, it gives the vehicle a pair of eyes, then it also serves when headlamps need to be turned on and finally they mean the vehicle is on, moving or not. That can be directly linked to displaying an autonomous vehicle's status. Mercedes Benz VISION AVTR tries displaying status and intent by placing moveable scales on the top of the vehicle. Mercedes named them Bionic Flaps (Mercedes-Benz, 2022).These show if the vehicle is in autonomous mode or manual mode and they react when the vehicle is braking, accelerating or turning.

Other images on this moodboard mostly include concept designs from the transportation industry that heavily use light strips, screens displaying text and other visual stimuli to communicate intent.


CROSS
smart
go ahead
TURNING LEFT
DON'T WALK

COMMUNICATION WITH THE ENVIRONMENT

Ideas

As research has shown, the most effective way for an onlooker to understand the projected actions of a vehicle is to look at its behaviour. I have set out to find a solution that goes beyond an LED strip or a screen displaying text as a form of communication. The idea was to create a way for the boat to communicate intentions through non-verbal communication, using various gestures and body movements. Despite this, I wanted to include designs like those in the testing that would happen later, as I have seen from previous research that it can be used for effective communication.

It was incredibly important that the eHMI design implemented as a part of the vessel does not disturb the clean exterior design that has been accomplished previously. Attaching something on top of the bodywork was not an option as it was decided that the eHMI design should act as an integral part of the boat. It was also identified that the locations of the eHMI should be on the places of the boat that can be seen the best from the water.

When placing an interface on the side of the boat exclusively, for example, when viewed from the front and back, the interface would be very hard to notice. This relates for the front and back too, places easily covered by the boat's own bodylines or position in the water. Because of this, the eHMIs should be placed in the corners or the top of the vessel, where they can easily be seen from more than one position.

A big part of the inspiration had us interested in creating a robot-like personality that humans can relate to and have a direct relationship. As noted earlier, this is a tricky task because of the GPS death phenomenon. I had also felt that I was influenced by this toy-robot approach because of mass media and its idea of the future. It is hard to escape these notions that have been planted in our minds throughout the years of what it means to have a self-driving machine capable of making decisions by itself. Nonetheless, I tried to look into this idea of making a personality for the vessel, something that will make the behaviour identifiable and relatable.

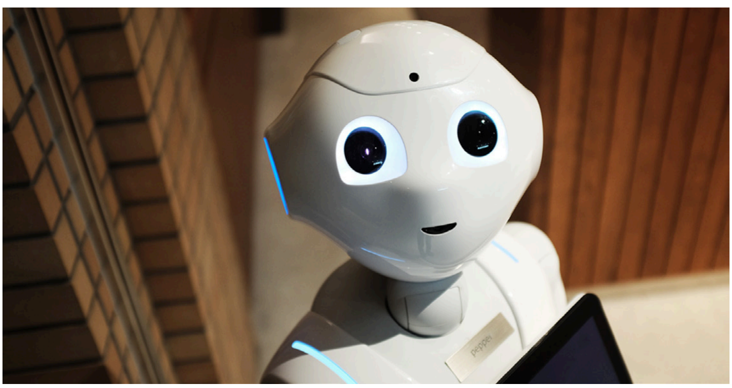


Photo credits: Mrgoodlife.net

Eyes can have a huge benefit when connecting to an entity. When talking to each other people often look in each other's eyes, which are said to be the windows to the soul. Some eHMI ideas even try to mimic these eyes as a part of the vehicle to give it a point of connection between a secondary user and the machine (Jaguar Land Rover, 2018).

Photo credits: *jaguarlandrover.com*

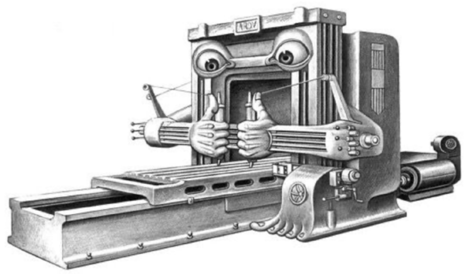


Photo credits: Boris Artzybasheff, Machinalia

Furthermore, when people are uncertain of a situation in traffic they try to look for eye contact with the driver to get a mutual understanding of what is about to happen. I were apprehensive on the idea of including eyes for the autonomous ferry as it was of the opinion that it would hinder the design of the exterior too much and that this vessel is not something that people look at for eyes.

According to the Oxford Languages dictionary, anthropomorphism is the attribution of human characteristics or behaviour to a god, animal, or object. This technique is often used when creating characters in children's stories, cartoons and similar. It can be interesting to use it when working with machines, especially autonomous ones, because it allows for the object to be more understandable to nature and get closer to the target user. Robots in particular strive to not only be a subject of anthropomorphism but ultimately become a reflection of the original inspiration. For the autonomous ferry especially, this can mean that the interaction with it feels less alien and more human, hopefully creating a better relationship of understanding between subjects.

COMMUNICATION WITH THE ENVIRONMENT

Besides this, pareidolia is the tendency to perceive a specific, often meaningful image in a random or ambiguous visual pattern (Merriam-Webster, 2022). It is most often seen as people seeing a face in an object that has no face at all. This can be used as a powerful tool when creating a vessel that has a direction, as it could potentially mark the 'front' as the face with particular design elements, even though there are no face features at all. Automotive pareidolia has been shown to improve car sales (Hoback, 2018), as it helps people connect with a car and see a familiar shape in its design. No doubt, this method would in a way make the vessel less of a boat and more of a robot.

Photo credits: everyonelovescartoons.com

As an example we can take a look at the Roomba house cleaning robot, included in the mood board above. It is a robot capable of cleaning floors in a home, working at set times, knowing when it hits something and docking to its station when done. It does not have a pair of eyes, or resemblance of a face yet still people treat it like something more than just a machine that does its chore. Research by Agnihotri et. al, it has been proven that Roombas have a personality. By adjusting the robots' different movements while cleaning, the team of researchers successfully created patterns of behaviour that other users could notice and classify to a particular personality (Agnihotri et al., 2020). This could be used analogously for the design of the ferry's movements, with the idea that users can understand the current intentions or status of the autonomous vehicle. After this short investigation I felt like creating a face on a 9 metre boat is not something I would like to pursue. It seemed like a boat is not a piece of machinery that people would expect to see a face on, as most of the vessels on water today do not have this approach. I trusted that eye-like confidence in communication was achievable with interfaces that lack those bio-inspired features.

Even though research has shown that text is especially effective when people see it and can understand it, the idea of displaying words seemed like an obvious idea I did not want to jump on immediately. Verbal communication, meaning using words, in an oral or a written way, is just one way of transmitting information between the boat and the secondary users. Non-verbal communication seemed like a direction that could be much more interesting and exciting if proven to be equally effective like text. Non-verbal communication in humans relates to many things, some being posture, body language, eye contact, tone of voice, facial expressions, gestures etc. Animals, since unable to talk a comprehensive language, also have some form of non-verbal communication with the environment.

This biggest limitation of non-verbal communication is its ambiguity, which is the quality of being open to more than one interpretation (Cambridge Dictionary, 2022). This is especially disadvantageous for this particular application case, as unequivocalness is crucial for successful communication between entities on water.

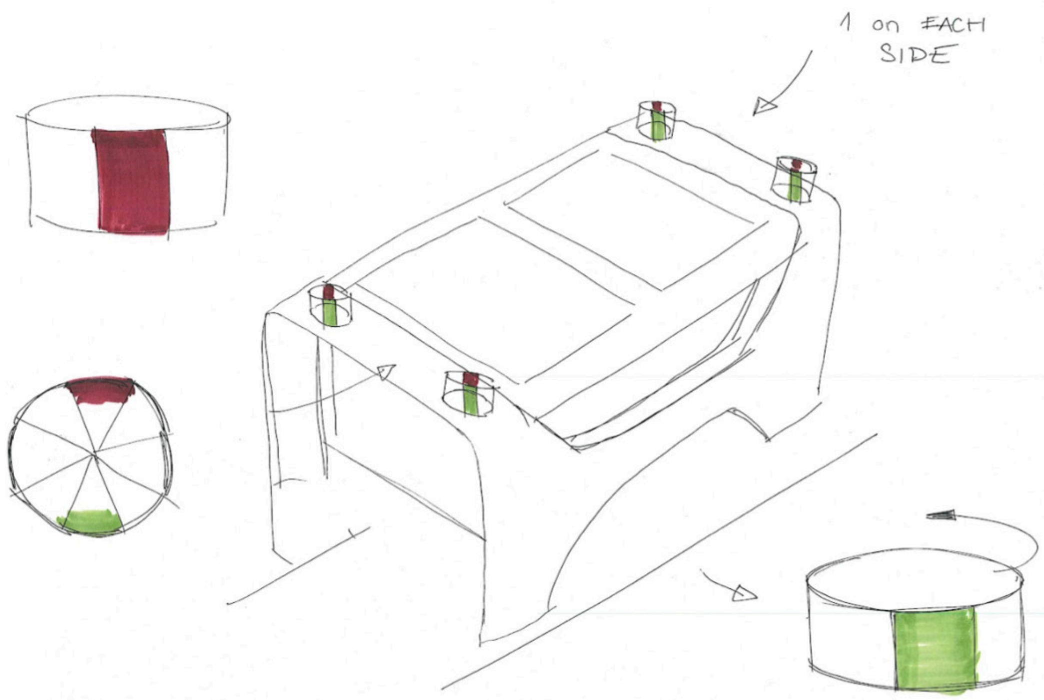
Before getting to the suggested ideas, a general idea was set. The design should have some moving parts on the exterior of the vessel, in an analogue way. In addition, digital advantages can be added to enhance the understanding of envisioned communication. This would allow the eHMI system to be flexible and easily adapt to new given situations, something hardly achievable with analogue solutions. Despite this, the physical part of the system is to mimic a behaviour or point out a movement that signals a solution for a nominal condition, putting the secondary user as the target of its communication. For instance, when cars break hard, the front of the vehicle squats down a bit, but on water, this becomes a different story. Acceleration and deceleration are very hard to spot, and leave bystanders not only uncertain but presumably confused of the intent of the vessel.

INDIVIDUAL PARTS

COMMUNICATION WITH THE ENVIRONMENT

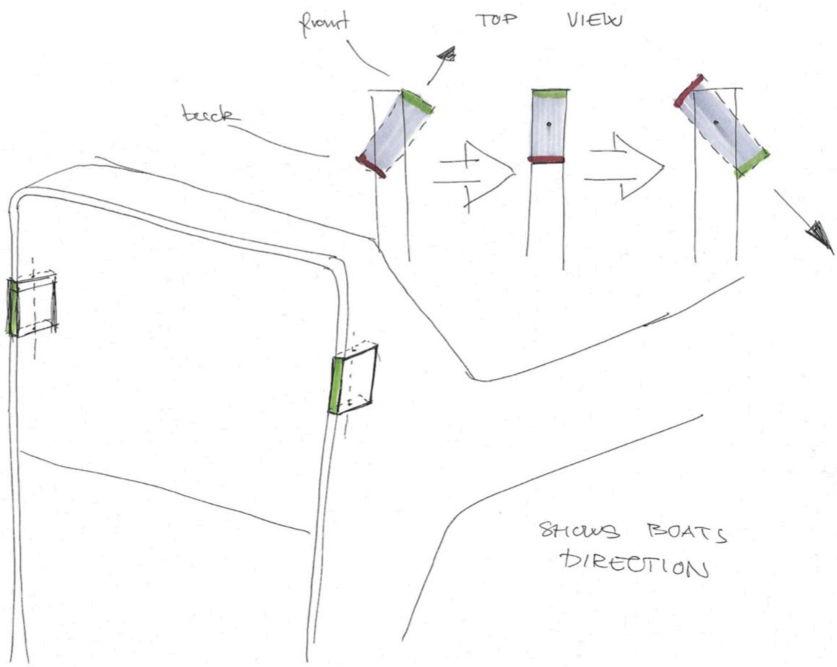
Round Idea

The idea for a round interface for external communication came from the shape of a compass. The concept splits a cylindrical shape in 8 sections placed on top of the vessel, one on each side. These sections indicate the moving direction of the vessel meaning north south east west and the possible combinations. The proposal is to light up one of the sectors of this cylinder to indicate which way the ferry is moving. Playing with lights in a round shape could also unlock the possibilities to show solutions for different kinds of nominal conditions, albeit incredibly abstract and ambiguous.



Flaps

The flaps presented in these concepts are placed in all four corners of the vessel, integrated as a part of the edge. They are envisioned to move around a central axis, showing the direction the ferry is moving in. Since they are a moving part of the boat they can dynamically move to show the way, either of the boat or the secondary user. On the front and the back of these flaps, lights are placed, similarly to the headlights and taillights in the car. The way going forward for the vessel would light up one colour, while the back, or the direction that the boat is not travelling in would light up a different colour. These flaps could be put into the neutral position when the boat is not operating to remain unseen, and thus not disturb the simplicity of the exterior design of the ferry.

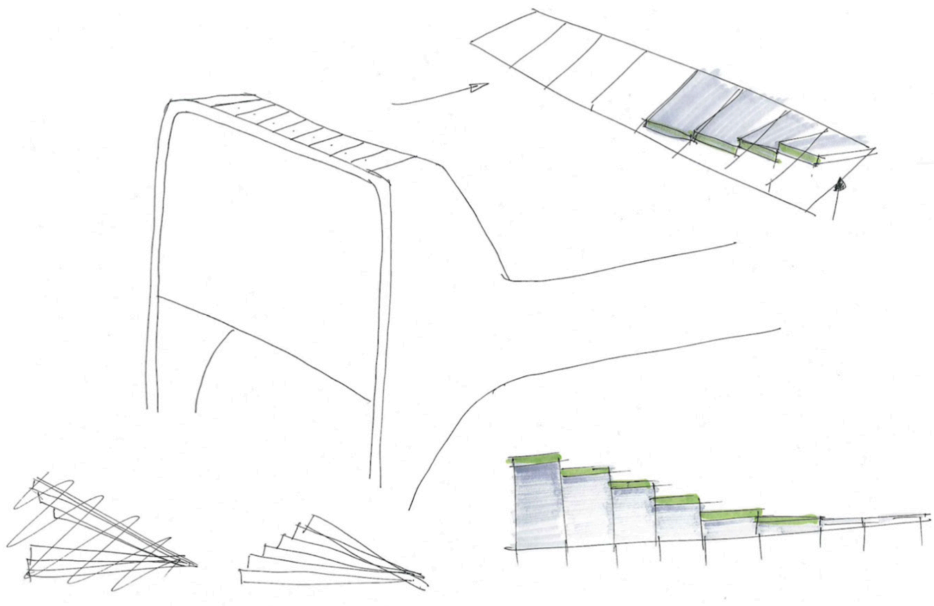


INDIVIDUAL PARTS

COMMUNICATION WITH THE ENVIRONMENT

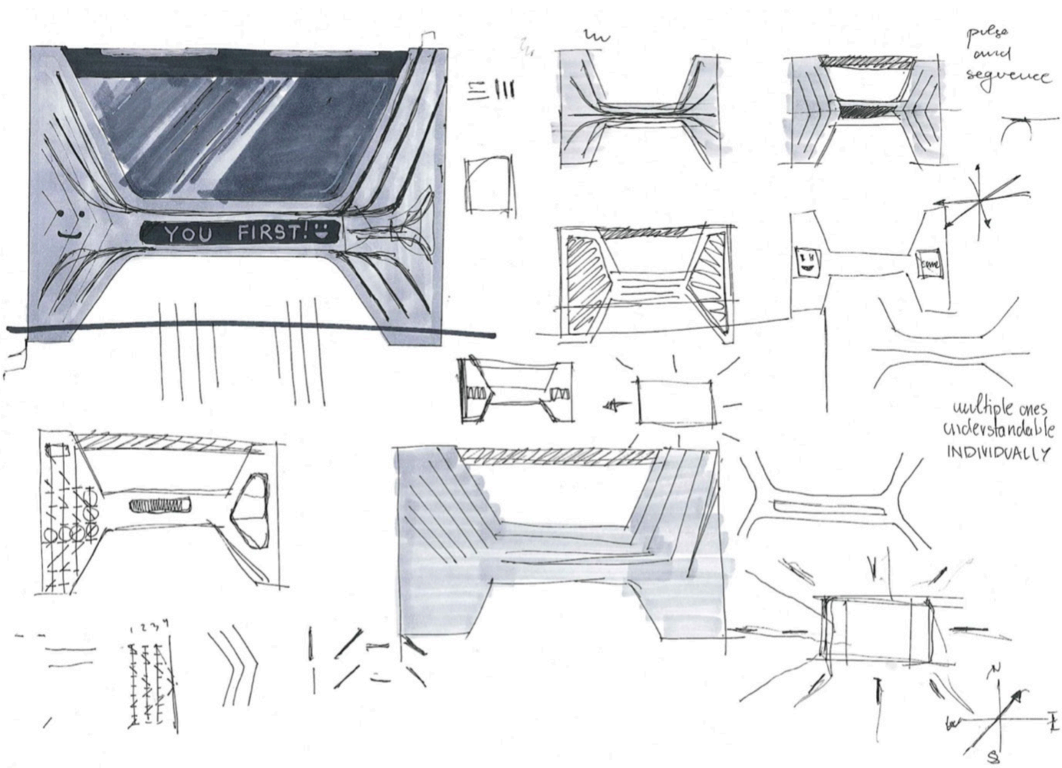
Piano Idea

The solution presented here was inspired by the idea of piano keys. Just like hands on the piano move while playing different keys, so move the keys themself. The idea is to place these key-like structures on the top edge of each side of the ferry, allowing them to move independently up and down creating swings of motion going from one side to another. Perhaps complicated to execute, these keys would sit flush with the surface, hiding, until it is time for the“m to communicate. Each key can move by itself, but they can also move as a whole group to show a signal that might be more important. This idea and its derivatives are unquestionably equivocal, so the movement of the keys themselves could mean anything to anyone.



Lights

Lights and light strips could be placed almost anywhere,as they come in all shapes and sizes while being easy to implement. Some of the ideas include placing strips of light on the sides of the ferry, but that does pose a question of what is made of the design when not in use. Lightbars could also be placed following the ferry's bodylines, hiding from plain sight and appearing when needed, even accentuating the bodywork at times. The possibilities of LED strips are almost unlimited but it should also be noted that they do lose some of their effectiveness in bright light and since almost acting as a line are hard to shape in a corner.

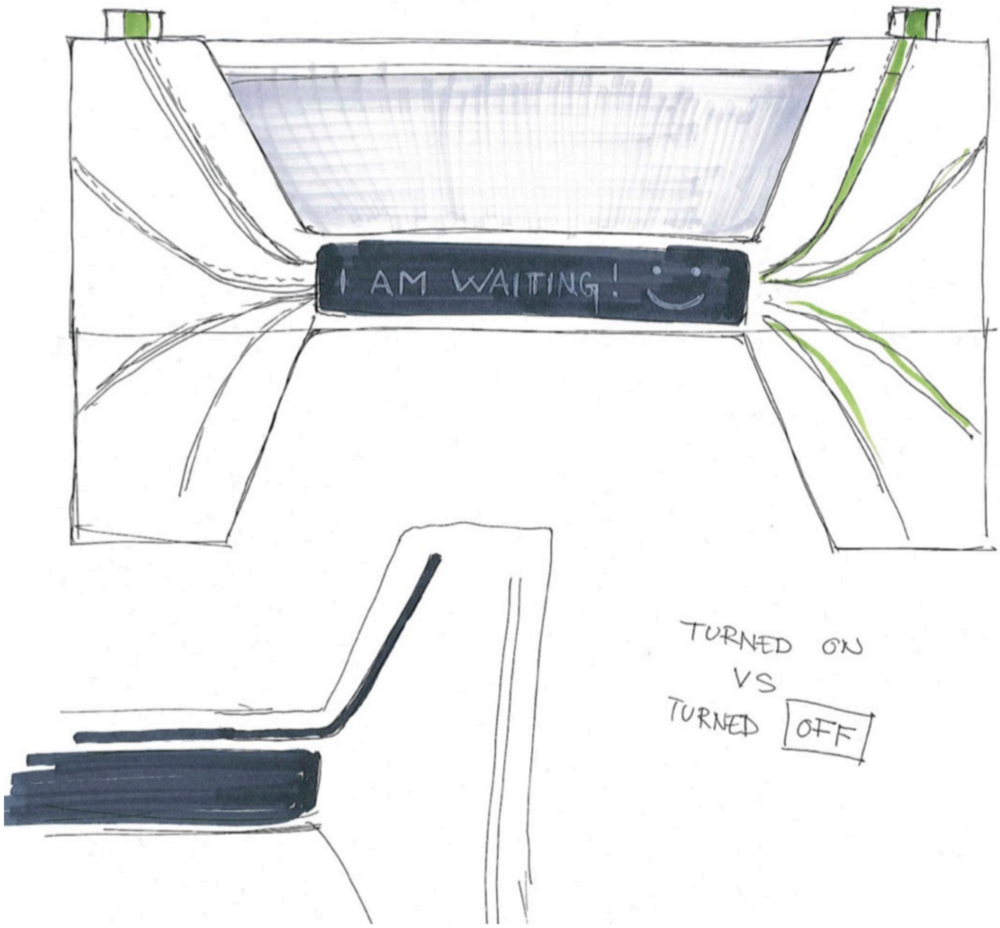


INDIVIDUAL PARTS
COMMUNICATION WITH THE ENVIRONMENT

Screen

The idea of using a screen has its pros and cons. Firstly, I was concerned about how the screen would look when turned off, since the colour black would need to be implemented in the exterior of the design to complement the body lines. Next, screens are usually flat and can only be put in an empty space that has a lot of surface area. They need to display text symbols or something else big enough so that the secondary users can see them from far enough to be legible and understandable.

Additionally, screens suffer from glare in direct sunlight and their view conditions are not ideal in situations where one does not look at them dead straight. Nonetheless, it is an easy eHMI platform that can display dynamic text adaptable to a nominal condition. In this idea it is placed on the longer sides of the ferry, as the front and back sides just do not have enough area to house one flat. This immediately means that the screen will not be seen unless the person looking at it is not close to perpendicular to its projection. Corners here remain unused as well.


I AM WAITING!
TURNED ON
VS
TURNED OFF

Testing

Designs used

Designs used in the testing process where a selection of ideas that have been translated from simple sketches to 3D animated gifs inserted in the questionnaires. These have been selected to have a range of different solutions including text, light and movement. It was decided to not combine any solutions together e.g. screen displaying text with led light strip, as to get clear results on what specifically works and what does not.

I have designed these concepts as solutions for certain nominal conditions in mind. However, the designs are a result of our own thinking and while their meaning might make sense to us, they might have a completely different meaning to someone else. Because of this I deemed it imperative to convey a test with the general public, to get a grasp on its interpretation of these signals. The included table shows a matrix of previously decided nominal conditions, concept designs, and how each one could solve the situation.

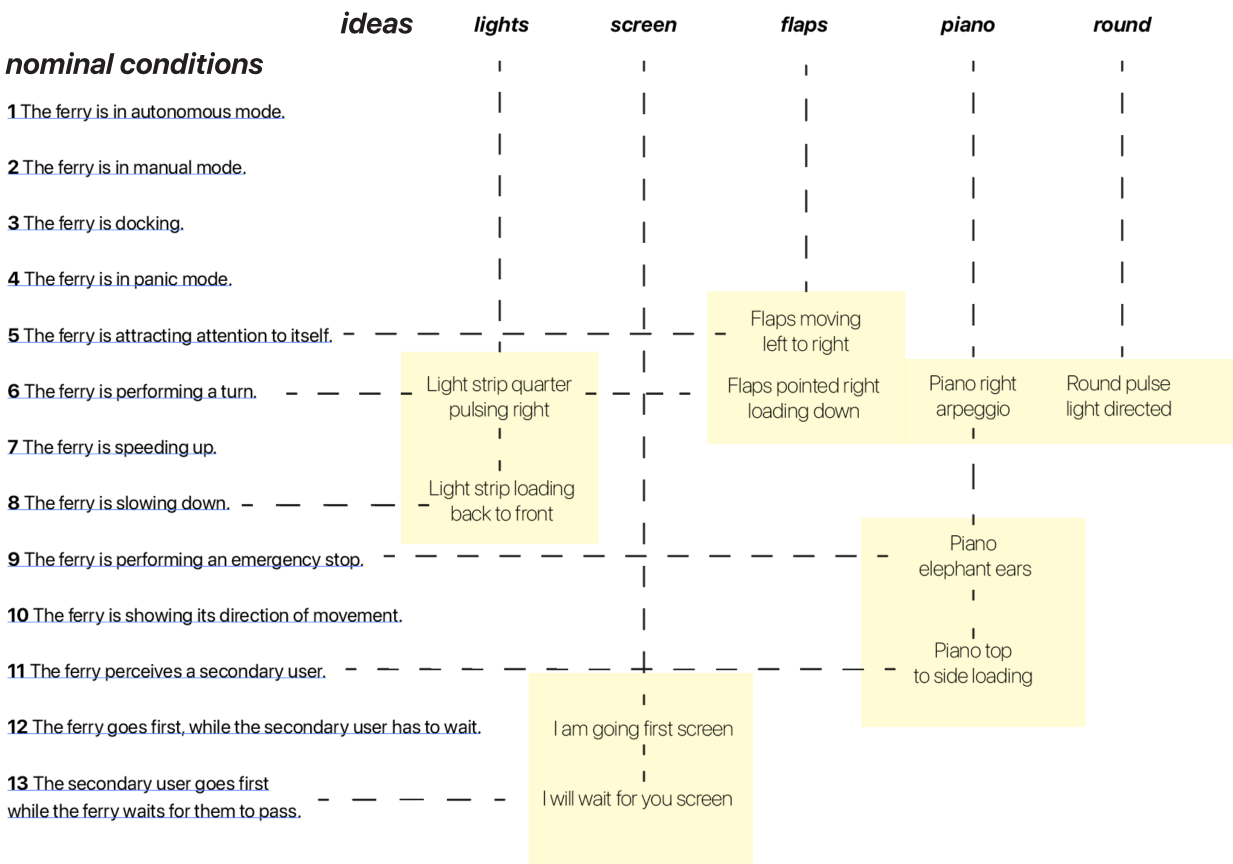
Lights
1 Light strip loading back to front
2 Light strip unloading front to back
3 Light strip quarter pulsing right

Flaps
4 Flaps pointed right loading down
5 Flaps moving left to right

Piano
6 Piano right arpeggio
7 Piano elephant ears
8 Piano top right to left
9 Piano top to side loading

Round
10 Round pulse light directed

Text
11 I will wait for you screen
12 I am going first screen


ideas
lights
screen
flaps
piano
round
nominal conditions
1 The ferry is in autonomous mode.
2 The ferry is in manual mode.
3 The ferry is docking.
4 The ferry is in panic mode.
5 The ferry is attracting attention to itself.
6 The ferry is performing a turn.
7 The ferry is speeding up.
8 The ferry is slowing down.
9 The ferry is performing an emergency stop.
10 The ferry is showing its direction of movement.
11 The ferry perceives a secondary user.
12 The ferry goes first, while the secondary user has to wait.
13 The secondary user goes first while the ferry waits for them to pass.
Flaps moving left to right
Light strip quarter pulsing right
Flaps pointed right loading down
Piano right arpeggio
Round pulse light directed
Light strip loading back to front
Piano elephant ears
Piano top to side loading
I am going first screen
I will wait for you screen

INDIVIDUAL PARTS

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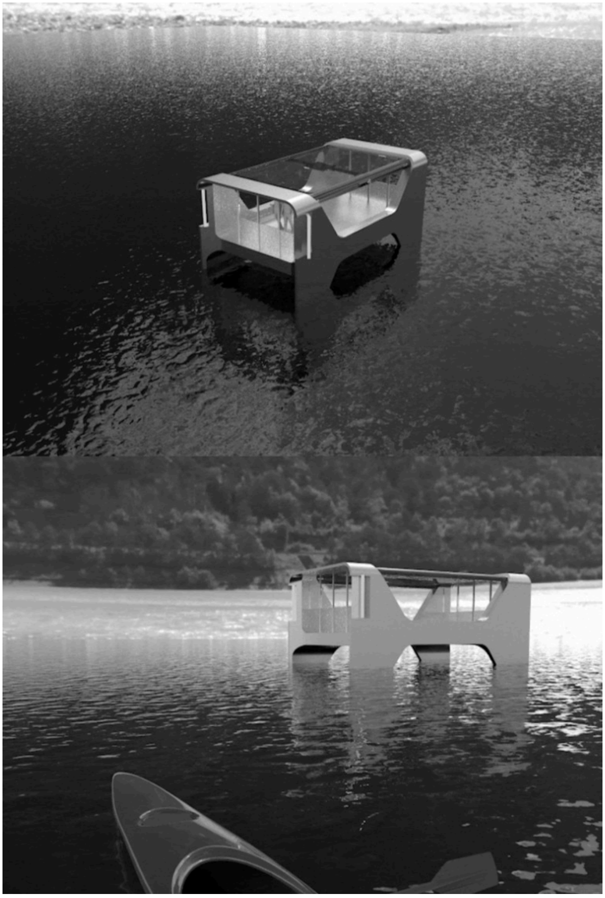


Example screenshot from the animation 5 Flaps moving left to right.

Other animated designs used in the testing process can be seen here (gifs)
https://miro.com/app/board/uXjVOwQQ3Ew=/?share_link_id=282003917660
One can also visit the links for the surveys and try it out.

Testing process (2 way testing)

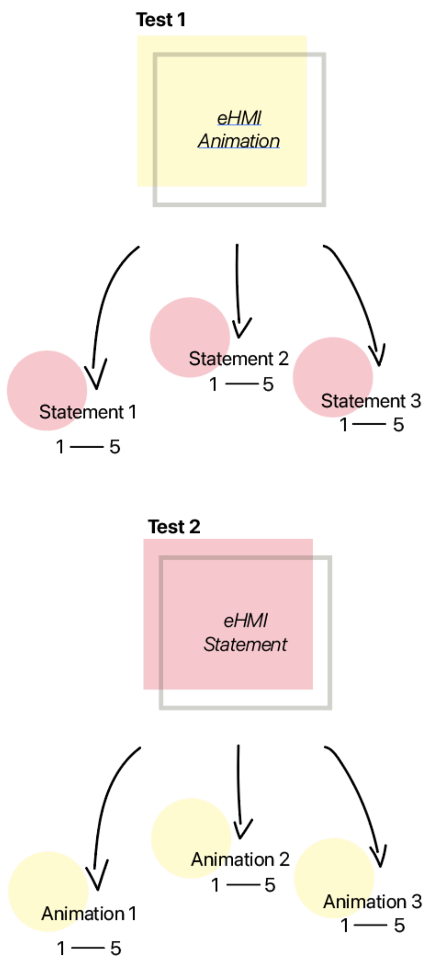
To get a better understanding of the public's understanding of these eHMIs, I have decided to conduct 2 surveys. Both of the surveys have been made to get a better view on what the general public thinks the signals and the eHMI's stand for. As previously mentioned, these should be unambiguous, which is extremely hard to achieve when working with abstract forms and unstandardised ideas.

The base for both tests were 2D video animations (perspective images) that display the movement of light, or a part of the vessel, to showcase a signal that has a certain meaning. The participant was put in the role of a nearby kayaker and had to state what they think the boat is signalling, from a range of offered answers. The animations were made in black and white, to remove the possible bias and distractions present in the animation, such as the colour of the kayak or reflection of the water. The platform used to conduct these tests was Google Forms and the participants' answers were anonymous.

Both tests asked the participant if they have any visual impairments or disabilities, as the tests rely on visual stimuli exclusively.

Another question asked before starting the surveys, that was used to eliminate some participants immediately, is whether they have a design education background. This question was put in place to exclude designers who might discern and search for a deeper meaning within the signal. I wanted to get the general public's view on these designs as I felt that it would give a better representation of the 'Average Joe'. Asking these questions to fellow designers that have very likely previously designed some HMI's would yield results that would not reflect the views of the general population.

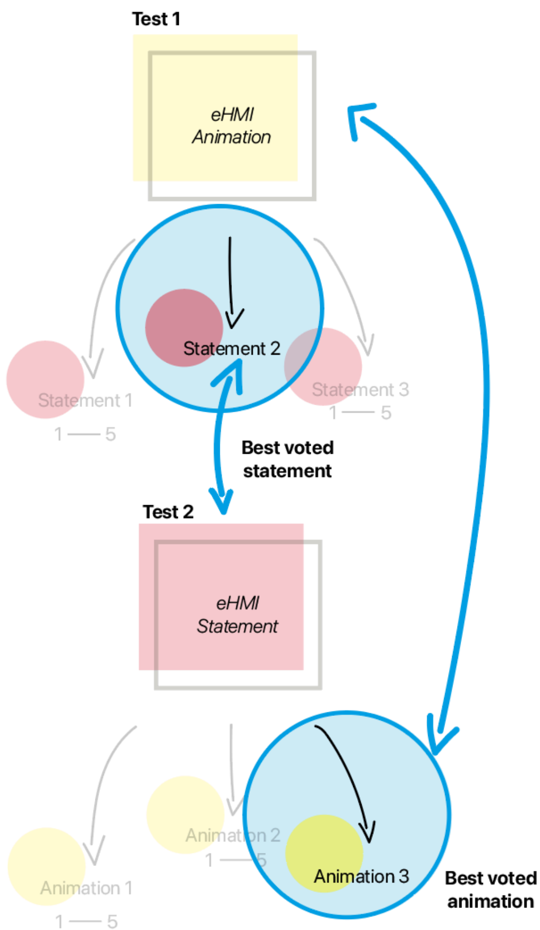
The first test was set up in a way where participants were presented one designed ehmi at a time, solving for a specific nominal condition, and had 3 offered statements describing what the boat is signalling. The task was to rate to what extent they agree that the statement correctly describes the animation. These statements could be rated on a linear scale from 1 to 5, where 1 meant Strongly Disagree and 5 meant Strongly Agree. For each picture, along with 3 offered statements there was also a blank field for a short answer text, where the participant



could express what they thought the signal meant, if they found none of the provided statements fitting.

In the second test, it was important that the participants doing it have not done test 1, or vice versa. It was critical that the participants were to be met with this situation and the designs for the first time, simulating a real-world scenario where effective communication must be established on the first try. This test ran in the opposite direction of the first one. Instead of presenting a design solution and asking people what it meant for them, participants were introduced to a statement first and then offered to choose the best design solution.

For example, one of the statements in the survey was; The boat is signalling that it is speeding up. The participants were then offered 3 animations to choose from and vote on a linear scale to what extent can the statement be understood from the presented animation. The scale ranged from 1 to 5 where 1 stood for Not understandable at all, and 5 stood for Very understandable. This test was made for 2 reasons, one, it put the user, or in this case the kayaker, in the position of the designer, giving them the opportunity to choose a design best fitting for a nominal condition. The goal was to see if there is a consensus in the public on what design best fits the statement. The other reason, however, was to confirm or deny results from the first test. I had hoped to confirm that the most chosen design for the statement would be the best understood design from the first test.



These tests were run for a week, after which the results were collected and analysed. You can do the surveys yourself, following these links.
Test 1: https://forms.gle/KdKZew8j3nPpa12M9
Test 2: https://forms.gle/XW6aubznDsJ6dXnNA

Results

Results of surveys 1 and 2 were based on the responses of 20 and 25 participants, respectively. Raw data of these Google Forms can be found in the appendix.

The test 1 results show the following: Light strip loading back to front was most voted as meaning that the boat is speeding up, with an average score of 3.5. Round pulse light directed has been voted most for meaning that the boat has seen you in the water with an average of 3.1. “I am going first” screen has best been voted with the meaning that the boat is not waiting, scoring 4.7 out of 5, showing a high level of agreement among the public. The other most voted option was the meaning that the participant (kayaker) should stop, with a score of 4.4 on average.

Flaps pointed right loading down were best understood as the boat slowing down, rated 3.3 on the scale. Light strip quarter pulsing right has most been agreed to mean that the boat is turning towards the participant (kayaker), with an average score of 3.7. Piano right arpeggio was most recognized as meaning the boat is turning towards the participant (kayaker) with an average score of 3.3. Piano elephant ears on the other hand have been voted to mean that the vessel has seen the participant, with 3.7 score. Flaps moving left to right have best scored a 4.0 with the meaning that the participant is to move first. With a score of 4.0 as well, Piano top to side loading was agreed upon to mean that the boat is attracting attention. Lastly, “I will wait for you” screen scored a perfect 5 with the meaning that the participant (kayaker) goes first.

Test 1

N		eHMI animation	most voted as	score
1	**A**	Light strip loading back to front	*Ferry speeding up*	**3,5**
2	**B**	Round pulse light directed	*Ferry sees user in water*	**3,1**
3	**C**	I am going first screen	*Ferry not waiting for user*	**4,7**
4		Flaps pointed right loading down	*Ferry slowing down*	**3,3**
5	**D**	Light strip quarter pulsing right	*Ferry turning towards user*	**3,7**
6		Piano right arpeggio	*Ferry turning towards user*	**3,3**
7		Piano elephant ears	*Ferry has seen user*	**3,7**
8		Flaps moving left to right	*User goes first*	**4,0**
9		Piano top to side loading	*Ferry attracting attention*	**4,0**
10	**E**	I will wait for you screen	*User goes first*	**5,0**

COMMUNICATION WITH THE ENVIRONMENT

What is interesting in this test, even though this was a very small sample size of people who might or might not have previous experience with the maritime regulations, some ways of signalling have been more successful than others. For example, when displaying pure text on a screen the public reach consensus almost perfectly (question 3 and question 10), with scores of 4.7 and 5.0. What is even more important is that the participants voted the other options in those questions with most one's (1) as scores, meaning it was clearly understood what the meaning is and what is not. Another pattern can be noticed when looking at results which is that no other solution was rated higher than 4 except the previously mentioned text-on-screen designs. Flaps moving left to right and Piano top to side loading have their best average scored a 4.0 but their other options were also voted fairly indecisively. How does one rate the success of a design if there are so many different understandings of the design? Perhaps, one could compare this to a traffic light, where it is imperative that every participating individual understands the meaning behind the lights 100%.

Furthermore, in test one, participants were free to add their own meaning or understanding to the animation if one of the suggested ones was not satisfactory. Some of the answers from those text fields include the following quotes: 'Unsure about the meaning of blinking lights... ', 'Unclear what the light is meaning', 'I do not know. As the kayaker, I would stop as I do not understand it.', 'The boat is dancing',. I would dare to call those designs unsuccessful in conveying the information or signals that they were intended to show, if there isn't a clear understanding of the public. It would seem like those signals have an almost arbitrary meaning. Yes, the test showed what each design means for most people, but it has also shown to what extent it is clear for them to understand the meaning behind the signal.

Test 2 was meant to serve as a confirmation of test 1, letting people choose the best design for a given situation. In this way, it would verify that people see the same meaning in the same design, when given a photo or a statement. For the statement the boat is turning towards you, participants mostly chose the Light strip quarter pulsing right, with a score of 3.4. For the situation of the boat speeding up, a score of 2.8 was on average given to Light strip loading back to front. When presented with an idea of the boat slowing down, most people rated the design Light strip unloading front to back as most understandable with a score of 3.1. The situation where the boat is waiting for the kayaker was best connected to the design "I will wait for you screen", with a very high score of 4.6. Furthermore, when presented with the opposite statement, the boat is not waiting for the kayaker, participants again chose the "I am going first" screen with a high understanding of 4.6 on average. Lastly, the idea that the boat is showing that it noticed the kayaker, the survey participants chose the Round pulse light directed as the most understandable option, with an average 3.0 score. These results can be seen in the included table.

COMMUNICATION WITH THE ENVIRONMENT

Test 2

N		Satement	most voted with	score
1	**D**	Ferry coming towards the user	*Light strip quarter pulsing right*	**3,4**
2	**A**	Ferry speeding up	*Light strip loading back to front*	**2,8**
3		Ferry slowing down	*Light strip unloading front to back*	**3,1**
4	**E**	Ferry waiting for user	*I will wait for you screen*	**4,6**
5	**C**	Ferry not waiting for user	*I am going first screen*	**4,6**
6	**B**	Ferry has noticed the user	*Round pulse light directed*	**3.0**

An compelling finding is that a purely light signal has been chosen as most understandable in this test in 3 different situations. Those are: boat turning towards you, boat speeding up and boat slowing down. I would attribute the success of these light signals to them being widespread in the automotive industry. Pulsing lights can be directly compared to a turn signal in cars, while a sweeping motion (loading) has also been present as a form of an indicator in the same manner.

Possibly the most fascinating part when comparing the two surveys side to side are the choices 2 different groups of participants have made when presented with 2 different methods. Light strip loading back to front, in the first test, has been chosen to best represent the boat speeding up. In the second test, when asked to choose the best design for the representation of the boat speeding up, light strip loading back to front was chosen. This correlation can be seen in the graphic symbolised by the letter A. The same pattern can be recognized for correlation B, C, D and E, where the interpretation of participants in the first group matches the choices group 2 had when solving survey 2. It could be said that these instances where the results of written situations match a specific eHMI design and vice versa, are signals that are more clear to understand and have a wider recognition among the general public.

COMMUNICATION WITH THE ENVIRONMENT

Discussion

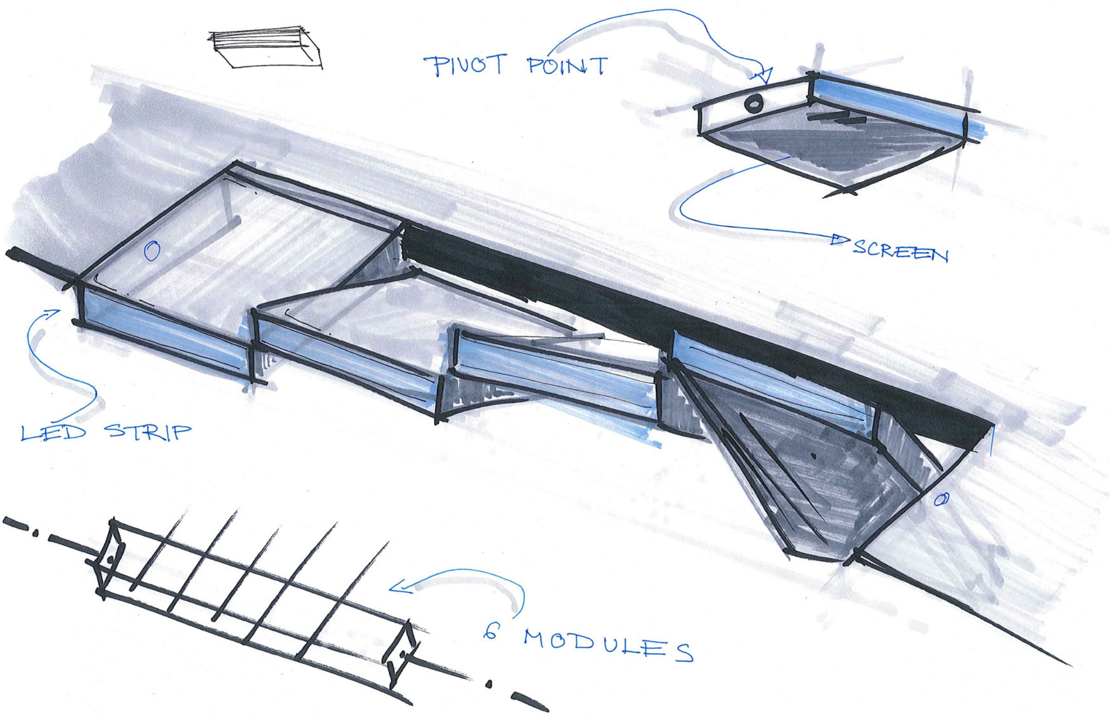
Even though the idea of communicating with the environment without having explicit orders written in text, results have shown that abstract designs are just too ambiguous to be used effectively. For example, if one design can be interpreted in an unlimited number of ways, the communication between the vessel and the surroundings has been unsuccessful and it is almost certain that an unwanted outcome will happen. Having a display on the other hand, that can display text, among other things, has shown to be the most effective as there was no need for further clarification of what the boat's intent is.

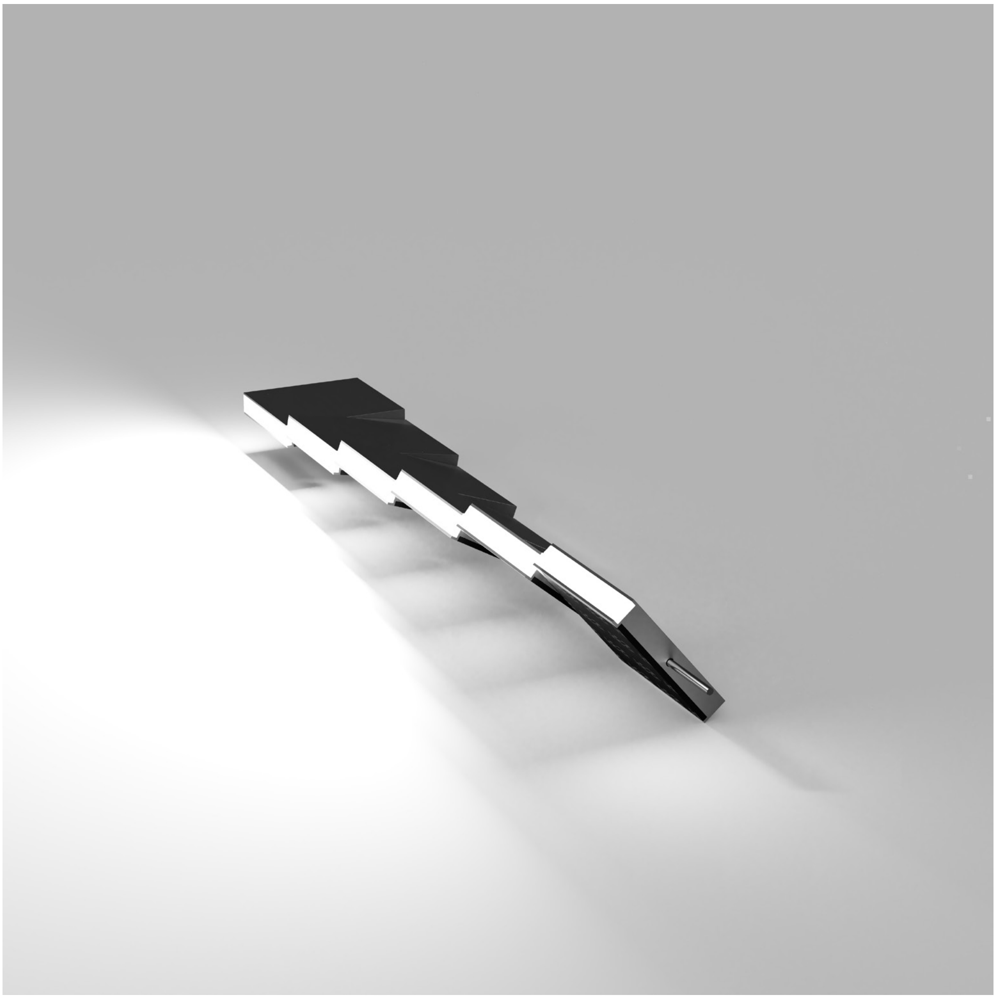
Another thing worth pointing out is that in the animations used in testing the boat is not moving, it is stationary. The only moving parts of the image are the animations of the possible signals, leaving participants unable to confirm the possible signal's meaning with the actual movement of the boat. This meant the communication had no redundancy, besides the sole signal that was designed on the exterior.

Chosen eHMI Design

The chosen eHMI design is a combination of physical movement, led strips and an adaptable screen. This design has been chosen as it provides the most flexibility for future decisions and for conveying different types of information when needed. The main goal for combining all of the different stimuli into one eHMI is to have redundancy during signalling. Although advantageous, this should be used carefully as it can easily result in cognitive overload, reducing the effectiveness of communication between the ferry and the secondary user. A way of doing that for example, would be to use one part of the eHMI to display status, another one for perception and the third one for intent (light, movement, text-on-screen).

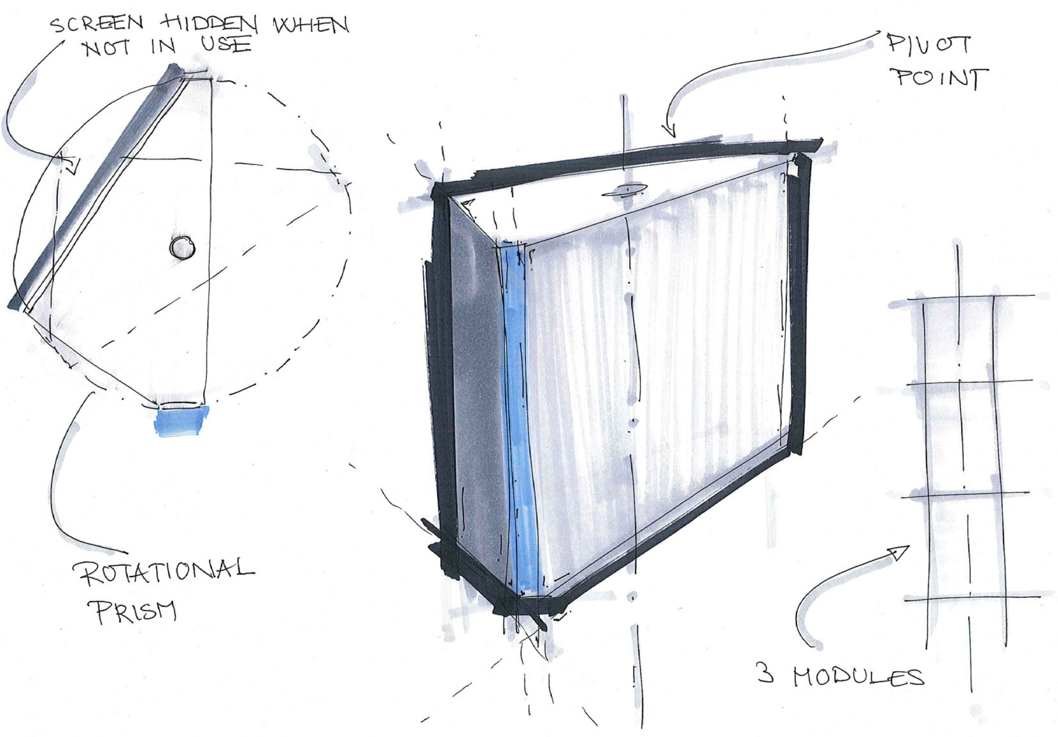
The design is symmetrical on both sides of the boat and it consists of 24 adjustable panels capable of rotating depending on the given situation. The top of the eHMI is a set of 6 keys that can be individually rotated. When not in use the keys sit flush with the rest of the body shape, only activating when it is needed. To make this possible, the top of the keys is made out of aluminium. The front portion of the keys house a light strip that supports displaying any colour in the RGB spectrum. The bottom of these boxes houses a screen that is hidden from plain sight when not in use. When needed individual keys can be rotated any number of degrees, either to display a movement, or to expose the screen to an individual, displaying any information that can be shown using one.

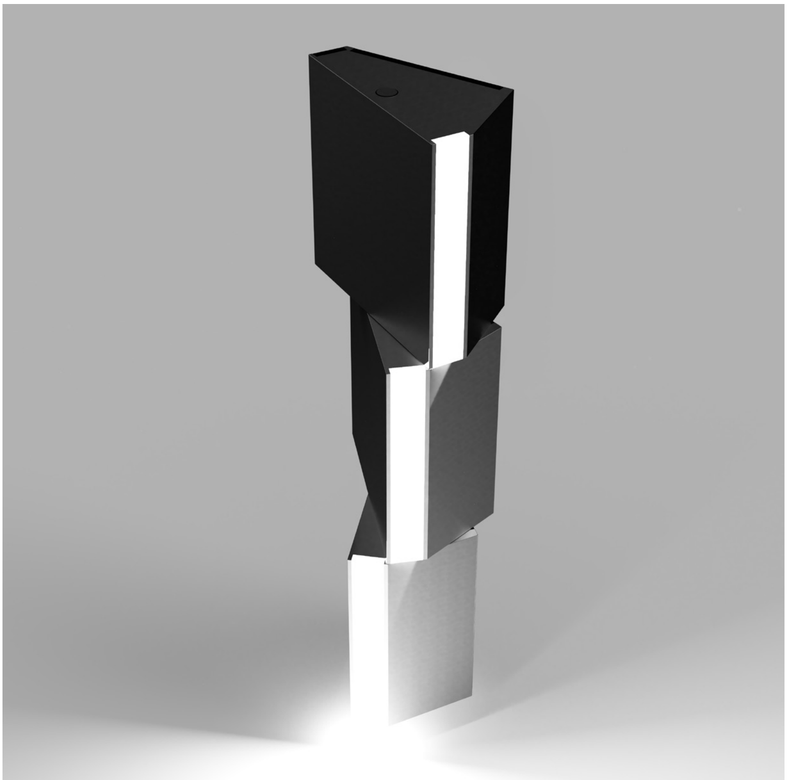

PIVOT POINT
SCREEN
LED STRIP
6 MODULES



COMMUNICATION WITH THE ENVIRONMENT

The 3 keys placed on each corner follow a similar formula. They are in the shape of a prism, however, to match the contours of the boat's design. Two of the prisms surfaces are aluminium plates, to match the exterior, while the third surface, hidden when not in use, houses the screen that can be exposed by rotating the prisms around. These prism shaped keys also serve another purpose, which is to point in the direction of the boat's trajectory, showing to everybody in the environment where it is going.





This eHMI design is a result of understanding the needs for what needs to be displayed and when, while still flexible enough to be discreetly hidden from plain sight and integrated in the simplicity of the vessel's design. Its flexibility allows the XAI to have various ways of displaying an action, strengthening the perceived meaning for the secondary user. This flexibility also enables certain communication conditions to be exclusive to one part of the eHMI, making it possible to display multiple meanings at the same time. Offloading ferry's non-critical intent to more ambiguous parts of the eHMI (like lights and movement) was the way to ensure unequivocally perceived interfaces available for crucial situations.

COMMUNICATION WITH THE ENVIRONMENT

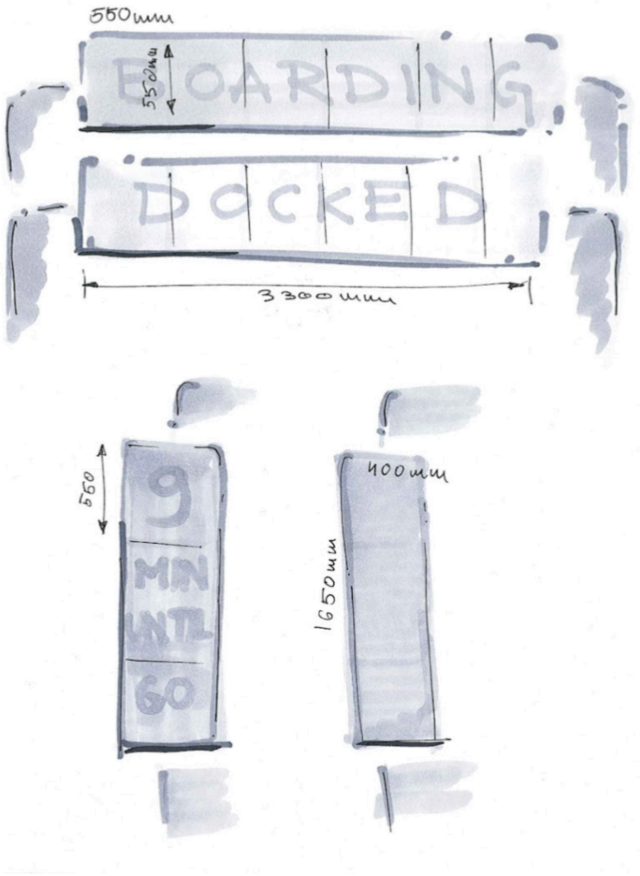
Implementation and Application

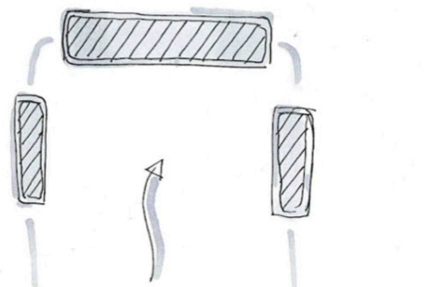
Circling back to the list of nominal conditions set at the start of this chapter, an appropriate application of the eHMI needs to be set. Considering the possibilities of the eHMI, different solutions can be created for particular situations.

The application of the created eHMI has among other things been influenced by the work of Jonas Selvikvåg, a student that has previously worked on creating communication patterns for the MilliAmpere 2 autonomous passenger ferry (Notion, 2020). He has outlined a number of situations and how to communicate the ferry's intent and actions using LED light strips on both sides of the vessel paired together with led light matrices on the front and stern of the boat. He has considered those as guidelines and gave a round of reflections as well as tested the ideas on a 1:10 scaled model of MilliAmpere 2.

Applications of the new eHMI have been directly developed by solving the previously outlined conditions and are a result of all the research, experience gathered from testing and rounds of ideation supervised by mentors. The following list presents the conditions and their respective solutions described in words. It also shows which part of the eHMI the action is using, as to give a quick overview of interface usage.

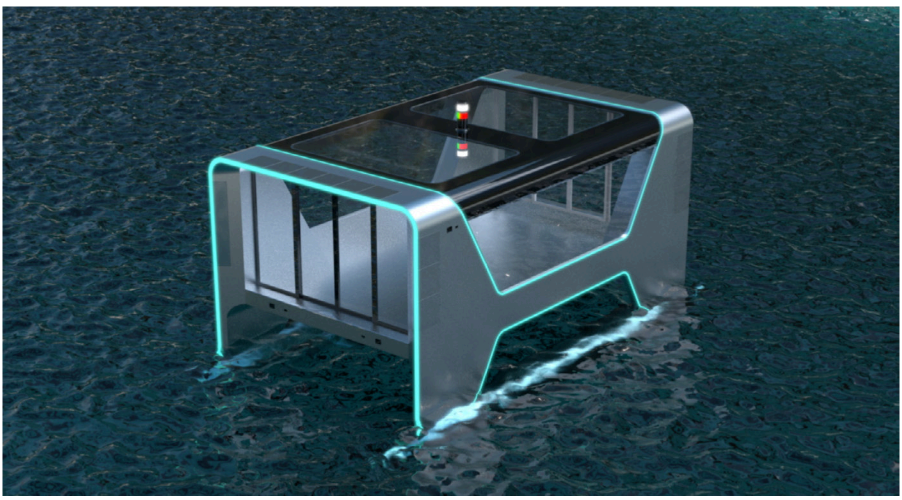
Animations of every solution can be seen in a short video on the provided link (Youtube): https://youtu.be/QhoJ9QtSrlk


550mm
BOARDING
550mm
DOCKED
3300mm
550
9
MIN
UNTIL
60
400mm
1650mm

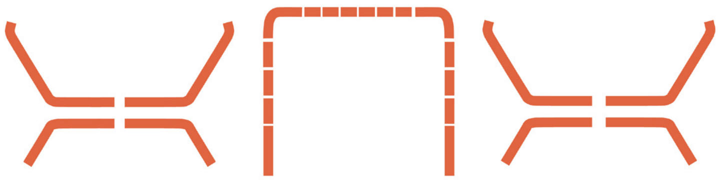

POSSIBLE
ZONES OF
COMMUNICATION.

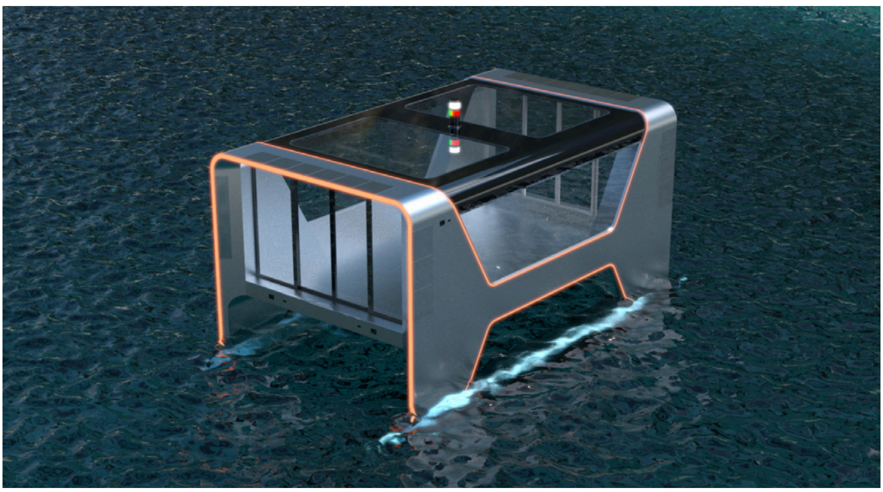
INDIVIDUAL PARTS
COMMUNICATION WITH THE ENVIRONMENT

1 The ferry is in autonomous mode.
-uses side lights, front lights
All lights glow turquoise (#40E0D0)

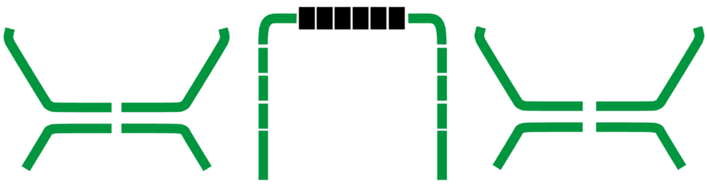


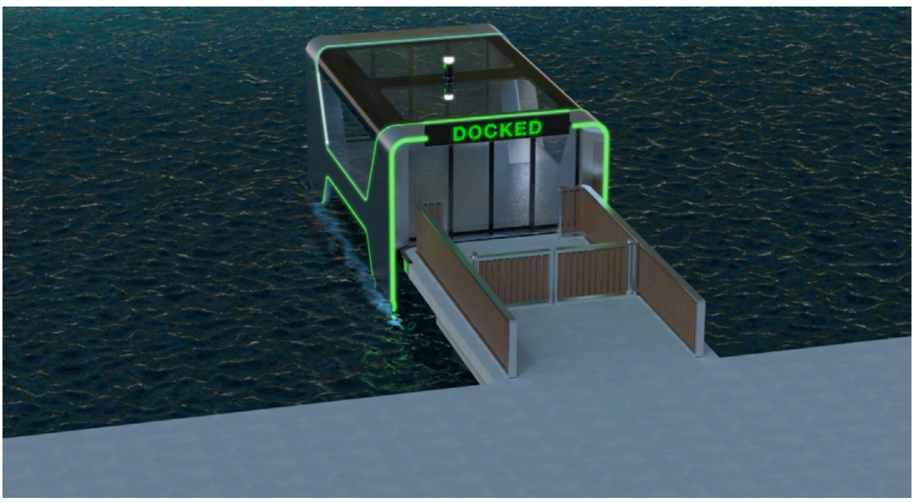
2 The ferry is in manual mode.
-uses side lights, front lights
All lights glow orange (#E06540).
This is a complimentary colour to turquoise in the RYB colour model.



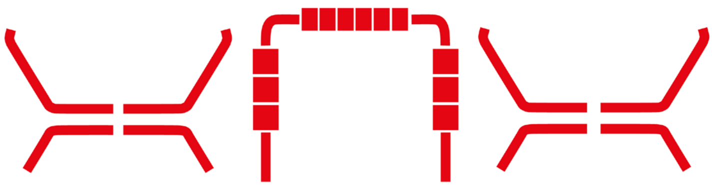


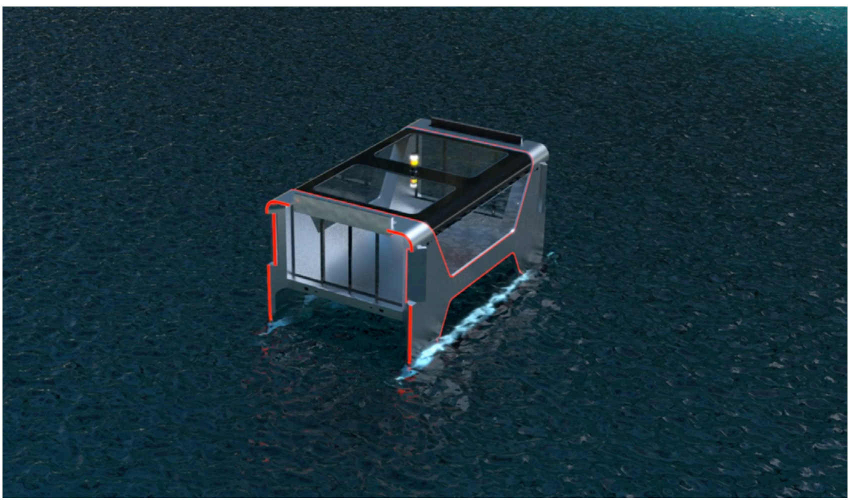
3 The ferry is docking.
-uses side lights, front lights, top piano, screen.
All lights pulse turquoise. The top piano makes a sequence of keys starting from inside out. 321123 with keys marked as 1 going first. When docking is complete all lights turn green and the word DOCKED appears on the top display. During this idling process of being docked, all lights breathe a green colour to show the ferry being in standby.



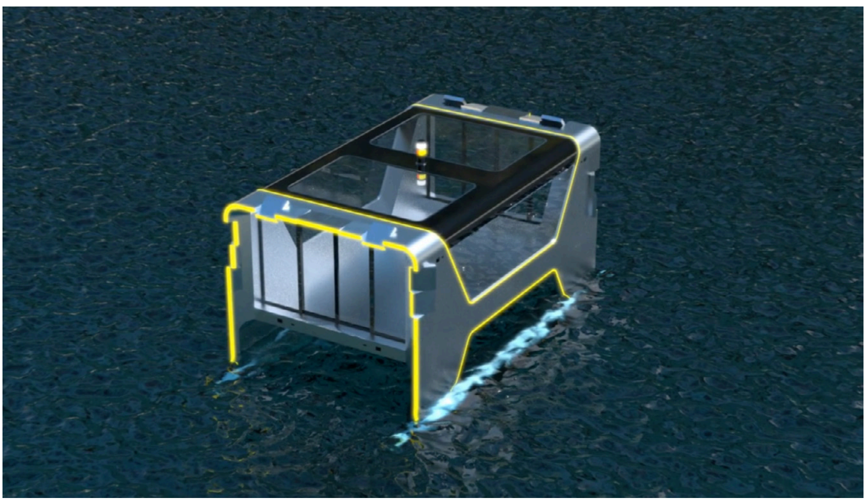


4 The ferry is in panic mode.
-uses side lights, front lights, flaps, top piano
All lights pulse red, the flaps move left to right together with the top piano keys going up and down.

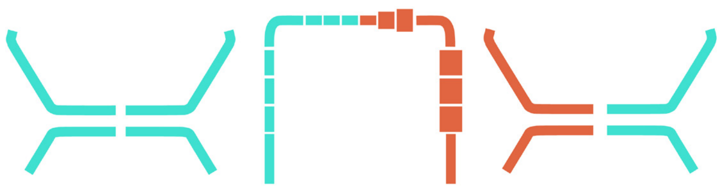


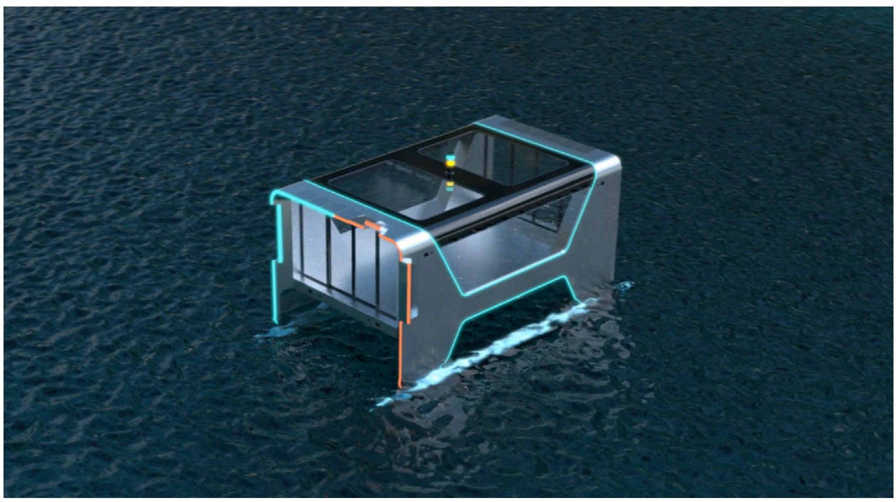


5 The ferry is attracting attention to itself.
-uses side lights, front lights, flaps, top piano
All the lights pulse yellow, the top piano and the side flaps create one complete sequence which starts from the middle of the piano going out.

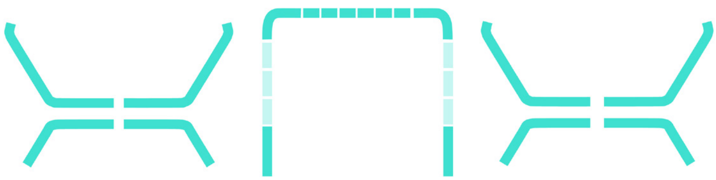


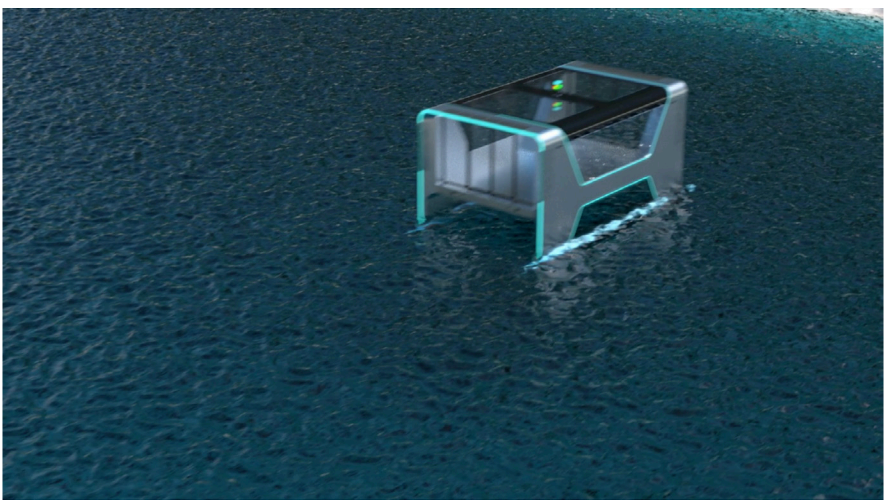
6 The ferry is performing a turn.
-uses flaps, top piano
This action is different from the condition: 10 Ferry direction of movement. This action refers to an abrupt movement by the ferry where the course of the vessel needs to be changed more than 30 degrees at once. The front 2 flaps point in the direction of movement and the turn while turning to orange and blinking, very similar to an automobile. The turning half of the top piano also turns blinking orange while following a movement from 1 to 3, first being the key farthest away from the turning corner. This sequence is used regardless of the direction the ferry is turning (left and right), just mirrored according to the side.



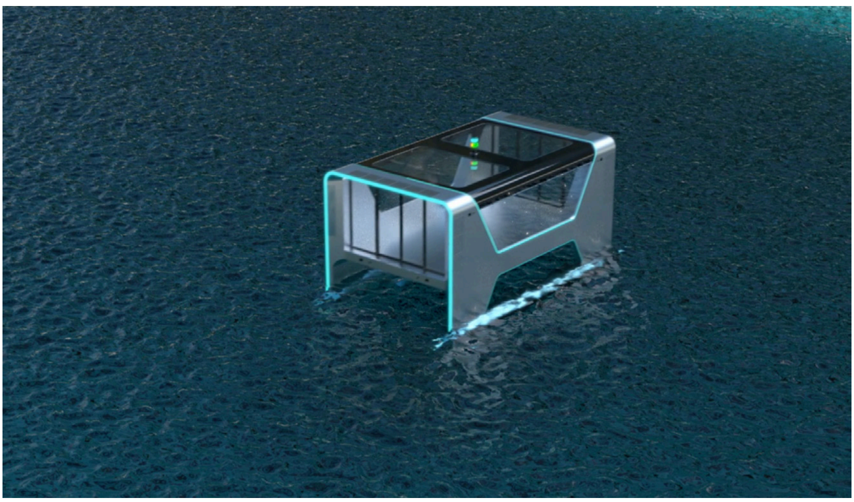


7 The ferry is speeding up.
-uses front lights
The flap part of the front lights pulse in the direction the ferry is accelerating in.



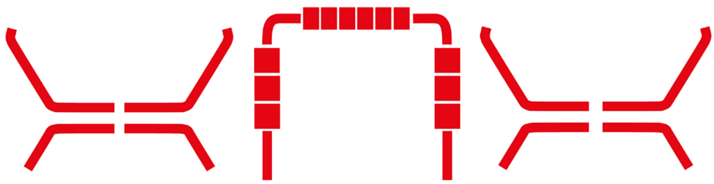


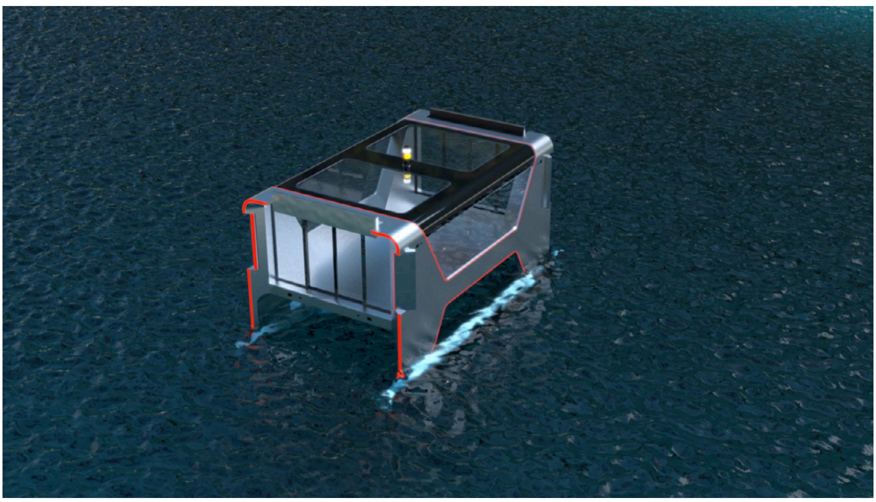
8 The ferry is slowing down.
-uses side lights
The bottom part of the side light pulses.



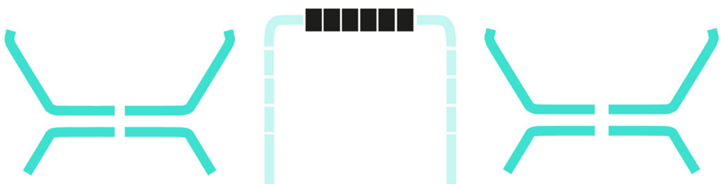
9 The ferry is performing an emergency stop.
-uses side lights, front lights, flaps, top piano

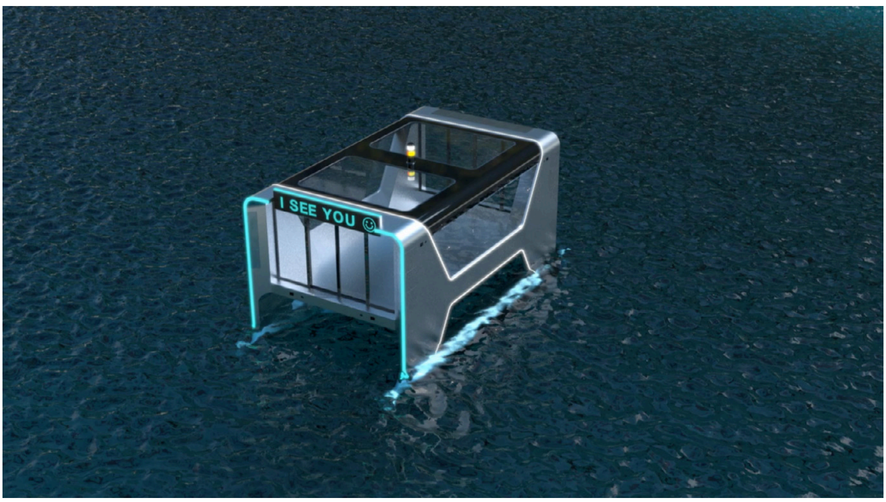
The flaps point inward, as well as all top piano keys, simultaneously. This idea is meant to remind of the flaps on a plane that is landing and braking. The lights start flashing red.



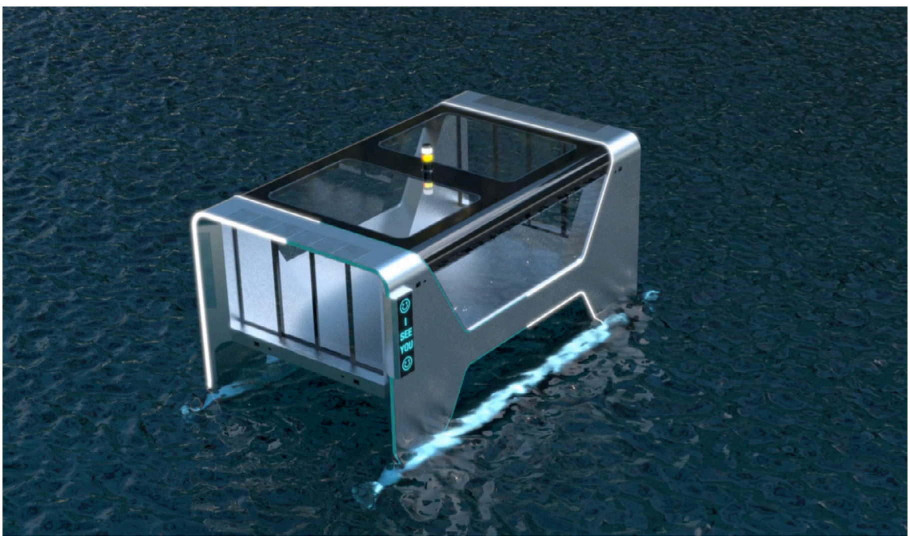


10 The ferry perceives a secondary user.
-uses side lights, front lights, screen
Situation 12 a)
The secondary user is closer to the longer side of the ferry. The closest flap turns into a screen and displays a message: I SEE YOU, following up with a smiley face. The quarter closest to the user pulses turquoise.

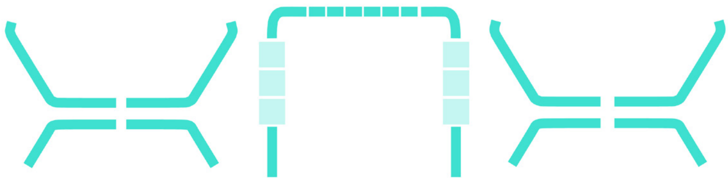


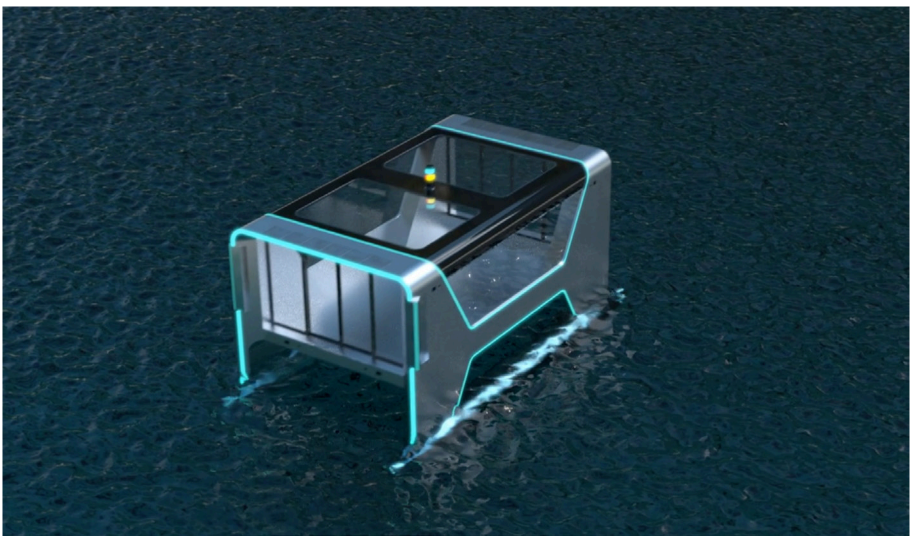


Situation 10 b)
The secondary user is closer to the shorter side of the ferry. The piano keys rotate into a screen and display a message: I SEE YOU, following up with a smiley face. The whole front of the vessel pulses turquoise.



11 The ferry is showing its direction of movement.
-uses flaps
The flaps point in the direction the ferry is going in. Those flaps also glow in turquoise.

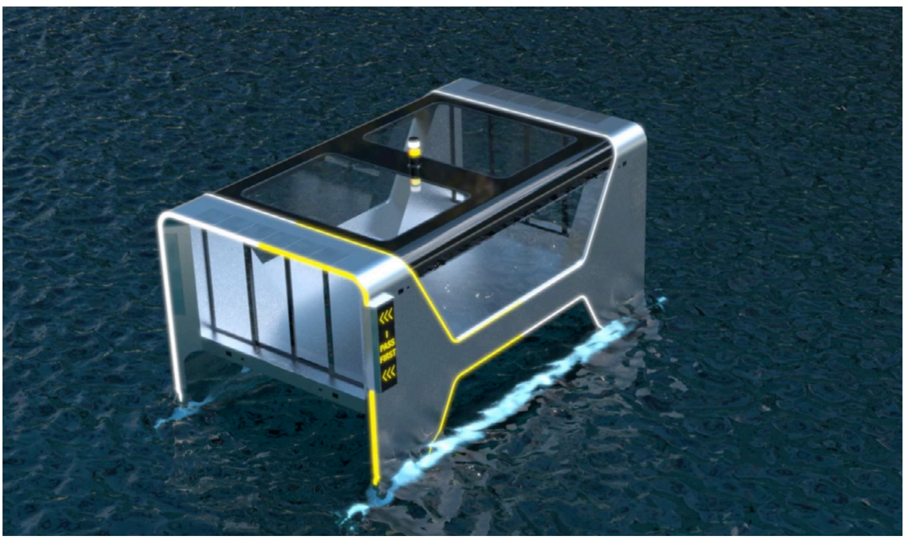




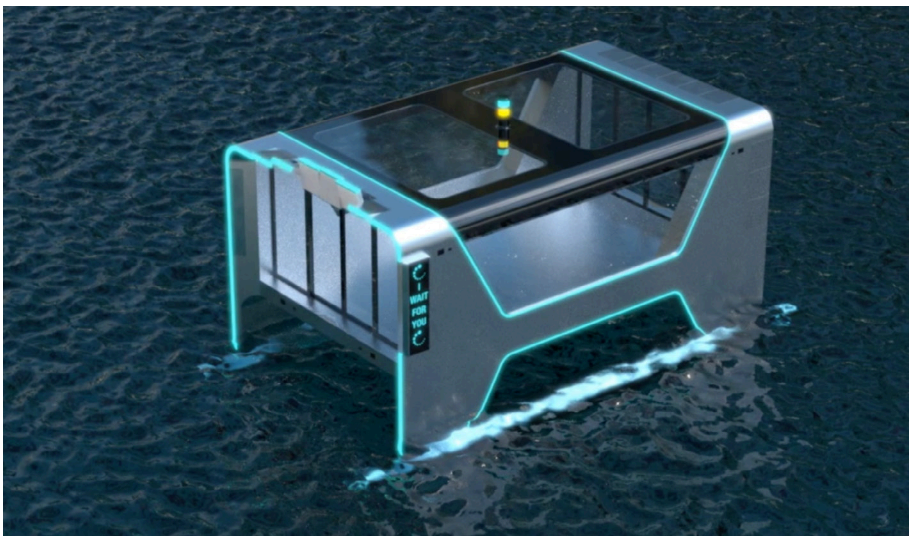
12 The ferry goes first, while the secondary user has to wait.

-uses side lights, front lights, screen

The quarter of the ferry starts pulsing yellow, to grab the users attention. The corner closest to the user rotates from the flap, transforming into a screen and displays a message: I CROSS FIRST. A discussion here is whether the message displays a third person's view perhaps, like: THE BOAT IS CROSSING FIRST, THE BOAT IS PASSING BEFORE YOU, or should the boat be considered its own separate entity. Furthermore, the inclusion of symbols can be beneficial, as they are most accurate and legible from a distance, but those require learning. They also need not to mark a direct instruction, as in: DO NOT CROSS, or similar. The included symbol for this situation is a pointed arrow, to show the direction the boat will be moving in.



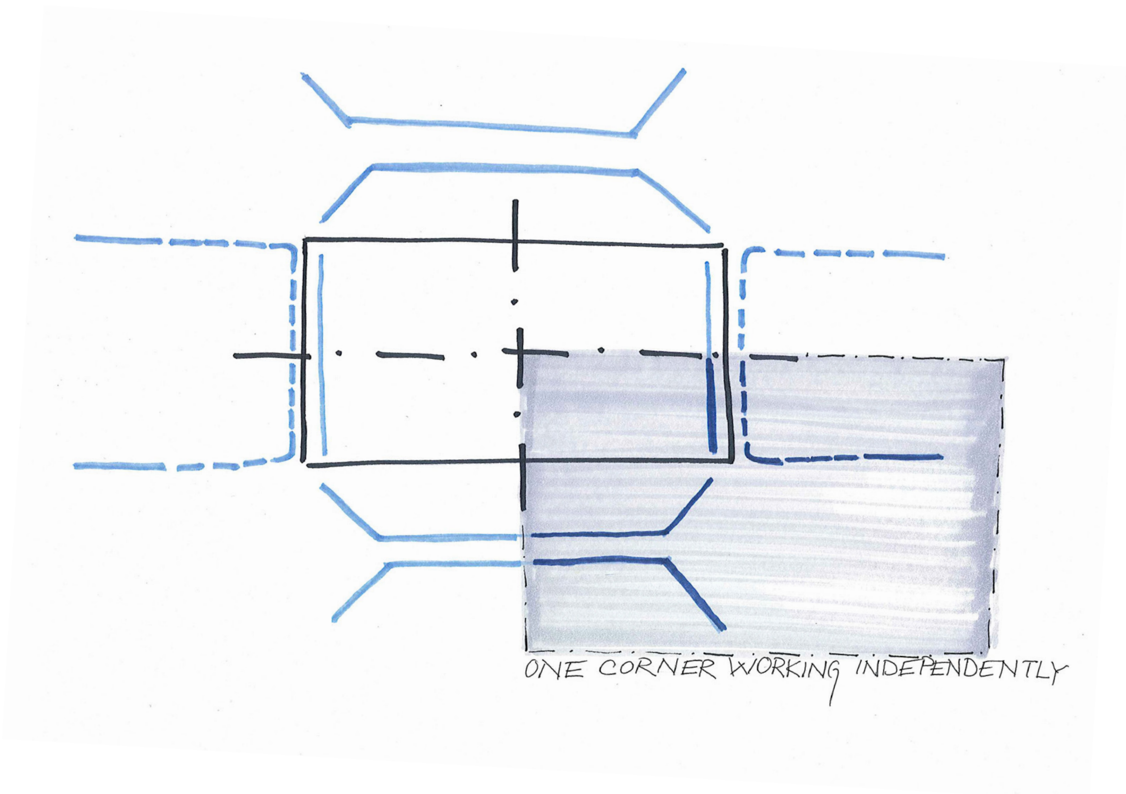
13 The secondary user goes first, while the ferry waits for them to pass.
-uses side lights, front lights, top piano, screen
The quarter of the ferry starts pulsing turquoise, to grab the user’s attention. The piano raises its keys from 1 to 6, first being the closest key to the user. The corner closest to the user also rotates from the flap, transforming into a screen and displays a message: I WAIT FOR YOU. The symbol used to add a layer of understanding is a simple loading symbol, an egocentric way of showing what the boat is doing. Symbols do pose a dilemma, if understood without reading the text the secondary user does not know if the symbols meaning applies to them or it applies to the ferry’s intention. Because of this, we concluded that it is a must to show a symbol in conjunction with the text, getting a correct understanding of the situations variables.



INDIVIDUAL PARTS

COMMUNICATION WITH THE ENVIRONMENT

The possibilities of the ferry are divided into quarters, and those quarters consist of a top part and a side part of the ferry, which basically implies there are 8 sections in total. The system works in a way where a signal of higher priority takes over the section. If, for example, the boat is turning right but also needs to communicate the right of way to the user, the quarter in charge of communicating crucial information stops signalling the direction and starts showing the screen to the user. This eHMI design allows for displaying multiple signals at once, depending on the quarter.



The legibility of the text depends on a number of factors. Some of them include, distance of perception, pt size of the text, typeface, etc. For the text used on this project, I have used Helvetica Neue Bold for the Top piano screen and Helvetica Neue Condensed Bold for the flap rotational screens. The latter was chosen as these screens are taller than wider thus the font placed there needed to fit inside the dimensions. Helvetica is known to be a widely recognized typeface and it has been rated as very legible (The Next Web, 2011).

The letters on the Top piano screen are around 30cm high, while the ones placed on the sides are around 15cm high. 30 cm text's maximum viewable distance is 84 metres, the distance for easy readability is 34 metres and the distance for the text to have maximum impact is 17m. 15cm's text maximum viewable distance is 46 metres, the distance for easy readability is 18 metres and the distance for the text to achieve maximum impact on the reader is 9 metres (The Sign Chef, 2022).

	Letter size	Max Vieawable distance	Easy Readability	Max Impact
Top piano screen	30cm	84m	34m	17m
Flap side screen	15cm	46m	18m	9m

Because of this, only on those distances or smaller it makes sense to display text on screen, as other scenarios would make the screens illegible. Light and movement however can be seen from much further distances (depending on the light intensity used) so it would be logical to use them accordingly.

Discussion and Conclusion (continuation and testing)

These guidelines for designed signals are up for discussion and included ones are a result of this design process . The external human-machine interface developed in this chapter, for the needs of the passenger ferry should be the base for the continuation of testing and further design. I have created this tool of expression for the boat that contains a combination of light, text and movement but the precise interactions that are to happen should be further looked into and decided upon. It is imperative that those at some point go through many rounds of testing, until a satisfactory result and a common understanding for the public is achieved. As mentioned previously, in the coming years of autonomy development there is a chance for the process of standardisation to take place. Nonetheless, a commercially available vehicle such as this, the next generation Zeabuz, will be capable of communicating its autonomy to the outside world - even if other included participants are not familiar with maritime rules.

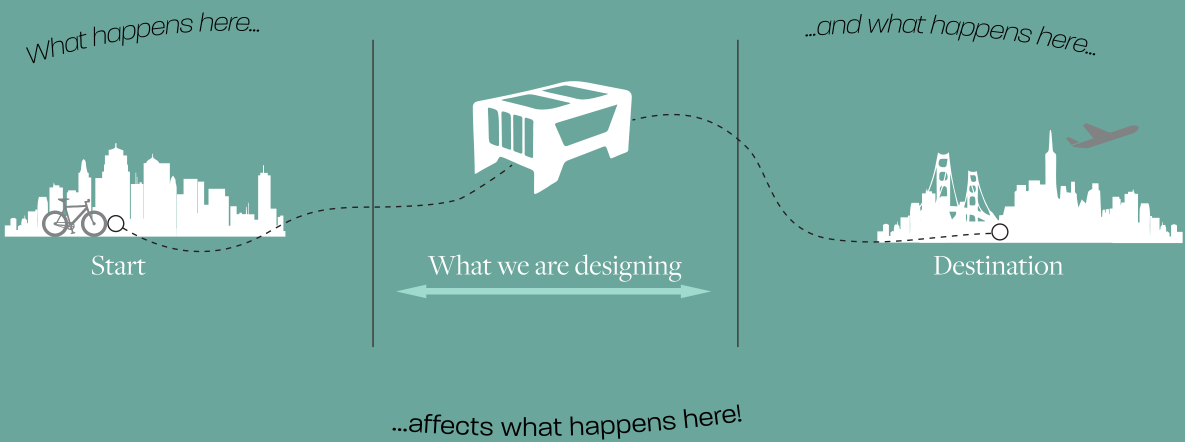
INDIVIDUAL PARTS

PASSENGER JOURNEY

The goal of this individual part was to dive deeper into the aspects affecting the passenger journey when taking the ferry. A major part of this work was designing a passenger journey map and conducting a user test for gathering insights on interior layout and passenger flow. Malene Liavaag had the main responsibility of this part. She worked closely together with Hilmar Nypan Claes as his work with the ferry interior was linked to the insights of the passenger journey.

While Følstad and Kvale (2018) use the term customer journey, we use the term passenger journey for this thesis, as the primary users are passengers. Følstad and Kvale (2018) describes customer journey mapping as the activities one must do to analyse a service as it is from the users perspective, often as a part of the research phase in a design process. These activities may be gathering qualitative or quantitative data, customer insights, the implemented service processes or other findings from the research. Developing the complete service design for Zeabuz is outside the scope of this project. Although, we wished for an overview of the insights we had gathered at this point, along with seeing how they could act out from a passenger's perspective.

The boundaries of the project are set to focus mainly on the design of the ferry. As the ferry will be a subpart of a larger urban mobility service, it is still a necessity to consider where the passengers start their journey, where they aim to travel to and what they are planning to do at the final destination. As an example, a student may bring a backpack, while a traveller may bring a suitcase on board. The passengers will need space for their belongings. Obviously this will affect the interior design. To gather a deeper understanding of how we could design the ferry to adapt for these different situations from the eyes of the user, a passenger journey map with service touch points was made.



What happens here...
...and what happens here...
Start
What we are designing
Destination
...affects what happens here!

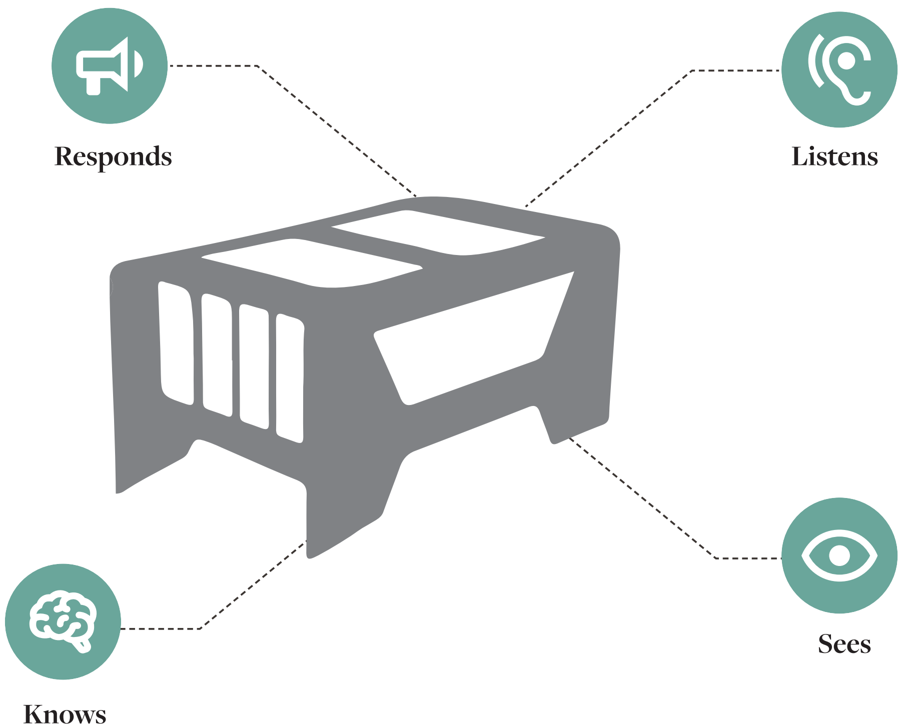
Research for making scenarios

Research from the insight chapter was used as a basis for mapping the passenger journey. In addition, topics such as trust in autonomous vehicles, insights from the MilliAmpere 2 project and universal design principles on ferries were investigated further in this individual part, for more solid data to make scenarios for the passenger journey.

Trust in autonomous transportation

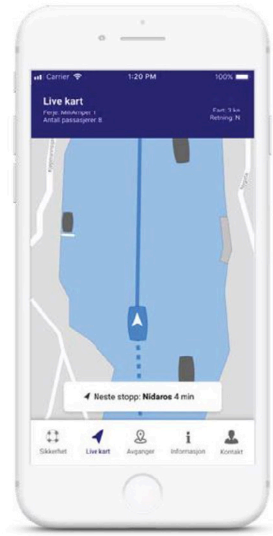
In the Trust-chapter, we briefly mentioned a report by Intel that discusses the importance of designing for trust in autonomous vehicles. There is a difference between autonomous cars and ferries, as passengers on board ferries are used to not seeing the operator. However, we believe some insights may be transferable when it comes to trust. Intel recommends four capabilities of the design for making it trustworthy. The first is that the passengers must know what the autonomous vehicle is sensing, both of its environment and of the passengers inside. The second capability is to provide clear, bidirectional communication. For example, passengers must be able to alert about emergencies, and they need to trust that the communication is reliable. Furthermore, the third recommendation is that the vehicle must respond to changes, so that passengers trust that the system is working correctly. Lastly, the fourth capability is to use multiple modes of interaction.

This is because different passengers use different devices. In addition, their attention will fluctuate during the trip. For example, if the service relies on providing information on an app only, a phone user will miss important information if they receive a call when taking the ferry. If the ferry uses several communication channels, such as an information screen and voice messages in addition to an app, it increases the chances for the message to be received by the passenger.


Responds
Listens
Sees
Knows

Live data sharing

For comprehensive sensing, Andreassen (2020) designed a live map in an app that shows what MilliAmpere 2 sees in the surrounding environment. In addition, for showing response to change, it shows the passengers how the ferry reacts to the environment. As a result, the ferry shows that the system is working correctly and may increase the passengers' feeling of safety. We believe in the idea of honestly showing what is going on. However, Universell Utforming (2022) recommends using several communication channels to provide information to the passengers, to make sure the information is available for all passengers. This is also in accordance with Intel's recommendations for multiple modes of interaction. Thus we decided to include live data sharing on an on board screen, in addition to a web page and an app. We took inspiration from the live map idea by Andreassen. A sketch of a live map was made to serve as an example for the renders in this project.



Map and app designed by Andreassen (2020)

Sketch of live map for screen on board the ferry

Safety information

It was discussed how safety information should be displayed on board. Pantelatos (2022) has been working on the ongoing research project TRUSST. He discovered that many of the participants expressed that they are not interested in a 2 minute auditory safety brief for a 2 minute ferry trip. He recommended us to have a poster with safety information, and provide auditory safety briefs on the app and at other stages in the user journey - for example, if the passengers have to wait for the ferry at the quay. Additionally, he recommended having a poster on board instead of a screen, for the risk of having technical issues.

Safety information on board MS Jektøy (Skipsrevyen, 2018)

Passenger emergency button

A physical emergency button was designed by Andreassen (2020) for contacting the shore control operator on board the ferry. This gives the passengers a feeling that they are in control of the trip, thereby it will align with Intel's recommendations of bidirectional communication and response to change. To further develop this idea, we recommend placing these buttons within reach for all passengers, to shorten the time from an emergency situation occurring until help is on the way.

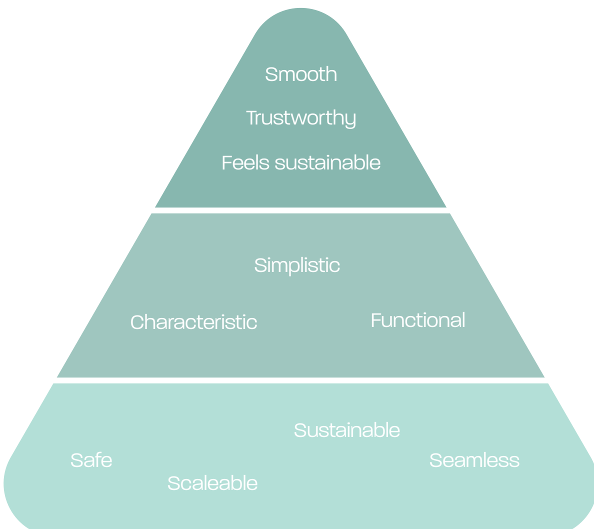
Button designed by Andreassen (2020)

Zeabuz' values

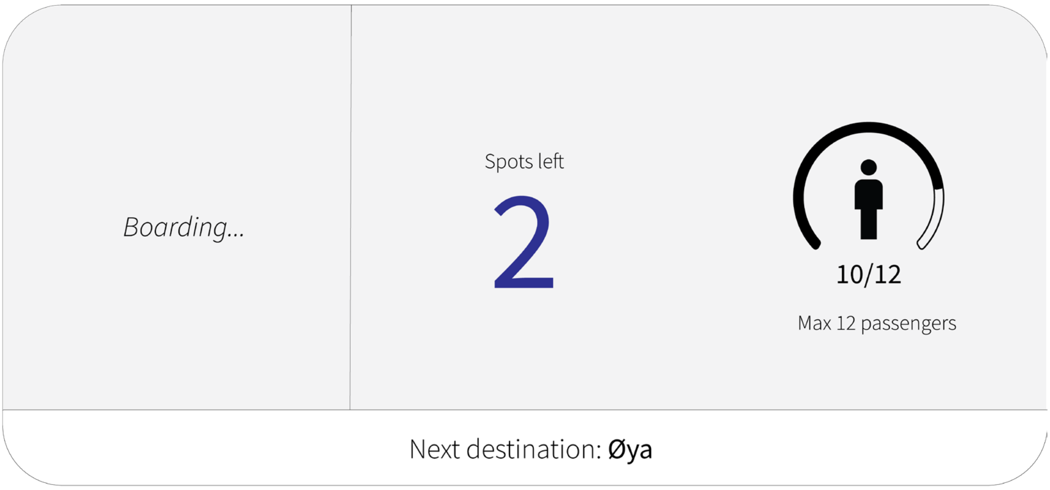
Another aspect that was considered when making the scenarios was to keep in mind the defined values from the workshop with Zeabuz and other wishes that have been expressed through our meetings.

The users should get a feeling of the defined values such as seamless, smooth, safe and sustainable after the meeting with Zeabuz' service. We believe a smooth and seamless journey is to be able to get from A to B without doing anything more than you need to. When discussing tickets, we decided the most seamless journey is to have a ticket-less system and use technology for passenger counting.

The Zeabuz ferry should be a part of the local municipalities mobility service. Ellingsen and Glesaaen (2020) argued in their master thesis that a passenger counting system by the use of camera technology should be possible. Ellingsen and Glesaaen (2020) made user interfaces for how the passenger counting can be visualised for passengers walking on board. This is in line with the recommendations of Intel, that the ferry should show the passengers what it is sensing. We took inspiration from Ellingsen and Glesaaens (2020) ideas, and made a sketch for illustration purposes.



Zeabuz' defined values



Sketch of screen showing passenger counting on board the ferry

Efficiency in public transport

Ellingsen and Glesaaen (2020) did interviews with citizens in the streets of Trondheim to gather an understanding of their user experiences with public transport. Despite their thesis focused on passenger docking ramps for MilliAmpere 2, they wanted to investigate if experiences with the existing public transport in Trondheim could be adopted to their case. When asking the citizens, efficiency was valued higher than enjoyment, when choosing a travelling route (Ellingsen and Glesaaen, 2020). This can be used as an advantage for Zeabuz when introducing their service to users. When going from A to B, the Zeabuz ferry may cover a part of the user's travel route. For example, the ferry can appear in travel route apps such as Google Maps. If the route with the Zeabuz ferry is more efficient, users may choose to travel with Zeabuz. When the Zeabuz ferry is suggested in the travel route, it should be easy for the user to navigate to Zeabuz' webpage to learn more about the service.

Universal design principles

Universell Utforming AS have made an online guidance document for how to universally design passenger ferries. The recommendations are for ferries with length over 15 metres. As there are no recommendations available for ferries at the size we are designing, we have tried to follow the principles we were able to. Universell Utforming (2022) recommends using several communication channels to provide information to the passengers, to make sure the information is available for all passengers. A report by BufDir (2018) summarises that disabled passengers in Norway have had the following challenges with passenger ferries: Blind people have had trouble with finding the correct ferries. Navigating on board is another challenge of the same user group, because of too little contrasts on board. For deaf people, it was reported that the information needed was difficult to access. People with cognitive disabilities have reported poor availability of information such as departing times, and in general an overload of impressions.

For the user journey map, we went through the scenarios with different disabilities in mind, constantly asking ourselves how to give a good experience for all citizens. This led to having information screens, physical references and both sound and light as interaction elements in the service touchpoints.

Further universal design recommendations we have aimed to follow for the arrangement inside the ferry are being addressed in the Passenger flow chapter at page 262.

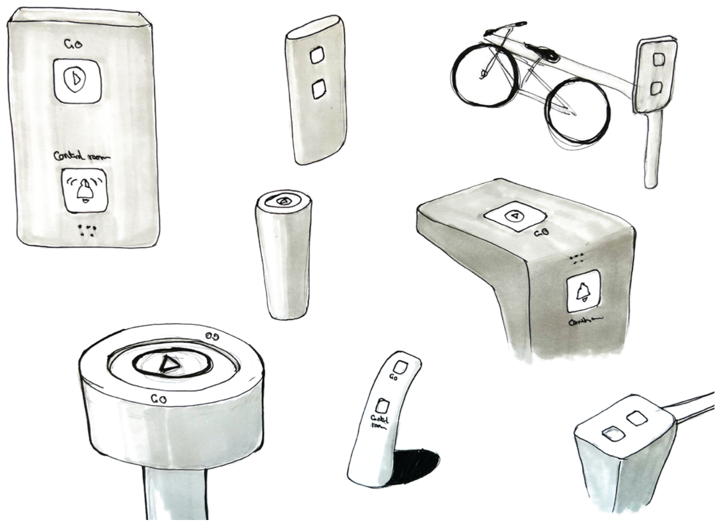
Universally designed interior in the passenger compartment at the ferry MS Harøy.

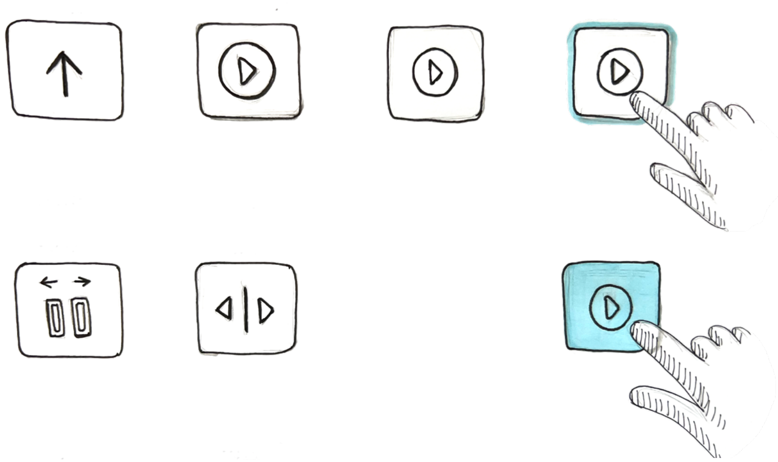
Go-button

Another thing that affects how seamless the journey feels, is to what degree the user controls when the ferry departures. There were different opinions in the group of what was the best solution. We had three proposed solutions:

1. The ferry departures when an on board passenger pushes a "go"-button
2. The ferry departures when no more passengers are being detected on the quay or when the ferry is fully boarded
3. The ferry follows a time-schedule

In the first iteration of the passenger journey, it was decided to design a "go"-button. After asking about this in the user test (see next chapter Passenger flow) we learnt that none of the 10 users wanted a "Go"-button. Thus, we reconsidered that solution 2 must be the most seamless solution, as it will adapt to the demand during the day. In addition, passengers will not have to worry about when the ferry is going, as they will get the first available ferry anyways when they get to the quay.


GO
Control room
GO



Passenger Journey Map

At this point in the thesis, the next step was to start designing the interior of the ferry. By making a user journey map, we aimed to use it as a guide for the interior design iterations. Further user insights were collected by testing some of the iterations (see next chapter Passenger flow). After testing, the user journey map was updated with the new findings.

The passenger journey map should not be considered as a presentation of all needed insights for the future service. We recommend Zeabuz to see it as an alive map that can be adjusted as more user insights are collected. The approach of using customer journey mapping for designing a service that may be, has been described as customer journey proposition by Følstad and Kvale (2018). As an example, a possible application for Zeabuz in the future may be to use it in co-creative sessions to get user feedback. For example, they may remove one service touchpoint, and ask users what they would like to have there.

The passenger journey map is made by building scenarios of the passenger's intentions and needs. As we are designing for the future, we cannot know for sure what technology the service touchpoints will be based on. However, we believe primary user needs today will still be relevant 5-10 years from now. The need to feel safe, to feel comfortable, to have sufficient information and to get efficiently from destination A to B will be just as important. Thus, the scenarios aim to describe primary user needs, while the service touchpoint map serves as an example of how Zeabuz may cover these needs through their service.

PASSENGER J

1 HOME/CITY

There are two scenarios for where the user journey with the service starts:

1. The user is at home or somewhere on the go in the city, planning to get to a destination in the city. When doing a travel search in google maps, the ferry occurs as a suggested travel route. The user learns about the service through a google search that leads to Zeabuz' web page. On the web page, the user gets information about the app, and where to download it.

2. The user is a tourist, that has learned about the Zeabuz ferry through travel profiles on social media. Other users have learned about the service through recommandations from their travel agency.

First-time users find answers to all their questions about the ferry and the service on the web page and in the app.

2 QUAY

Physical installations clearly shows that the passenger can board the ferry here, in both daylight and at nighttime. Information screen and calling-button are easy to notice for all users.

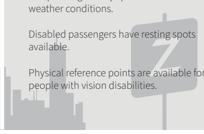
The app detects GPS signals from the passengers phone, and gives a notification that you can call the ferry. The passenger calls the ferry by pushing the calling button. A sound and light signal from the button gives feedback that the ferry is on its way.

The information screen provides information about the state of the ferry and how many passengers are on board. If the ferry is not at quay, passengers will be provided with information about approx. arrival time.

The passengers stays protected from the weather conditions.

Disabled passengers have resting spots available.

Physical reference points are available for people with vision disabilities.



3 ENTERING

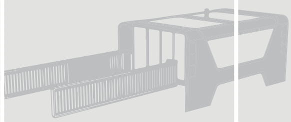
Railing and solid ramps keeps all passengers safe the way from the quay to the entrance. Moving lights shows the way.

The ferry sends sound signal followed by a voice message when it is ready for boarding.

A gate with motion sensors register each passenger. A sound and light signal gives feedback that the passenger has been registred.

The sliding doors of the ferry is normally closed, and opens when motion is detected.

When the ferry is fully booked, the message is shown on the information screens. In addition, the ferry makes a sound and light signal for passengers on quay and passengers on board.



4 RESTING

The passenger finds a comfortable resting area on board, with good view.

The passenger can drop hand-held luggage next to the resting area.

The passenger thinks the resting area looks scandinavian and instagrammable.

The temperature is at a comfortable room temperature.

5 DEPARTURE

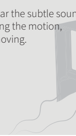
If no other passengers are being detecte on the quay, or if the ferry is fully booked it will automatically start departuring.

The passenger is being told when the fer is about to departure on the information screen and with a sound signal followed by a voice message. If a passenger changes its mind and walks through the doors within 5 seconds, they will be detected by motion sensors. The doors will be held open until motion is no long detected, then the ferry will continue on its departuring process.

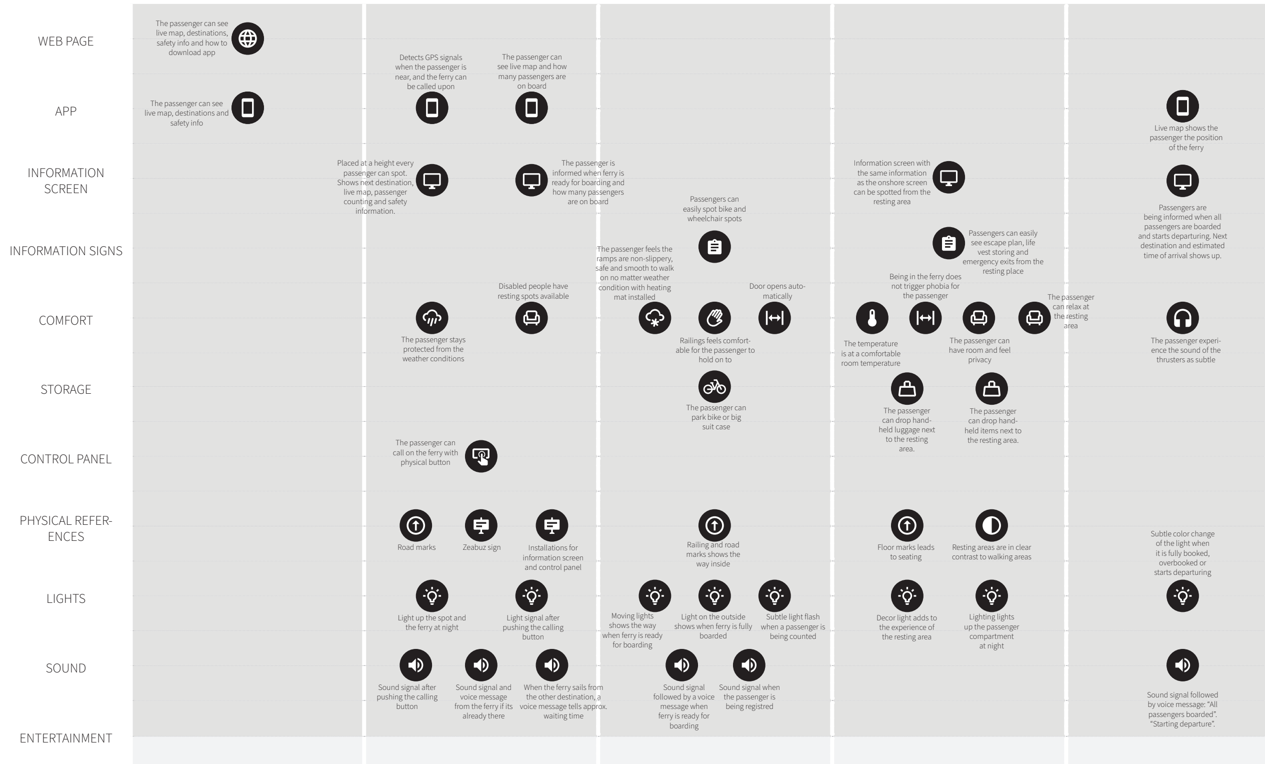
A live map on board and in the app show what the ferry is doing and planning.

By looking out of the windows, the passengers can see when the ferry starts moving.

The passengers can hear the subtle soun of the thrusters changing the motion, when the ferry starts moving.



SERVICE TOUC



MAIN SERVICE P

SOUND & LIGHT TECHNOLOGY

Can be used at all steps at the docks and onboard, to ensure that all passengers including disabled get access to the needed information and get feedback on actions. In addition, decor light may be used for enhancing the experience on board. Furthermore, sufficient lighting at night may reduce the risk of vandalism occuring.

LIVE DATA SHARING

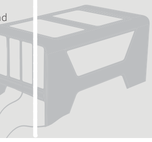
If the ferry communicates what is senses and plans to the passengers, their feeling of safety may increase. The passengers will also be able to see if the ferry is sensing its environment correctly. A live map and passenger counting will communicate that the ferry is alive and functioning. The map should be available at multiple channels to be available for all.

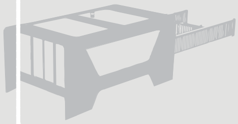
PASSENGER EMERGENCY BUTTONS

To provide a two-way communication and give the passengers a feeling of control, emergency buttons should be available on board the ferry. The emergency buttons may serve as calling buttons, for contacting the operator at the shore control centre.

OURNEY

6 FERRY MOVES	7 ARRIVAL	8 EXITING	9 QUAY	10 DESTINATION
The live map shows what the ferry does. The steering direction, next destination and time until arrival shows on the information screen. When the ferry spots an object, it appears on the map as an object. If the ferry has to stop moving or changes direction, a message will appear on the information screen with an explanation for the devation motion. Safety information can easily be spotted from where the passengers rests, and on the web page and in the app.	The passenger are being informed on the information screen when the docking starts and time until arrival. When docking starts, a sound signal and subtle light signal followed by a voice signal is being played, so the passenger is being informed it is soon time to leave the ferry.	A sound signal will appear, and be followed by a voice message when the ferry is moored and ready to unboard. A gate with motion sensors register each passenger. A sound and light signal gives feedback that the passenger has been registred. Railing and solid ramps keeps all passengers safe the way from the quay to the entrance. Moving lights shows the way.	The passenger stays protected from the weather conditions. Disabled passengers have resting spots available. Physical reference points are available for people with vision disabilities.	The passenger reaches the other rural area, workplace, school, hotel or home. The passenger felt the use of the ferry was smooth, safe and sustainable.





HPOINTS

6 Ferry moves

- Live map shows the passenger what is happening and why
- Passengers are being informed about steering direction, next destination and time until arrival.
- If the emergency button is being pushed, a message will occur on the screen
- When the ferry spots an object, the passengers can see it on the live map in additon to information text
- The passenger can push an emergency button for calling the shore control lab
- Emergency button lights up if it is being pushed
- "Calling shore control lab"
- Something changeable adds to the experience, and excites both citizens and tourists: Self serving Ice cream machine, self serving svele machine, seasonal decor light-show

7 Arrival

- Passengers can see when the docking starts, and time until arrival.
- Passengers are being informed to please wait
- The passenger experience the sound of the thrusters as subtle
- Sound signal followed by voice message: "Arriving destination in 20 seconds."

8 Exiting

- Message informing that the ferry has docked appears.
- Passengers can see exit sign at the exit
- Door opens automatically
- The passenger feels the ramps are safe no matter weather condition
- Railings feels comfortable for the passenger to hold on to
- The passenger can fetch bike or big suit case at spot without blocking for other passengers
- Floor marks shows the way to exit
- Railing and road marks shows the way to the quay
- Moving lights shows the way to the exit
- Subtle light flash when a passenger is being counted
- Sound signal followed by voice message: "Doors are opening"
- Sound signal when the passenger is being counted when exiting

9 Quay

- The passenger stays protected from the weather conditions
- Disabled people have resting spots available
- Road marks
- Zeabuz sign
- Installations for information screen and control panel
- Light up the way to the quay, the spot and the ferry at night

ROPOSALS

WEB PAGE & APP

Zeabuz should have online platforms were users can learn more about their service . Multiple channels should be used for reaching all users.

ONSHORE INSTALLATIONS

To make the service dicoverable for all passengers including disabled, Zeabuz should have physical on-shore installations at docking spots. Safety information, resting spots and weather-protection should be installed at these spots if there is waiting time for the ferry.

PASSENGER & MOTION DETECTORS

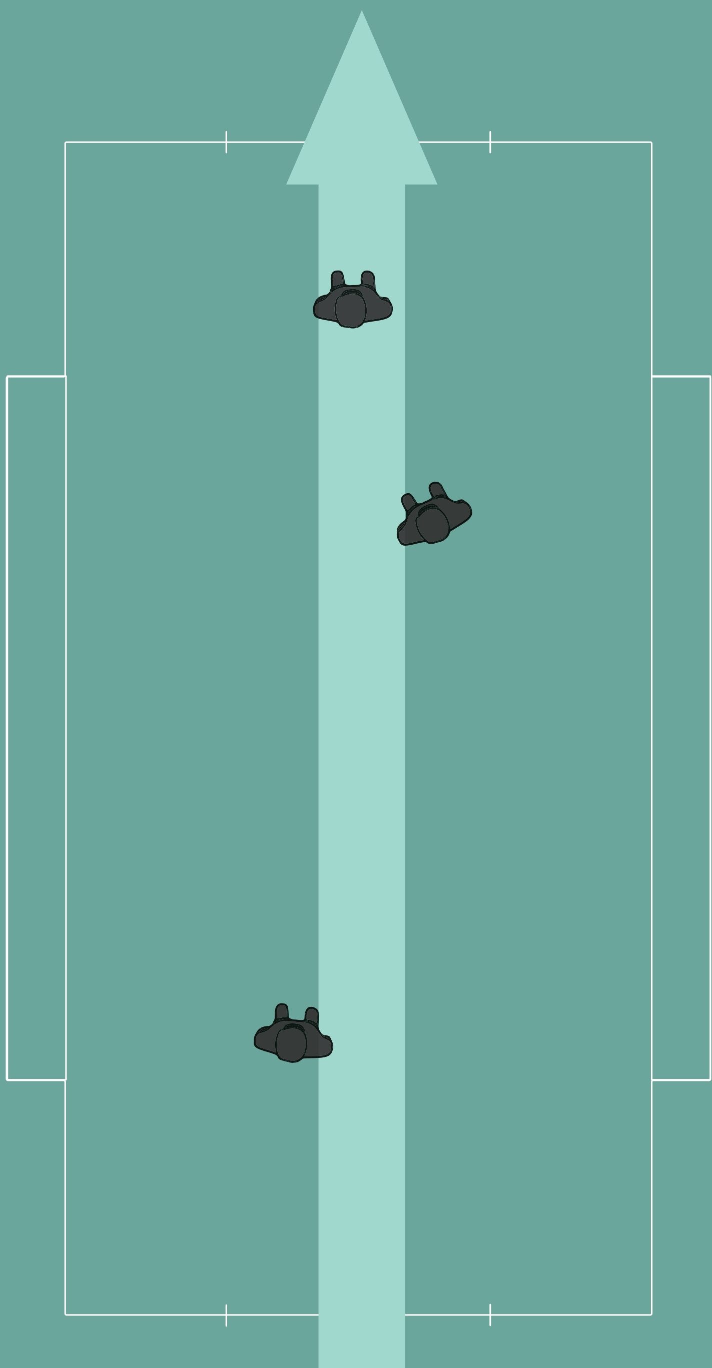
For a smooth and seamless passenger journey, the passengers should not have to do tasks such as buying and registreing tickets. A passenger counting system will handle boarding all passengers automatically. The ferry can departure when it is fully boarded or when all passengers on quay are on board. Door motion detectors keeps doors normally closed, to ensure the passengers stays protected from the weather.

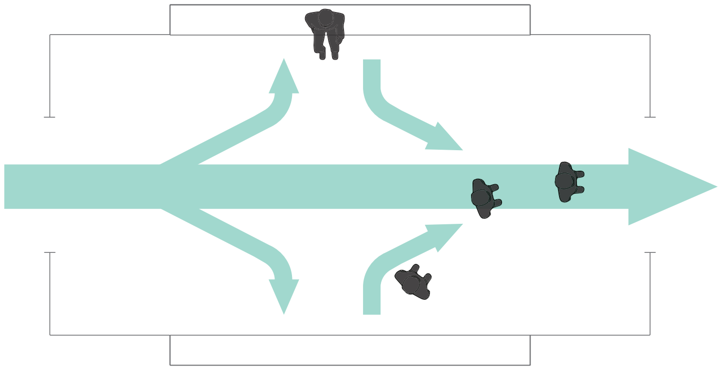
Passenger Flow

This chapter focuses on how the ferry may be designed for optimising the flow of the passengers. A good flow, aligns with Zeabuz' values of having a smooth and seamless user journey. When visiting Vard Design AS, we learned that they use VR technology to give their customers a feeling of the ship they are designing. Undoubtedly it would be a great tool for testing how one user may experience the interior design in this project. However, it would provide feedback of a very rare use case. In rush hours we can expect the ferry to be fully boarded with 12 passengers.

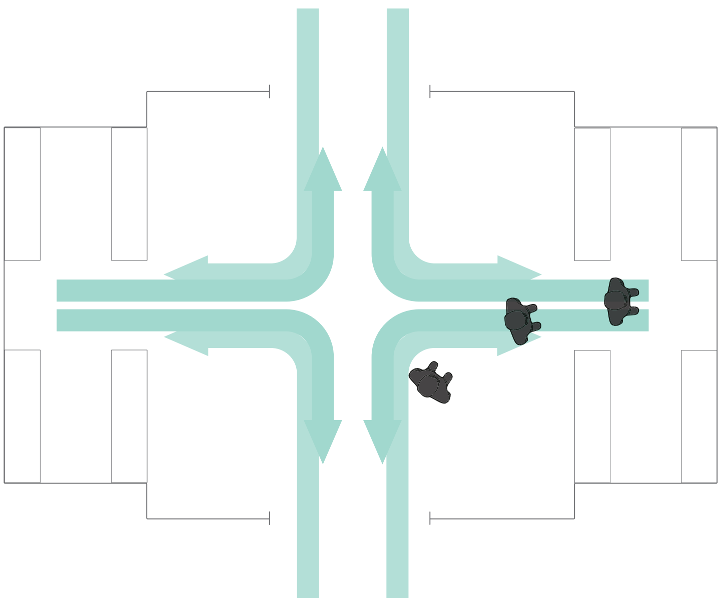
Involving representative users gives feedback that helps fulfil their needs (Østerman, 2016). In addition, it is recommended in ship design processes to involve users as early as possible, because making alterations may be costly when the construction has started (Østerman, 2016). In our meeting with Maritime Partner AS, it was said that alterations are often done in the construction phase (Tore Fiskerstrand, 2022). For those reasons, we aimed for gaining user insights of the 12-passenger scenario, by testing the passenger flow in a full scale low fidelity mockup.

Universal design principles for ferries were investigated for mapping the dimensions needed for fulfilling the users needs on board. Many interior layouts were sketched and tested in full scale in the mock up. The layouts were evaluated based on the requirements of our design and brief tests conducted by the team and employees in Zeabuz. The evaluation led to picking two different layouts that were tested by representative users in the full scale mockup.





Passenger flow with entrance and exit at front/stern of ferry



Passenger flow with entrance and exit at portside/starboard of ferry

Entrance and exit placement

With entrance and exit at front and back of the ferry, the passengers may walk on board at the ferry's aft, walk through in a straight line, and exit at the ferry's front. This will naturally form a line of the passengers along the direction of the longest side of the ship, when passengers are ready to unboard. In other words, the flow is logically going in the forward direction of the ferry. With entrance and exit placed at the sides, it is not self-explanatory which door should be used for exiting the ferry. In addition, there may be occurring lines of people in several directions when passengers are exiting. If several lines or clusters of passengers have to merge on the way to exit, passengers may experience confusion, pushing or other obstacles that lead to a less smooth user journey.

Interior arrangement

To make the ferry available for all people, universal design recommendations were investigated. The insights were used to map the needed sizes of inventory, seating, entrance and exit, free spaces and walking zones.

Doors

The door opening requirement for passenger ferries is at least 900 mm, but 1200 mm is recommended (Universell utforming, 2020). Ellingsen and Glesaaen (2020) developed the passenger docking systems for MilliAmpere 2 in their master thesis. They emphasised that passengers should not be treated as cows or machines - but rather as flexible, thinking human beings. To achieve a good passenger flow on the ramps, they suggested having sufficient space for passengers to walk in two directions. The entrance and exit doors should allow for the same flexibility to avoid bottlenecks on the passenger flow when boarding or unboarding. If someone changes their mind after boarding, they should be able to turn around and walk on shore. In addition, a wide door can allow for passengers to leave in clusters or several lines for more efficient boarding and unboarding. Thus, it was decided to test a door opening with enough space for two wheelchairs to pass each other, which is 1800 mm.

Navigating on board

Universell utforming AS recommends that a ferry should be designed for easy navigating by having dedicated walking zones (Universell utforming, 2020). Norwegian Association of Disabled (NAD) made a guidance document for universal design for ferries in 2006. For corridors, NAD recommends having sufficient space for elderly and disabled persons to move freely around and wide enough for a wheelchair user to pass a walking person (Norwegian Association of Disabled (NAD), 2006). NAD's guidance does not directly apply to the Zeabuz ferry as there are no corridors, but it was decided to try to strive for easy navigating by having walking zones with at least 900 mm width and possibility for taking U-turns or 360 degree turns for wheelchair users.

It was discussed if the ferry should have designated spots for bikes and luggage. Universell Utforming AS recommended to avoid placing luggage in the walking zones (Universell utforming, 2020). We cannot override the passengers thoughts or actions, but designated spots may steer some of the passengers. If bikes are stored far away from seats, passengers with bikes need to cross other passengers to fetch their bikes before exiting. The same goes for suitcases. This leads to a flow going in multiple directions when boarding and unboarding, which may lead to a less smooth passenger experience. As the ferry is designed for max. 5 minute trips, we assumed that passengers would like to have luggage right next to them or in sight. It was decided to make sufficient space for suitcases and bikes right next to resting areas on board, and put to test what the passengers would choose to do on the user test in the full scale mockup.

Other recommendations from Universell Utforming AS we used as guidelines for the design was at least 225 cm free height at walking zones.

Resting spots
Even if the trip with the ferry takes five minutes, we believe most people would like to rest if they have the possibility to. As an example, passengers on public transport choose to sit if there are any seats available, even if they are travelling for only two bus stops. To make the passengers' experience as smooth as possible, it was decided to strive for resting spots for all 12 passengers. Seats for public resting spots are recommended to have at least 40 cm depth, at least 50 cm width and 45 cm height for one person (Standard Norge, 2011, s. 32). This was used as a guidance for the arrangement sketches. Tables at public resting spots should have free spots for wheelchair users, with at least 670 mm height under the table top and 500 mm overhang (Standard Norge, 2011, s. 32). The minimum feet area around seats and standing inventory was set to be 400 mm, based on testing in the full scale mockup.

Control panel
Pushbuttons for doors are recommended to be placed at a height between 80 cm and 120 cm (Universell utforming, 2020). Thus, this was chosen as the height of the passenger control buttons on board.

Information screens
Communication channels are recommended to use both auditory and visual formats. Screens should be easy to spot from different positions in a ferry (Universell Utforming, 2020).

Interior layout of the chosen concept

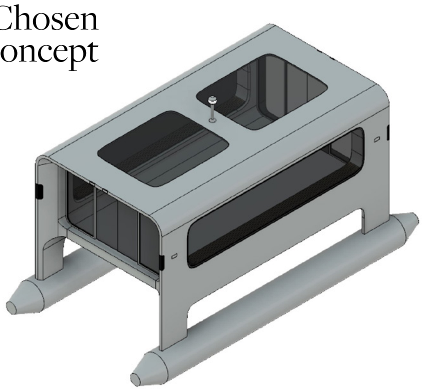
The work on the passenger flow was the next step for further development of the interior design of the chosen concept at the end of the conceptualizing phase.

As mentioned in the development of three concepts at page 156, Zeabuz required that the ferry must be at least 8 meters long. The chosen concept was 3D-modeled with a passenger compartment with 8 meters length to be sure the ferry would fulfill this requirement. The design had to be quite wide to provide sufficient stability for the swath hulls, thus it was 3D-modeled with 4,5 meters width in the passenger compartment. This was not too far from the dimensions of MilliAmpere 2, with 8,4 meters length and 3,5 meters width.

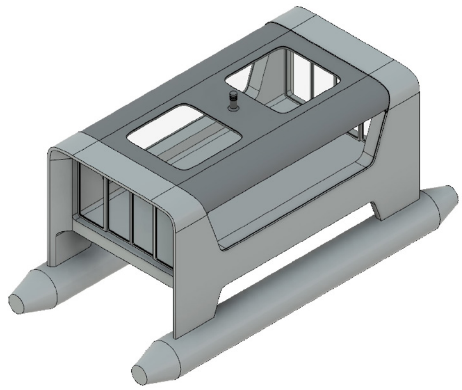
We could not know for sure if these dimensions were correct at this point. To gain these insights, we had to do interior layout mapping based on universal design recommendations. The planned user test would then verify if the dimensions and recommendations work in real life.

The concept has thick sidewalls for storing space of equipment. This wall thickness was used for integrated benches in the windows. The inside walls of the passenger compartment in the 3D-model was used as the set point for the further layout ideation.

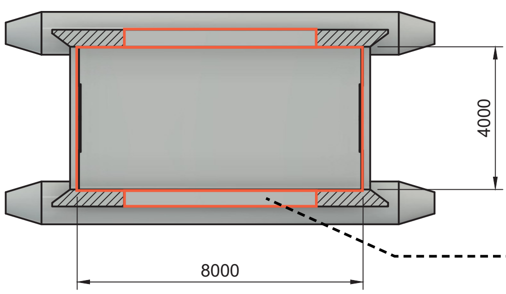
Chosen concept



Adjustments in detailing phase



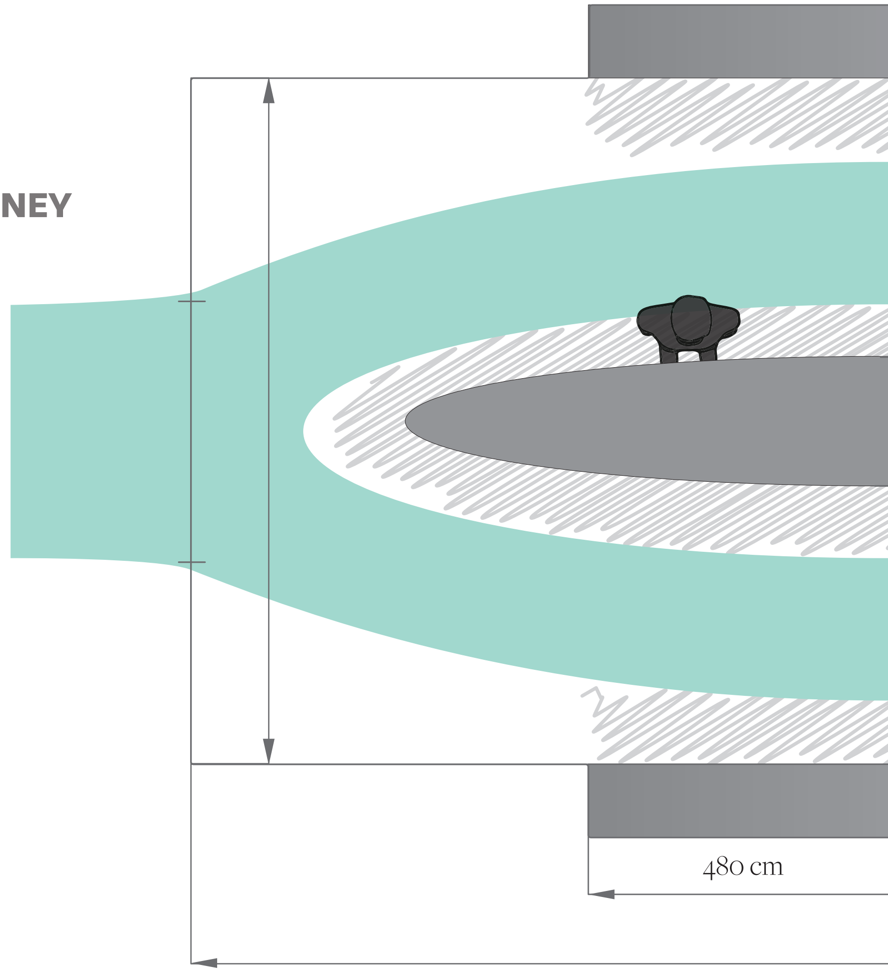
Setpoint for interior mapping

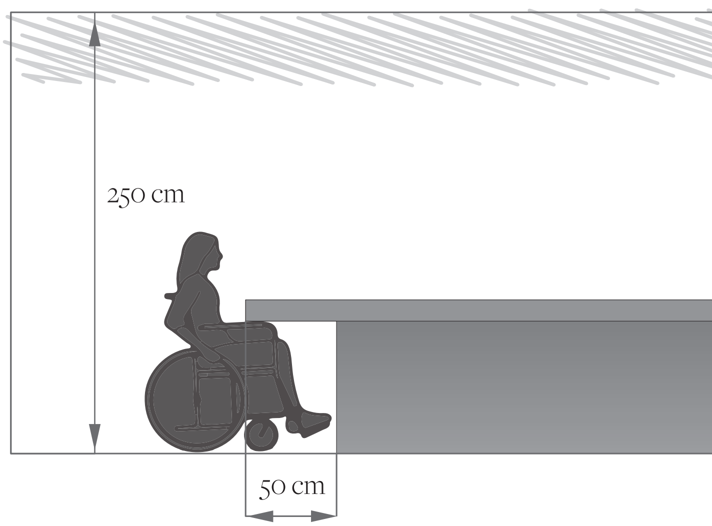


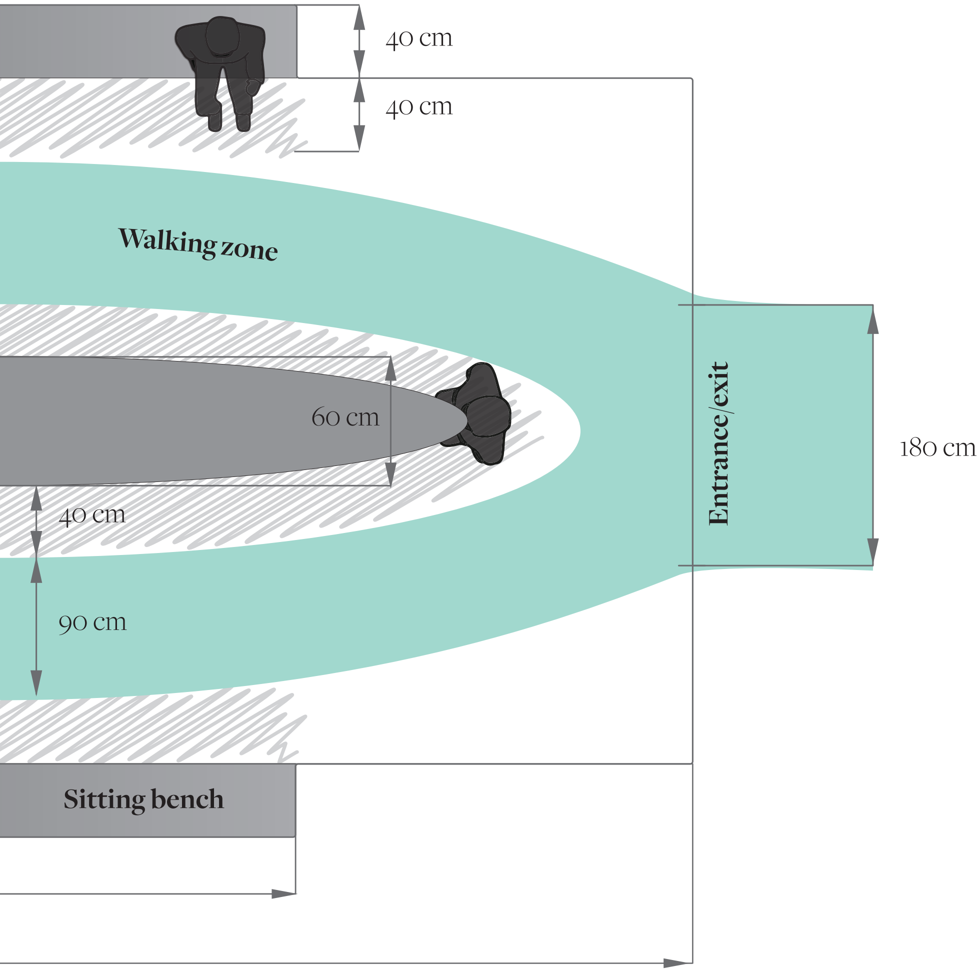
Inner walls passenger compartment

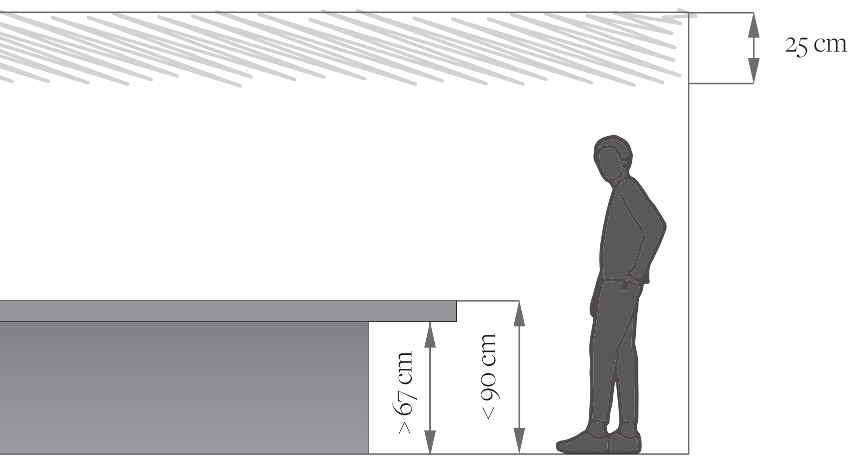
Sitting benches

INDIVIDUAL PARTS
PASSENGER JOURNEY






40 cm
40 cm
Walking zone
60 cm
Entrance/exit
180 cm
40 cm
90 cm
Sitting bench

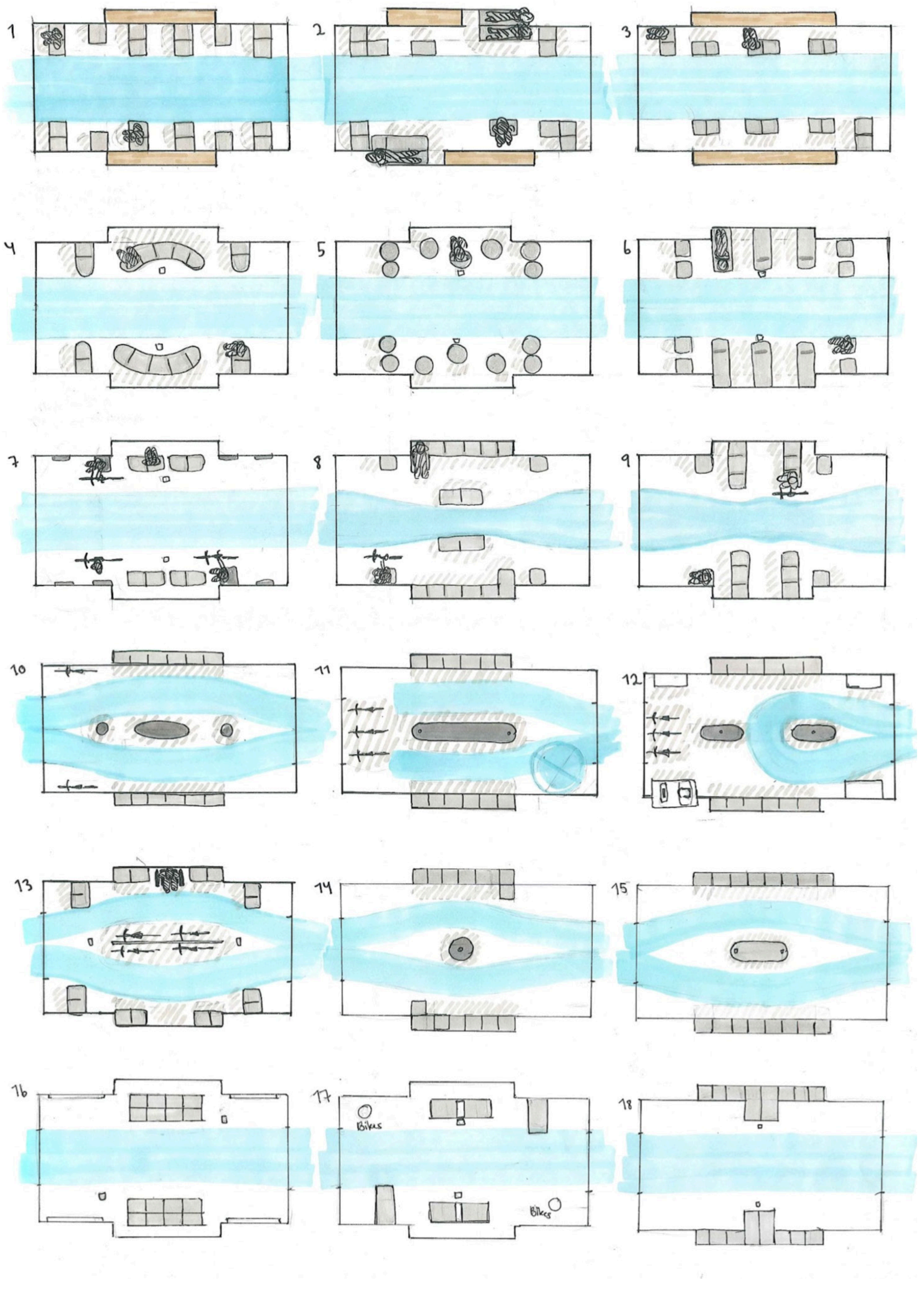

25 cm
> 67 cm
< 90 cm

INDIVIDUAL PARTS

PASSENGER JOURNEY

Initial interior layout iterations

Based on the mapping of space needed for the different areas on board the ferry, several layout iterations were sketched in a 1:50 scale.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
Bikes
Bikes
18

INDIVIDUAL PARTS

PASSENGER JOURNEY

Building a full-scale mockup

A full-scale prototype of the passenger compartment of the ferry was built for ideating more on the layouts and to do tests. We knew the dimensions had to at least correspond with the mapping that was done for fulfilling universal design principles. For example, we knew the width should be 4 metres based on the layout sketches. Simultaneously as Malene Liavaag worked with the passenger flow, Hilmar Nypan Claes were working with designing a modular furniture system (See next chapter Interior). He had designed the benches to be 120 cm long to fit his furniture system. We wanted some extra space to play around with in the mockup, so we made the window length 480 cm, so it could fit 4 benches. Furthermore, we started the building by laying out planks to see the main dimensions in real life. We realised that the 9 metres length we had modelled in the 3D-model provided more space than was necessary. Thus, we decided at site to reduce the main dimension to 4x8 metres.

See timelapse of building the mockup here: https://www.youtube.com/watch?v=QhoJ9QtSrlk

Interior layout iterations in the mock up

In the full scale mockup, all layouts were tested by rearranging benches and modules. Role play was used to step into the passengers' needs. Every seat was tested, to check if information screens were easy to spot and if control panels were within reach. Suitcases and a wheelchair were brought into the mockup to check if the space was sufficient.






PASSENGER JOURNEY

Each idea was evaluated on how well they suited the values in the value triangle, the visibility of important information, the view out of the windows, how accessible control panels were and to what degree they followed universal design principles. Brief tests were conducted by the team and employees in Zeabuz.

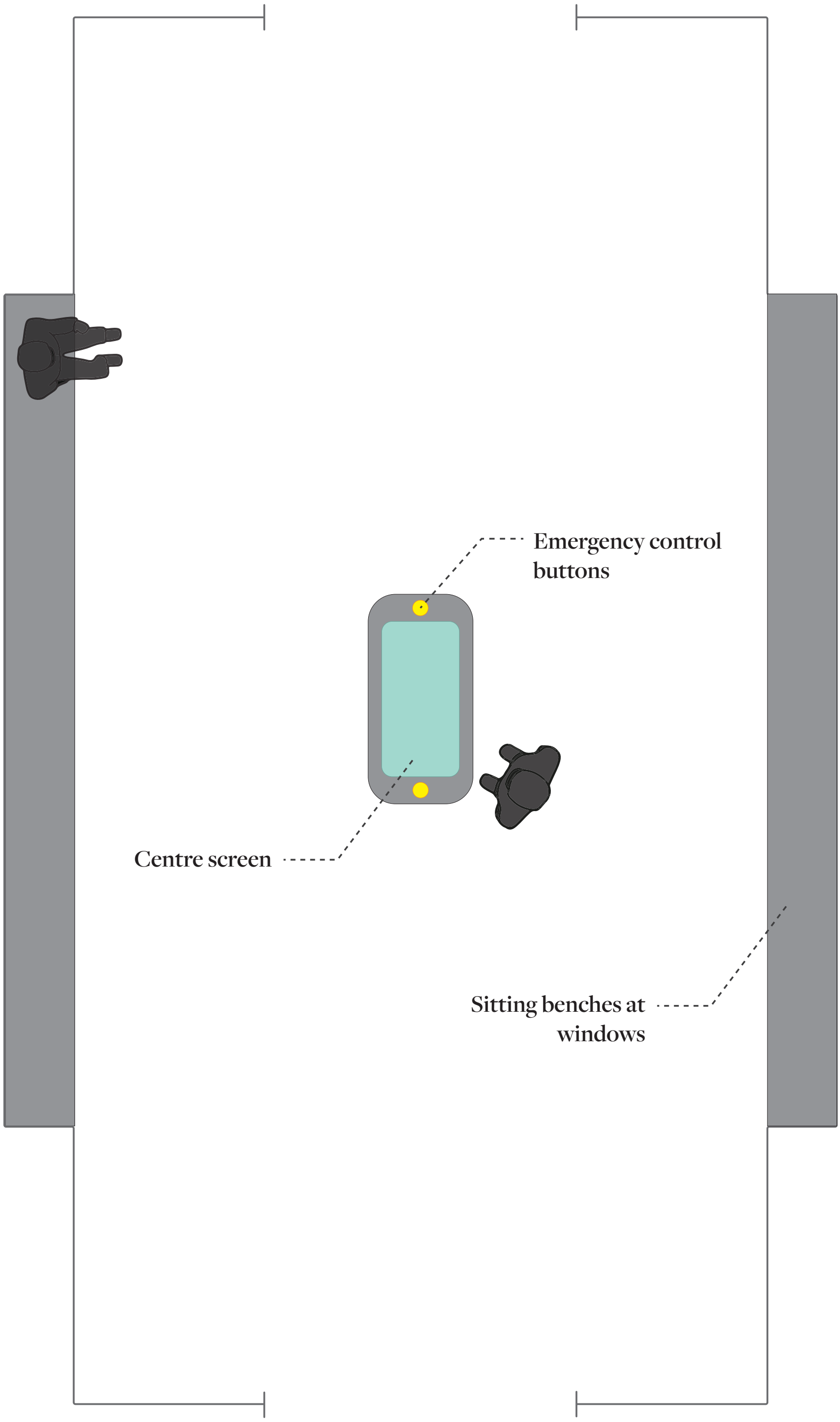
Free-standing passenger control panels

Centre screen with emergency buttons at edges

Choosing two layouts for testing

The two ideas that were assumed to give the most optimal passenger flow were further developed.

Layout 1 has an information screen in the centre of the ferry, placed in the facing direction of all passengers. Control panels for buttons are placed on the edges of the centre screen, within maximum 2 metres reach for all passengers. With two long sitting benches, it was assumed that the passengers would split into two main streams - one going to the portside bench and one going to the starboard bench. With large open spaces at both the entrance and exit, it was assumed the passengers would use these areas for bikes and wheelchairs. The concept has at least 90 cm of walking zones on both sides of the centre screen in all assumed scenarios. Thus, the concept is universally designed with sufficient space for a wheelchair user to go onboard, sit next to the window benches or turn around and leave at the entrance if they change their mind.

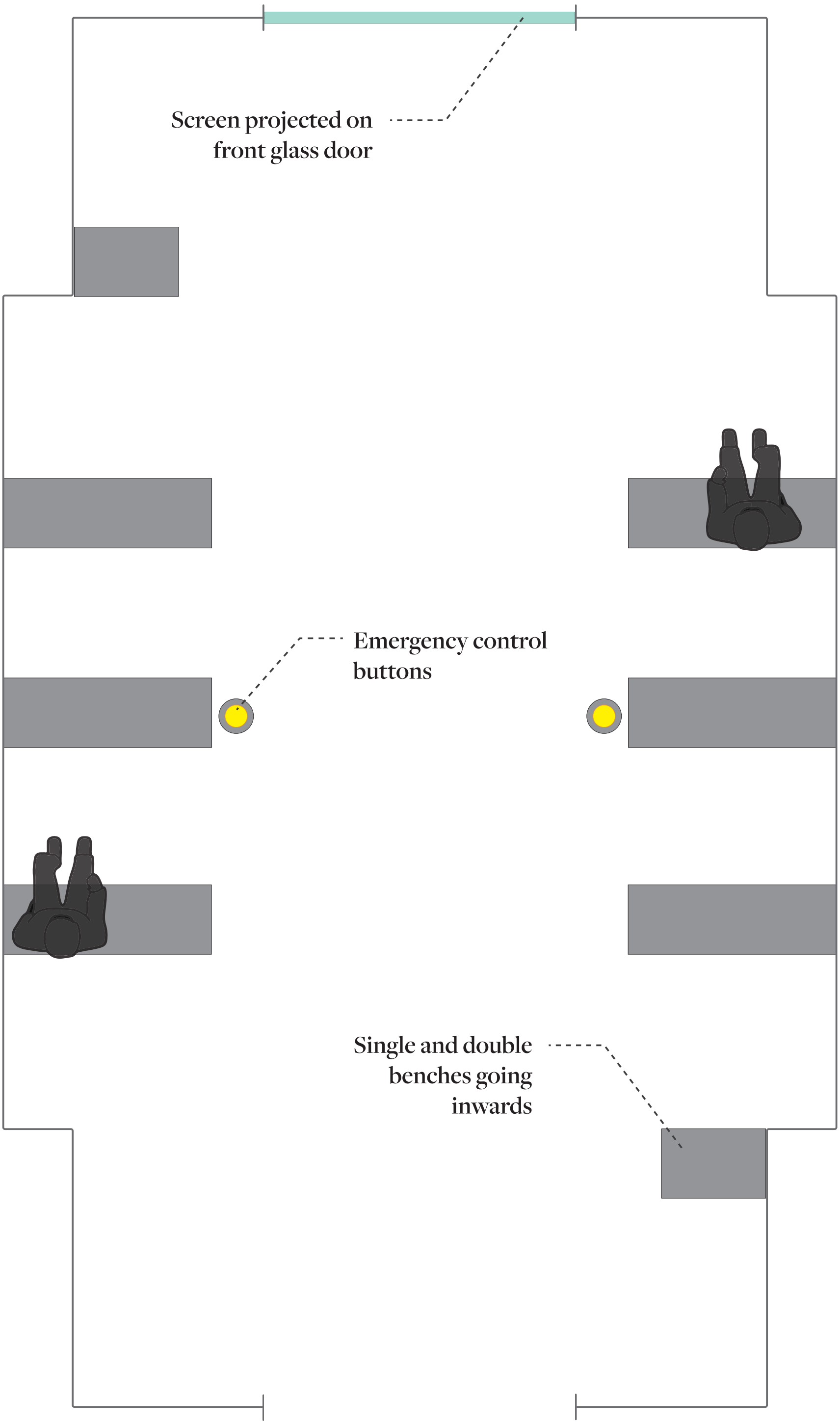

Emergency control buttons
Centre screen
Sitting benches at windows

Layout 1

PASSENGER JOURNEY

Layout 2 has benches facing inwards the ferry. The main idea was to let the passengers sit in the same direction as the ferry is going. It was assumed that it feels safer to see where the ferry is going. To sit in this direction will also make it equally convenient for the passengers to look into the ferry or out the windows. With benches without back rests, they can be used in both directions of the bidirectional ferry. The middle is a wide walking zone of 160 cm, which is the recommended diameter for an electric wheelchair to turn around. It was assumed that this would give one main stream of passengers that would split into the sides after boarding, and would reoccur upon exiting as a zipper. The information screen is projected to the front or back glass doors, as they will be directed towards the sitting direction of the passengers and can be seen from all spots in the ferry.

The control panels were placed in the centre of the ferry on both portside and starboard. In this position, they should be easily spotted when going on board the ferry, and within reach for all passengers. One of the functional values of the Value Triangle was scalability. Two adjust the design for use-cases that require seats for passengers both travelling alone and in group, we wanted to test a concept that also has single seats. Thus, two single seats were added to the concept. These were placed in the areas that are open in layout 1. We wanted to test if these spaces can be used for seats without negatively affecting the passenger flow.


Screen projected on
front glass door
Emergency control
buttons
Single and double
benches going
inwards

Layout 2

User Test

Østerman (2016) and colleagues had a good experience with combining scenarios with 3D-models, for getting user feedback on the design of a ship bridge working station. In a participatory workshop, scenarios were paired with a 1:1 plywood mock up, a 1:16 foam mock up and a digital 3D-model. The different models gave different sorts of feedback. For instance, the participants altered their opinion on dimensions when switching between the different 3D-models. In fact, the 1:1 model was particularly appreciated by the participants as they could use their own bodies as a size reference. Østerman (2016) experienced that the participants were able to provide feedback beyond what was present in the model, by building on their experiences and reflecting on other use cases and consequences of the design.

We wanted to test the same approach of pairing a scenario with a full scale mockup in the user test. In this way we hoped to evaluate the two layouts in terms of the users needs in the fully-boarded scenario, along with feedback that may extend beyond what is present in the mockup. A more cost-effective way for testing passenger flow may be to use small scaled models and do role play, as Ellingsen and Glesaaen (2020) did in their master thesis when designing the passenger docking ramps for MilliAmpere 2. A lack of either knowledge, support for or use of design approaches with end users in the maritime domain have been described in literature (Mallam, 2017; Østerman, 2016; Ahola, 2018). Likewise this was our experience from visiting Maritime Partner AS and Vard Design AS; None of them includes end-users in their design processes. Hence, we preferred testing with representative users.

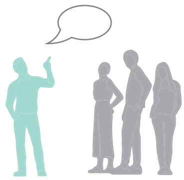
The Zeabuz Team in the full scale mockup

Test plan and preparations

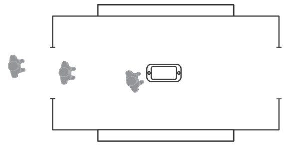
It was considered not necessary to collect GDPR for the user test, as we found other ways of collecting insights without storing personal information.

See the plan for the user test.

1 Info about test & scenarios

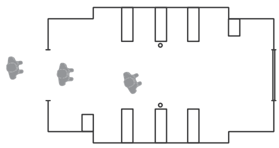


2 Test layout 1



3 Answer online survey 1

4 Test layout 2



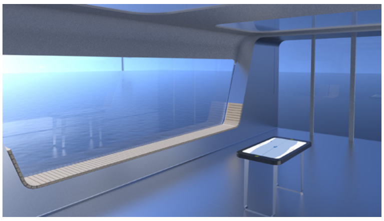
5 Answer online survey 2

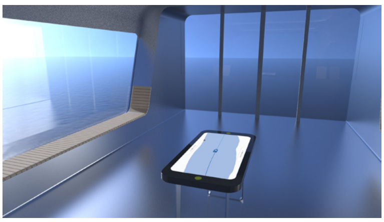
6 Focus groups

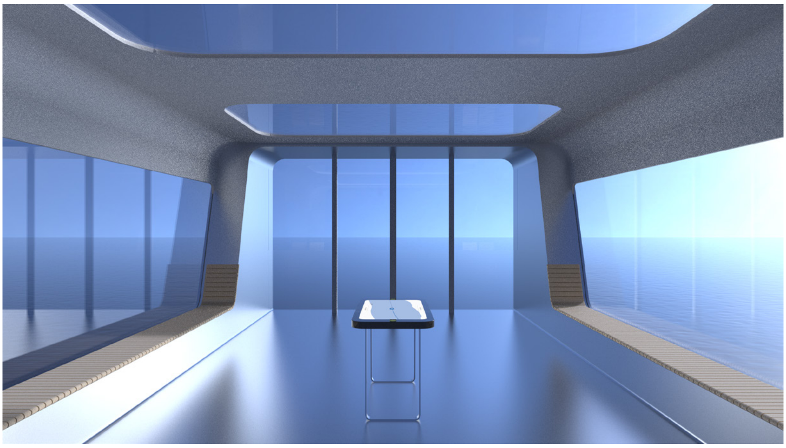
INDIVIDUAL PARTS

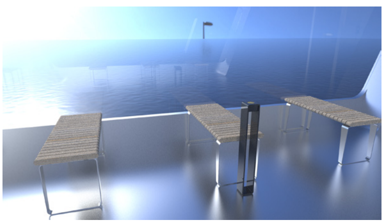
PASSENGER JOURNEY

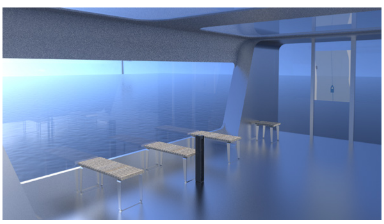
It was strived for making the user test feel efficient, smooth and fun to be a part of for the participants. A detailed time-schedule with the program, location and information about the project was sent to the participants one week in advance of the user test. The location of the mockup was a dusty and cold hall. Thus, we tried to make it more cosy by setting up a coffee and snack station. Some chairs were provided as well in case there had to be some waiting.

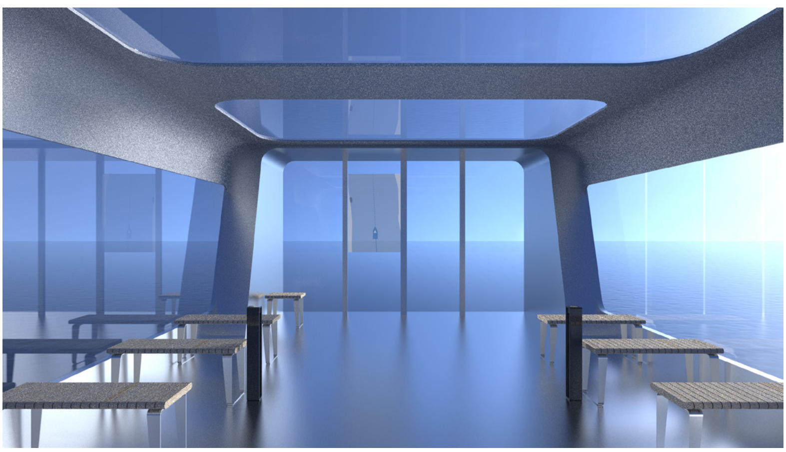




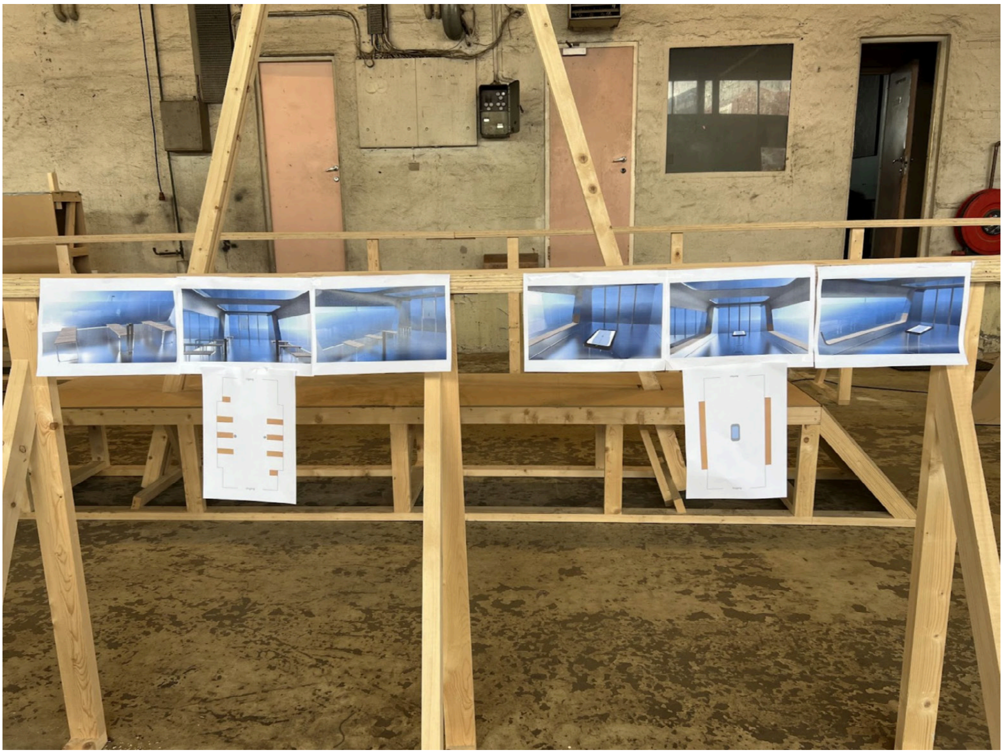








To get the passengers to fully envision the scenario of how the mockup should look like in real life, we hung up posters of realistic renders.



PASSENGER JOURNEY

The participants were supposed to be "on board" the mockup for 5 minutes. One on the team took notes, while another one measured the time of the trip, boarding and unboarding. A poster of a QR-code of survey 1 was planned to be hung up at the snack station while the participants are "on board". As soon as the participants have unboarded, they should be guided to the QR-code to start answering Survey 1. The same procedure was planned for the testing of the second layout. The QR-code for the first survey should then be removed, to make sure no participants answers the wrong survey. In case some participants were missing smartphones, two laptops were brought to the location. It was also planned for having a backup plan if some participants could not show up on the test day. Two additional participants were asked if they could show up on short notice if needed.

Participants

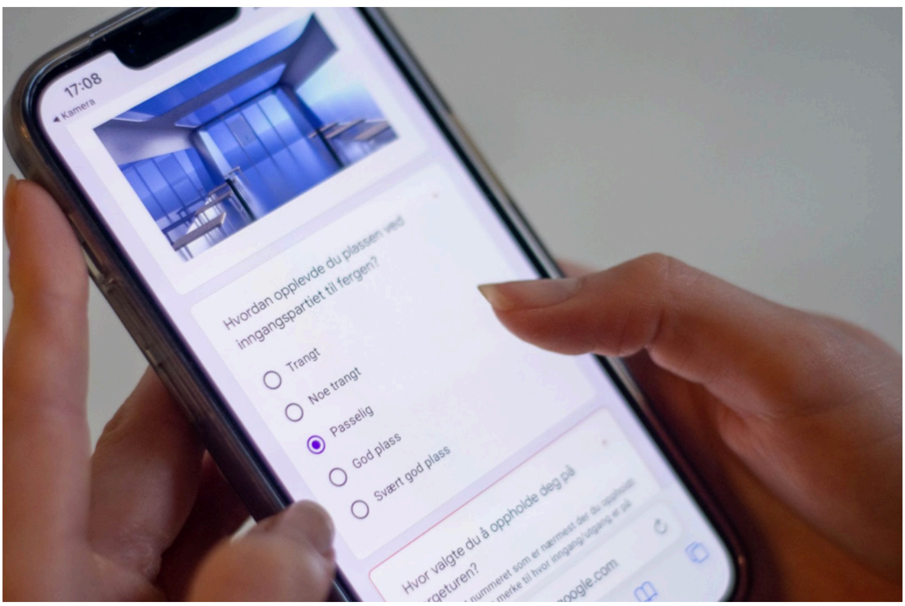
Different cities will have a variety of passengers. In Amsterdam there may be a need for many bikes, while in Stockholm there may be more walking passengers. As we are not designing the ferry for a specific case, we decided to include a variety of users - both kids, adults and elderly. The range was people from 0 to their 70's. To test a variety of cases, four users were asked to bring bikes, one was asked to use a wheelchair and two were asked to bring a large suitcase for the trip. To test how different social connections may inflict the passenger flow, we invited both people who could travel together and some who travelled alone. One of the invited groups was a family of two adults, a 2-year old and an infant. In addition, two groups of two people who know each other were invited. The rest of the invited passengers were "travelling alone". All participants were asked to dress like they were about to travel from one area to another in the city - if that meant bringing a purse, a backpack or a coffee cup was completely up to them.

It was planned to invite 12 passengers in total, to test how the ferry works at its maximum passenger limit.

Illustrations of the participants with luggage , groupwise

Questionnaires

To make the gathering of data effective, it was decided to use online surveys. In this way, the data will be electronically stored right away without collecting GDPR. The method works well for comparing quantitative data. The downside of the method is that it is more difficult to get in depth information, as you cannot come with follow-up questions like in open or semi structured interviews (Preece et al., 2015, pp.332-333). To avoid this, the users were asked about both how and why they acted in specific situations. Yes or no questions were completely avoided. Another pitfall of structured interviews is to lose important information, as the questions are formulated based on what information you already have (Preece et al., 2015, p.333). Several measures were used to avoid this. For one, the users were asked if they had experienced any other situations than those suggested. Secondly, they had the possibility to add their own options if they could not find one suitable. Thirdly, the focus groups after testing were used as an arena for the users to discuss anything they would like to of their experience.



To effectively map where the users chose to stay and what they brought with them to the test, some initial multiple choice and checkbox questions were made to cover that. This information was needed to be able to see their use case in relation to their experiences. Overall, the survey was made as short as possible to avoid fatiguing the participants. All questions were required to answer, to make sure that the users were not skipping any. The questions were formulated through several iterations, while constantly asking ourselves what we aimed to find out in the test.

Our main topics were:

- Does the passenger journey feel seamless and without bottlenecks?
- How does the arrangement affect the view outside and overview inside the ferry?
- What layout will leave the passengers left with impressions that are in accordance with the values of Zeabuz?
- How equally good was each seat compared to the others?

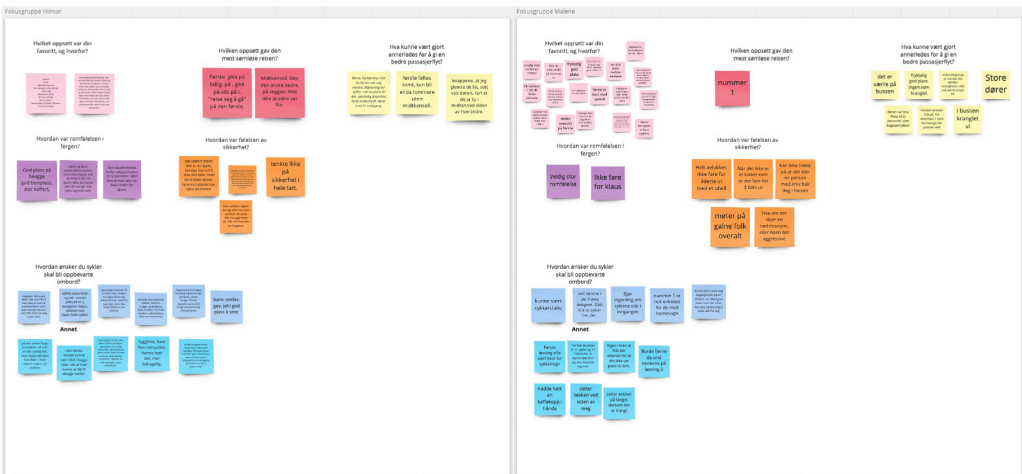
To quickly let the participants evaluate how functional and innovative the layout felt, how social the seating was, and how well the view, overview and visibility of information and control panels were, we used semantic differential scales in the survey. The method has been described by Preece et al., (2015, pp. 348-349). This means that there is an axis, with one word at each end. The two words should be in contrast to each other, like a positive and negative pole. The participants must place the concept somewhere on the axis. This allows us to evaluate the concepts on their own, but can also be used for comparison between the concepts. While it may be tempting to use the average score on the axis for comparison between the two concepts, it may not represent the opinions of all participants. Thus, it was investigated if there was a large or small spread in the responses when comparing.

PASSENGER JOURNEY

It was decided to have one survey right after testing each layout, instead of having one comparative survey after testing both layouts. Firstly, the goal was not to find one perfect layout for Zeabuz' ferries, but rather to explore how these different layouts affect the passengers' behaviour. Secondly, we feared that details of the first test may be hard to remember if both surveys are conducted after both tests. This meant that in the second layout test, the survey will be biassed by their impression of the first layout test. To reduce the potential effects of this, we showed renders and sketches of both layouts before testing layout 1. In addition, the focus groups afterwards were used for discussing the two layouts, to gather additional data about their differences.

Focus groups

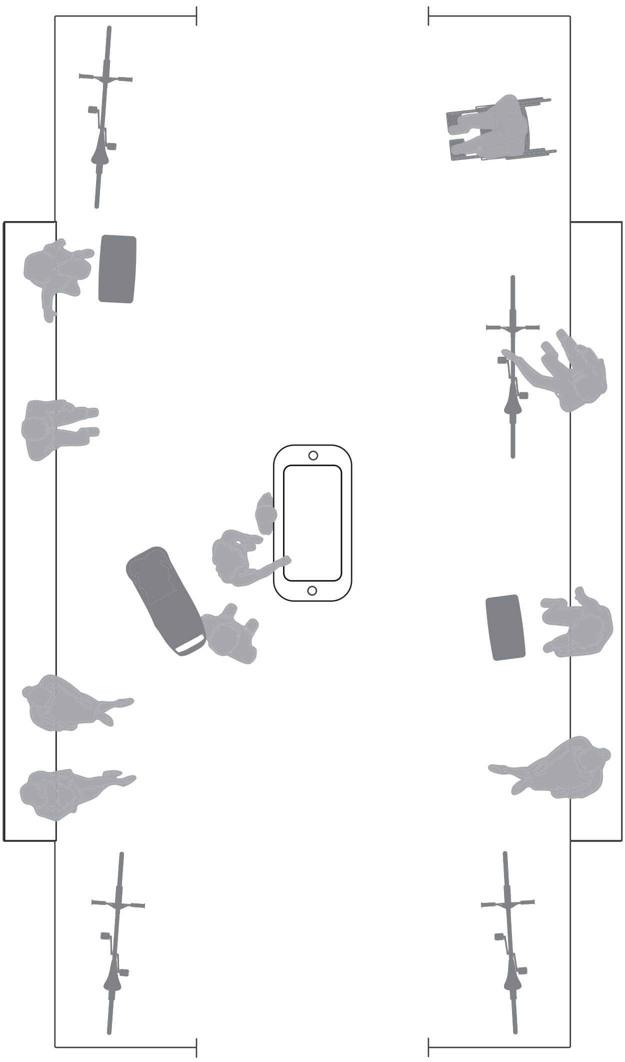
For efficient data gathering when having focus group sessions, post-it notes on boards in Miro were prepared in advance. Some main discussion themes were decided, to make sure both groups went through discussing the same themes. It was planned to have one designer and five adults present at each focus group.



Results

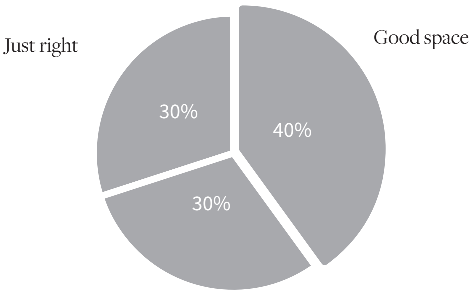
The user tests were conducted in Norwegian, in the participants native language. The data was collected and analysed in Norwegian as well. The findings have been carefully translated to English, by the two Norwegian-speakers on the team.

Layout 1
See the raw data from the survey in Appendix.



Participants during test 1

Space at entrance



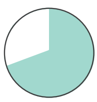
90%
Agreed with

Stand up and walk off the ferry went seamlessly

10%
Agreed with

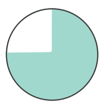
I had to wait for the person next to me

Boarding time



41 sec

Unboarding time



46 sec

Suggestions

- Screen should be more visible
- Should have something to hold on to, for example straps
- Would like to sit with the people I'm travelling with
- More variation of seats

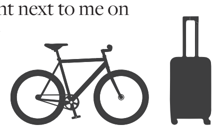
Luggage

"I placed the bike at the entrance because there was sufficient space for it"

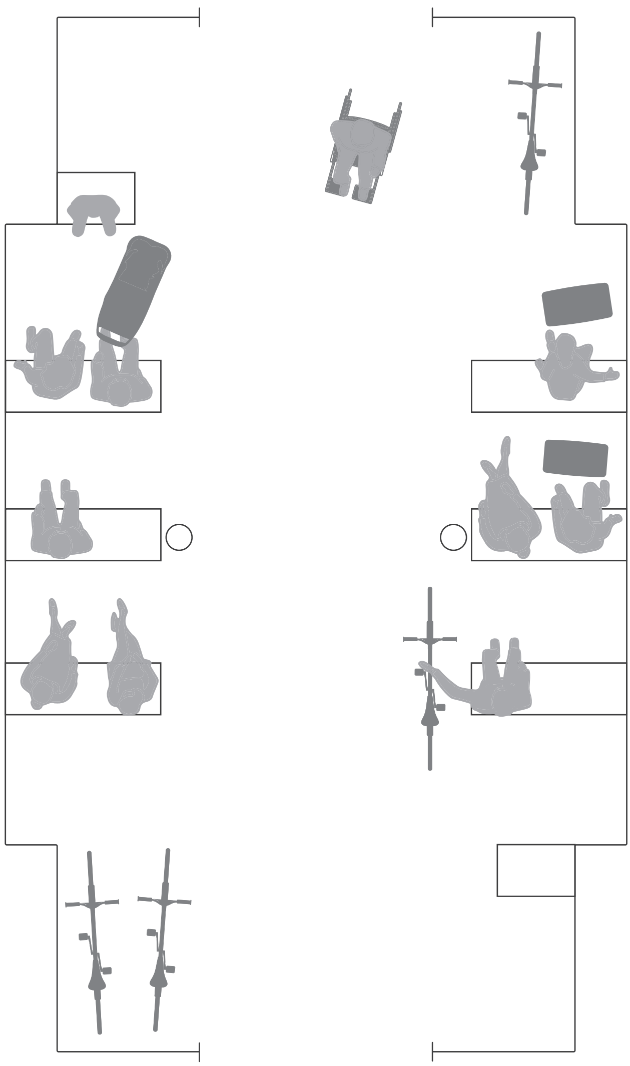
"I didn't have space for the bike at the sitting bench so I placed it at the entrance. That was not an issue for me."

"I had the suitcase in front of me, so that I was able to watch it during the trip"

"I had the backpack right next to me on the bench, like I usually do when taking public transport"



Layout 2
See the raw data from the survey in Appendix.



Participants during test 2

70%
Agreed with

I could stand up without feeling I was in the way

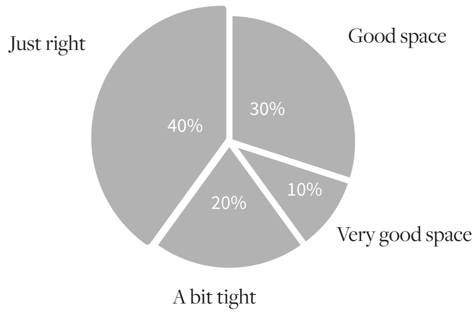
50%
Agreed with

Stand up and walk off the ferry went seamlessly

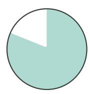
40%
Agreed with

I had to wait for the person next to me

Space at entrance

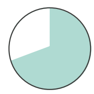


Boarding time



50 sec

Unboarding time



43 sec

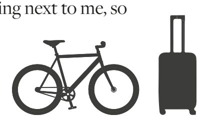
Luggage

“I placed the bike at the entrance. There was sufficient space for it”

“I held my bike next to the bench I was sitting at, because my bike does not ahve a stand”

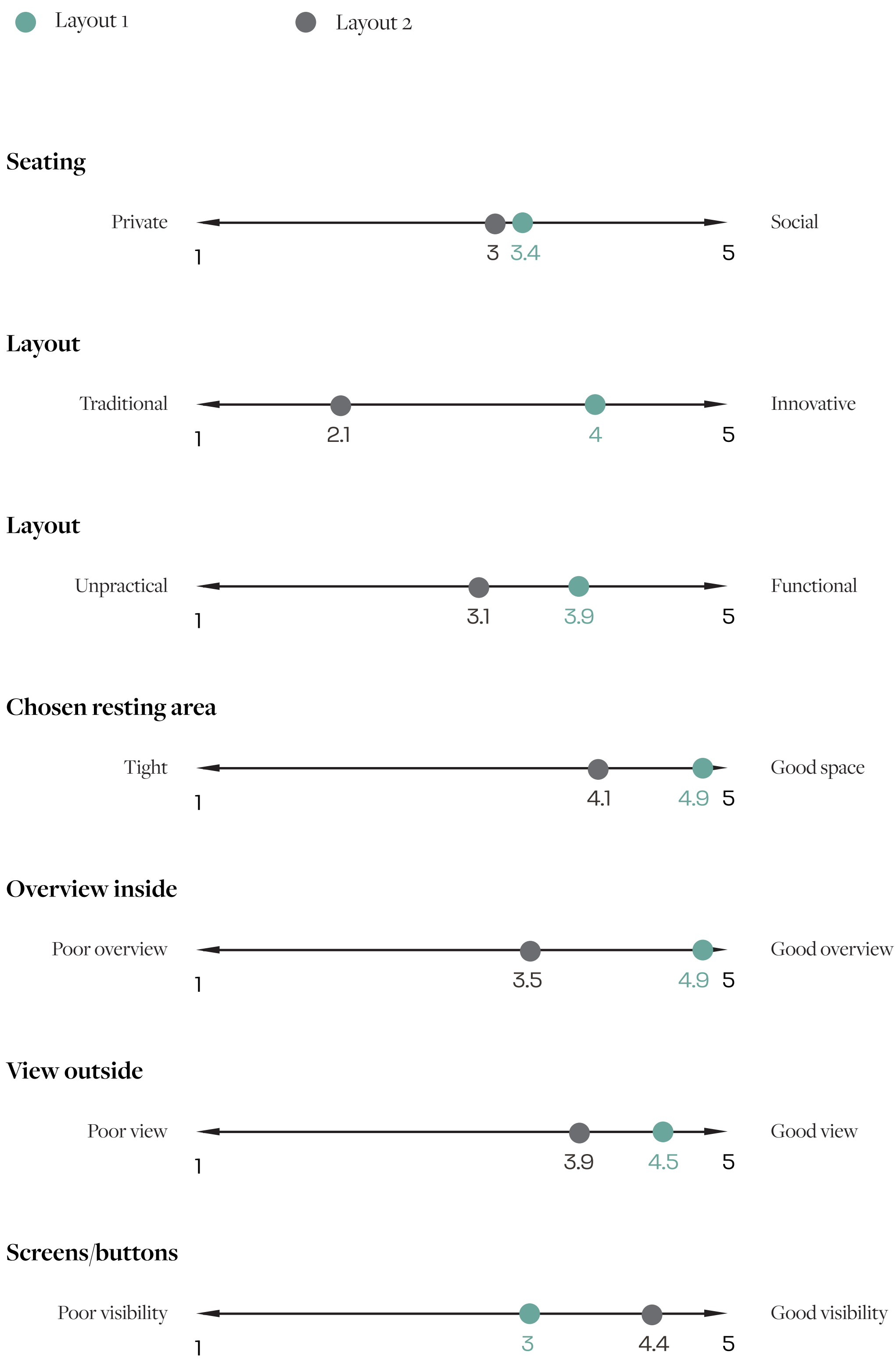
“I had my belongings in front of me so that I could watch it”

“I had the luggage right next to me on the bench. No one was sitting next to me, so I had sufficient space for it”

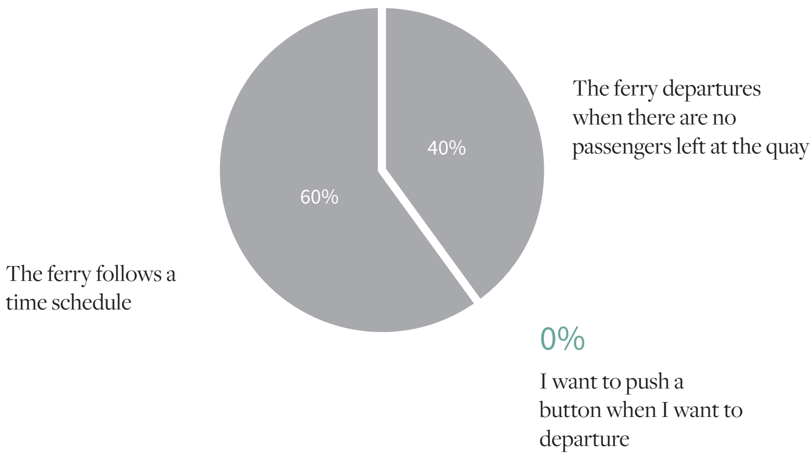


Suggestions

- Backrests. Maybe some seats can face each other.
- Buttons more distributed
- Remove small seats and centre panels to give more space for bikes
- Buttons should be placed at doors


Layout 1
Layout 2
Seating
Private
Social
1
3
3.4
5
Layout
Traditional
Innovative
1
2.1
4
5
Layout
Unpractical
Functional
1
3.1
3.9
5
Chosen resting area
Tight
Good space
1
4.1
4.9
5
Overview inside
Poor overview
Good overview
1
3.5
4.9
5
View outside
Poor view
Good view
1
3.9
4.5
5
Screens/buttons
Poor visibility
Good visibility
1
3
4.4
5

What should decide when the ferry departures?



The main takeaways from layout 1 were:

- More innovative layout
- More space at entrance
- More seamless when unboarding
- More functional arrangement
- More space for bikes, suitcases and strollers
- Better overview inside the ferry
- Equally good spots for all passengers

– Centre screen is not visible for all when people stand around it

The main takeaways from layout 2 were:

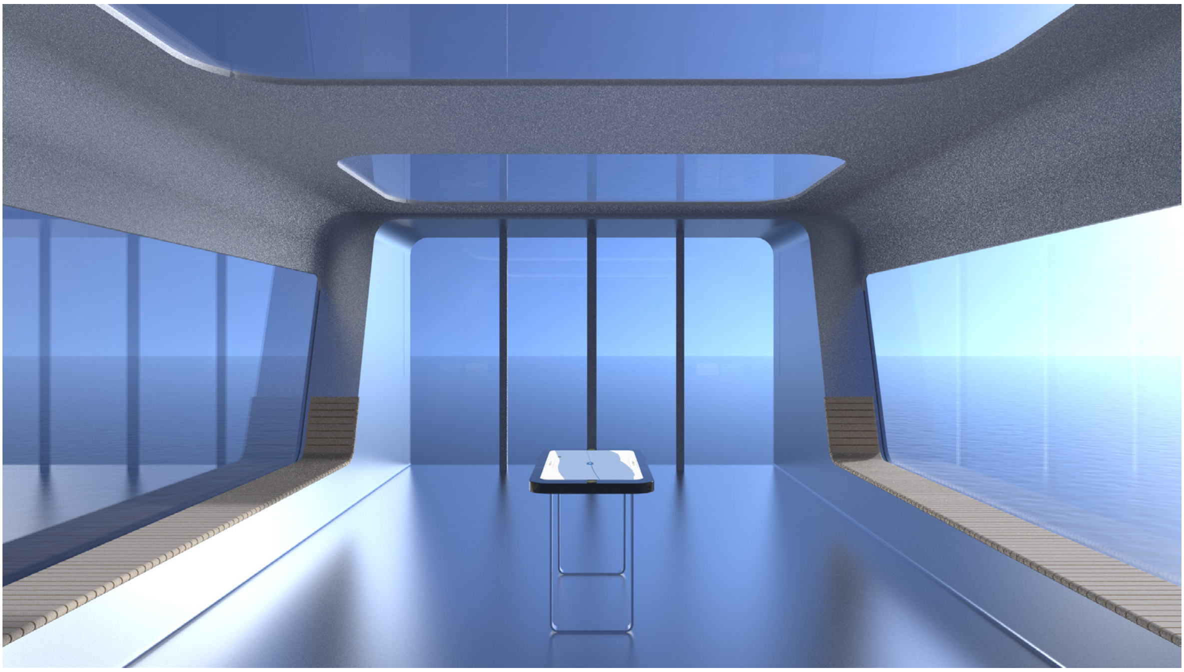
- More traditional layout
- Better overview of screens
- More social seating - you can sit facing to the group you are travelling with
- More space in midway
- Equally good spots for all passengers

– Control panels could be better distributed
– Not sufficient parking spaces for bikes
– Wheelchair user sat in the midway

Chosen layout concept

Layout 1 was chosen for final detailing for this project, to serve as a showcase. The passengers intuitively boarded and unboarded the ferry in a smooth manner with this set-up. For instance, the first passengers walked to the seats and bike spots at the front. The next passengers sat down aft of the first passengers. The last bikers chose to park their bikes at the spots by the entrance. In fact, the passengers kept almost the same line on board as on shore. As a result the flow went seamlessly. 8 out of 10 adults in the user test preferred this layout.

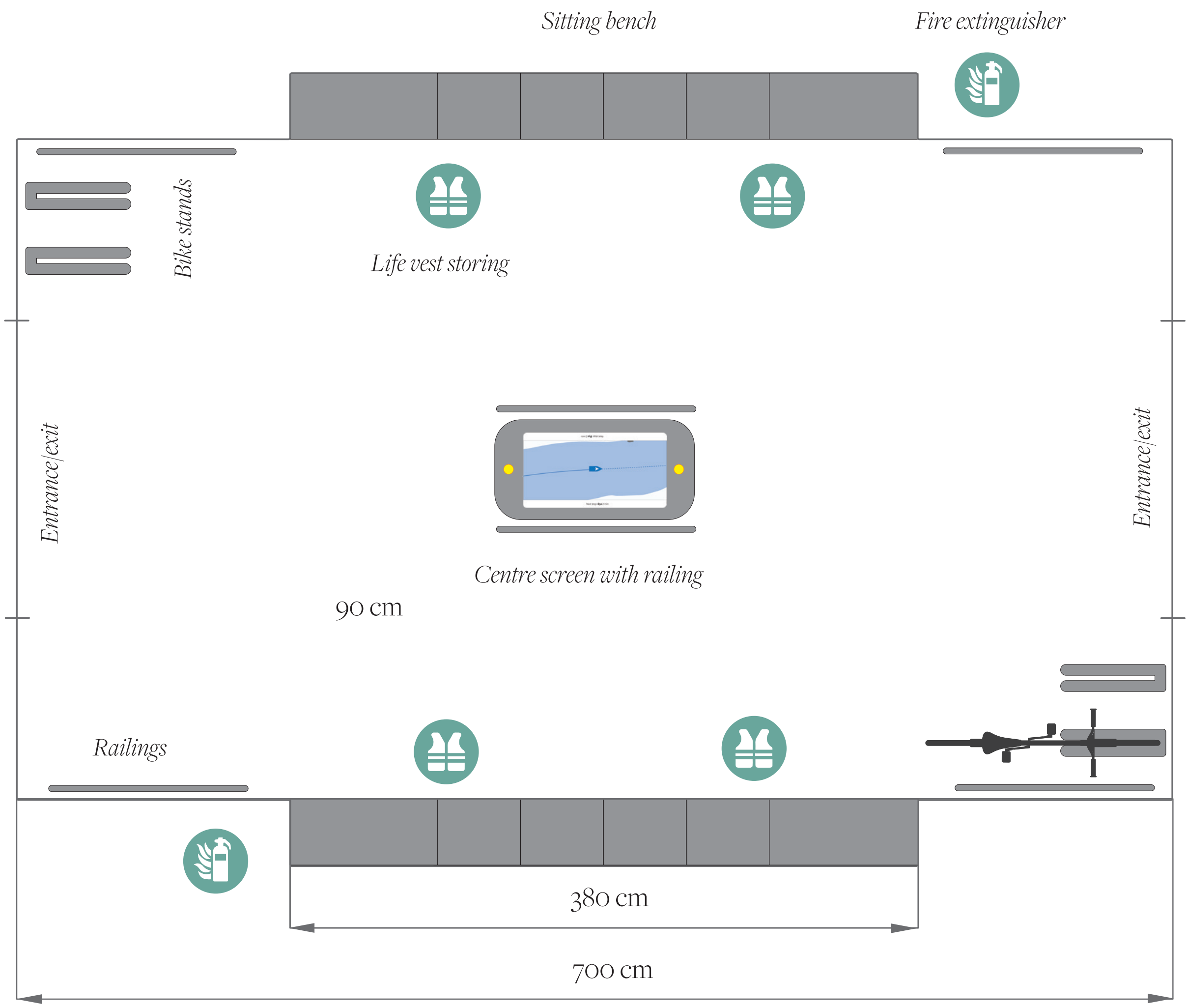
Layout 2 had quite good passenger flow in the test as well. Hence, the layout is a good option if Zeabuz would like to offer more social seating to selected cities. Yet, we believe this setup works better for longer trips than five minutes, due to more time needed to settle down. In addition, the need to sit in groups with travel companions may not be as important for a five minute trip.

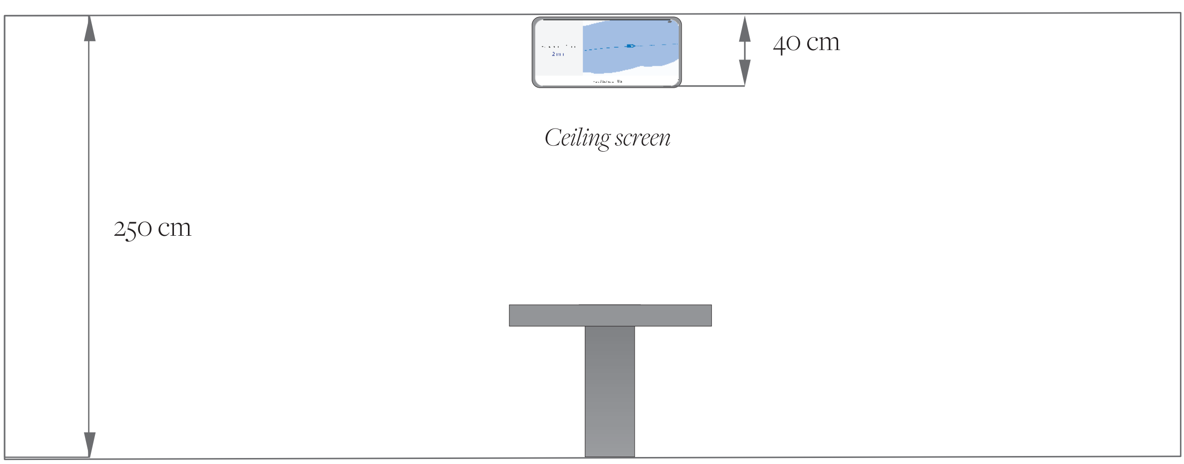


Final iteration

Based on the results and feedback from the user test, following changes were added to the chosen layout:

- Information screen mounted in ceiling at centre ship
- 1 metre removed from the window length to reduce seats
- Bike racks at front and stern corners
- Support - railings and armrests
- Signs for life vest storage
- Remove go-button


Sitting bench
Fire extinguisher
Bike stands
Life vest storing
Entrance/exit
Entrance/exit
Centre screen with railing
90 cm
Railings
380 cm
700 cm


40 cm
Ceiling screen
250 cm

INDIVIDUAL PARTS

PASSENGER JOURNEY

For further work, we must emphasise that the chosen layout works well for the tested scenario. We can argue that a city with a large percentage of bikers requires more bike spots, while a tourist ferry should consist of more separate, social sitting groups such as in layout 2. Statistical data about choice of transportation (walking, biking, etc.) were not found for the investigated cities. In addition, we cannot know exactly what the user group will be 5-10 years from now. Thus, we were not able to design for specific cases. When expanding to new cities, Zeabuz should analyse the user groups of the selected area, and tailor the choice and arrangement of interior modules to fit their needs. With the modular furniture developed in the next chapter, this should be achievable with our design.

Recommendations for future interior designs to keep a good passenger flow:

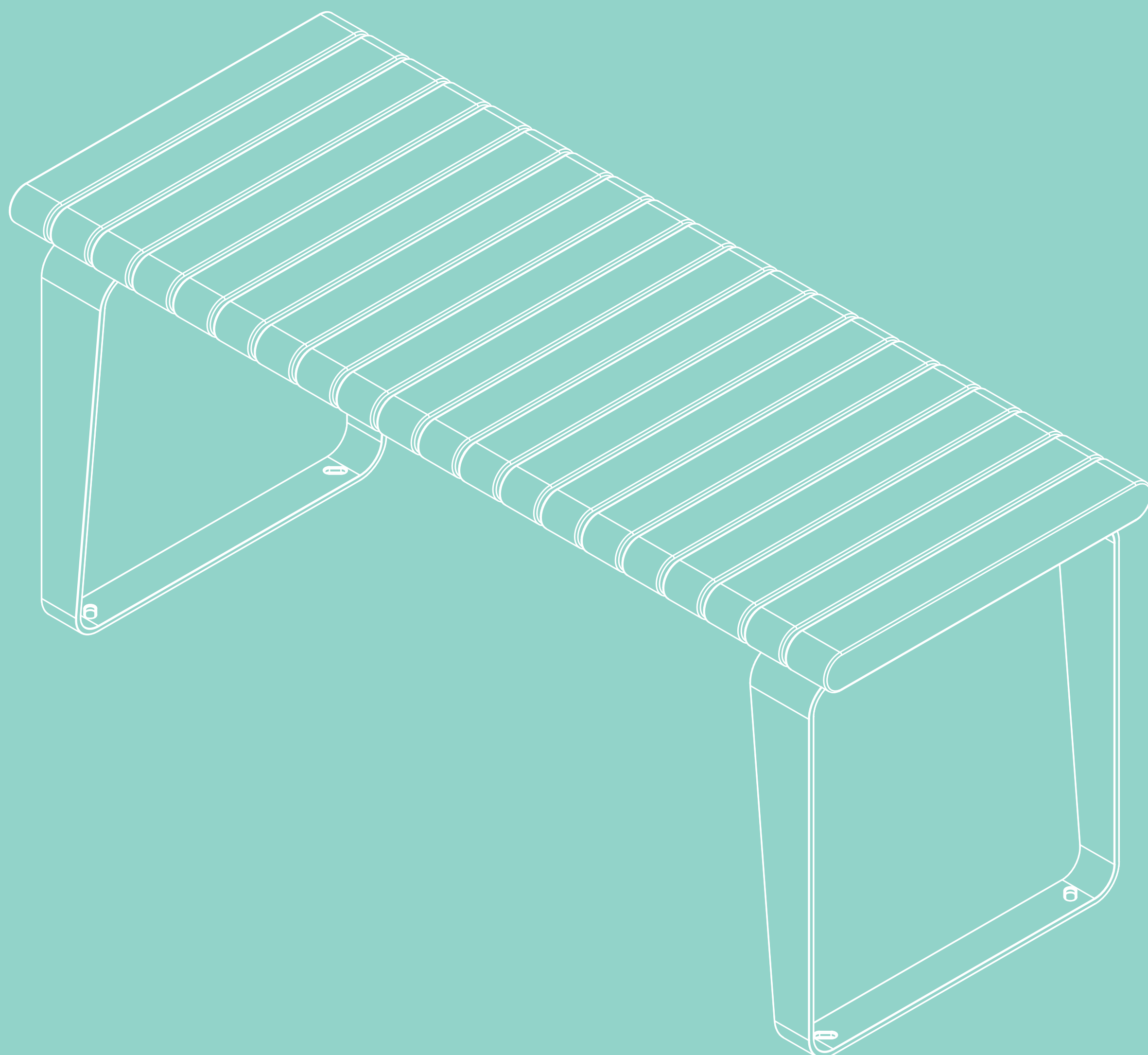
- Walking zones with at least 90 cm width, and the possibility to turn around
- Have 40 cm open space in front of seats to accommodate space for feet and luggage
- 40 cm depth on seats are sufficient
- Have 40 cm open space around floor mounted islands/control panels for sufficient space to stand around it
- Bike Stands should be provided
- Wide doors at 180 cm give an effective and smooth flow

As long as Zeabuz follows these principles, we believe all layouts should work as long as the choice of furniture is tailored to users needs in the specific city.

INDIVIDUAL PARTS

INTERIOR

The interior of a vessel is what passengers will touch, sit on and relate to during the crossing. It's a big part of the journey and experience of the ferry. Accordingly, the interior has to match the values created together with Zeabuz and the design of the exterior superstructure, making it a holistic and smooth experience. The focus working on the interior has been on developing a modular furniture system that adds flexibility to the ferries functionality. This was done by developing a design language through designing a bench, conducted through sketching, 3D modelling and building prototypes. The design language was then applied to different modules that we saw as useful on a ferry, for example interactions surfaces, bike stands and hand railing. Further on, we looked into how lighting can be integrated in the inside of the ferry. This chapter will present the process of the development of the different parts of the interior.



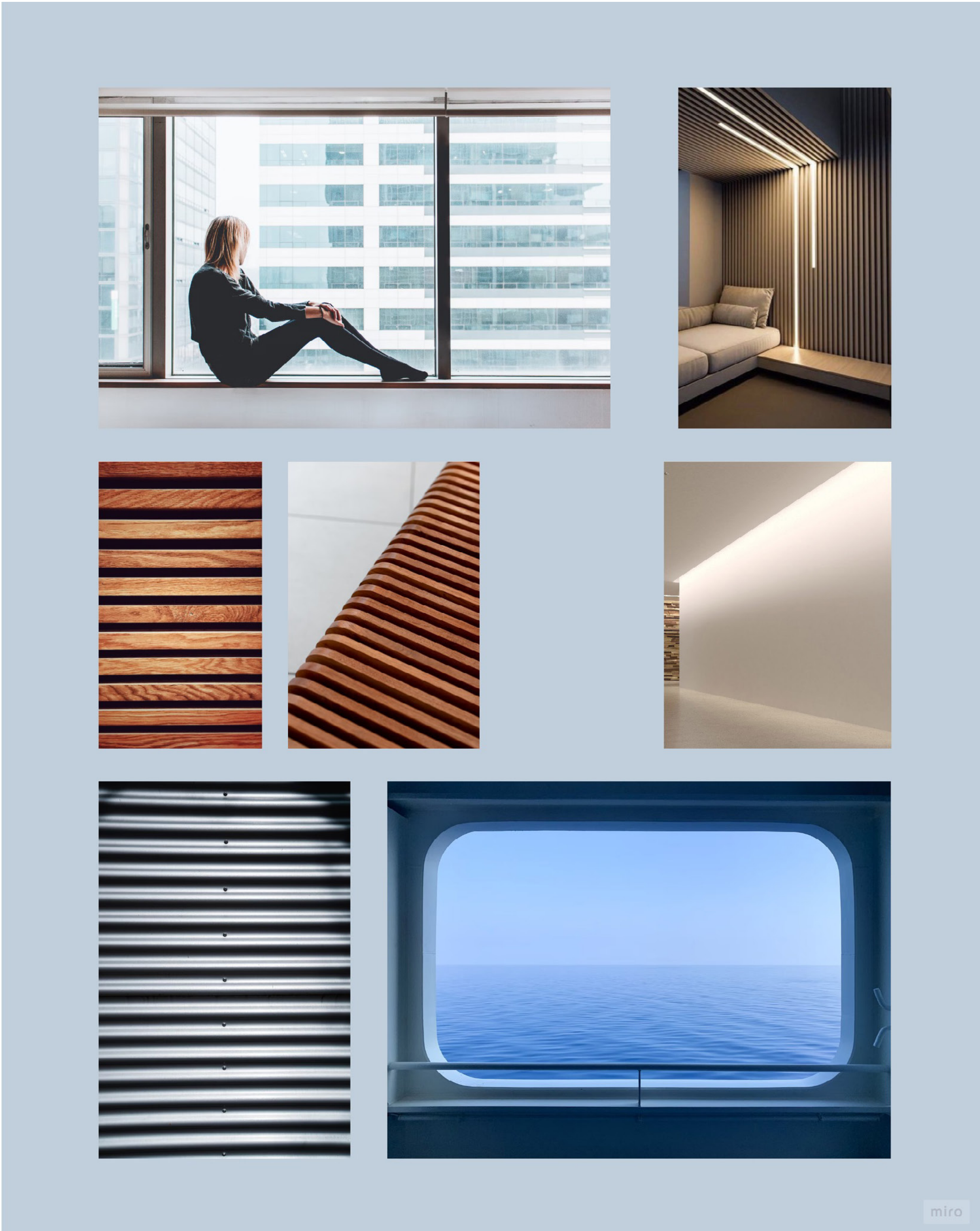
INDIVIDUAL PARTS

INTERIOR

Insight

Moodboard

Having a moodboard for the interior gave a direction when starting the process of ideation. It shows contrast in materials, between warm and cold materials. It shows the desired experience of a big window. Lastly, it shows different lighting solutions that can amplify the internal shape of the boat.


miro

INDIVIDUAL PARTS

INTERIOR

Ferry interior recommendations and regulations

Most of the recommendations and regulations influencing the interior are covered in the insight chapter. Here is a summary of the most important legislatives for the interior.

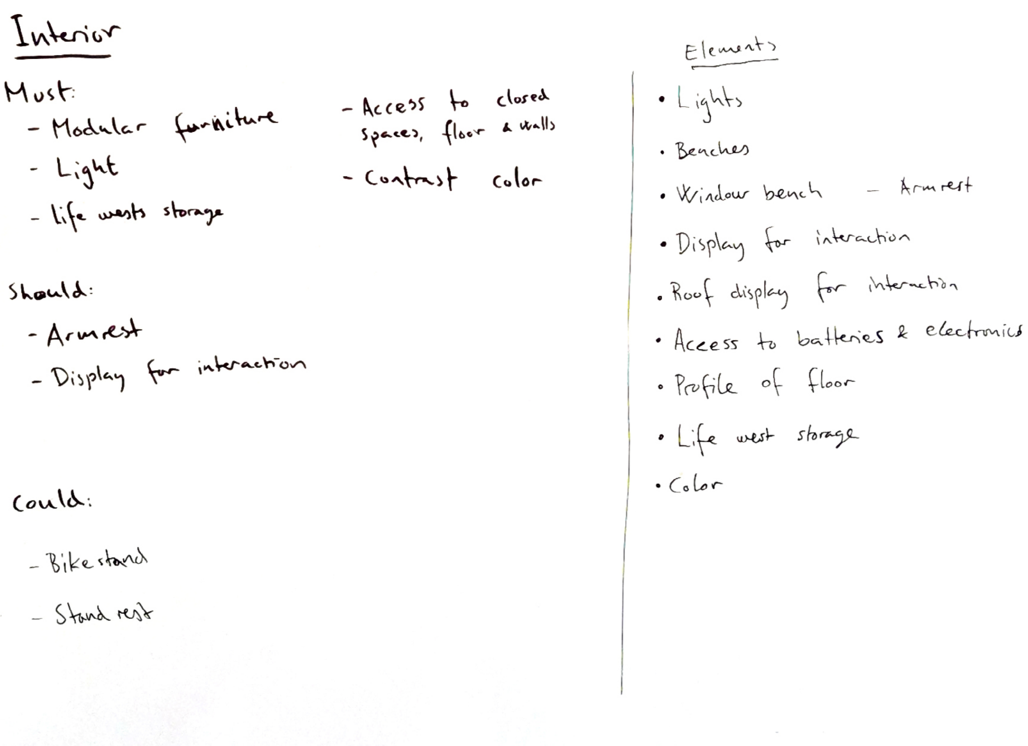
The recommendations(Universell utforming, 2020) regarding use of colours in public transport is to use contrast to help people with reduced sight to distinguish the different elements. The contrast should be between the floor and the walls and elements in the room.

Recommended height of benches is 450 mm and depth is 400mm. A person sitting on a bench also requires at least 500mm of width. A table should have access underneath the table top, so that wheelchairs can have their legs underneath it. (Standard Norge, 2011, s.32)

Life vests on board are a requirement for safety on board. It must be obvious for the passengers where the life vests are stored for easy access. It is common on ferries and cruise ships to store life vests in benches, or storing life vests has been utilised as a bench. Requirements regarding storage of life vests is that they should be stored well ventilated and easily accessible (Forskrift om fartøy under 24 m som fører 12 eller færre passasjerer, 2020).

Must-Should-Could

A prioritised list of elements that needed to be included into the interior part was created at the beginning of the process of making the interior. This became an ever growing list during the project as there are a lot of elements to consider inside a ferry.



Looking around

Travelling by train, busses and aeroplanes and walking around in the city, we have gotten impressions on how furniture and lighting can be solved in public spaces. For example, sitting on a bench at Rotvoll gave inspiration to how the assembly of the bench could be solved.

Ideation

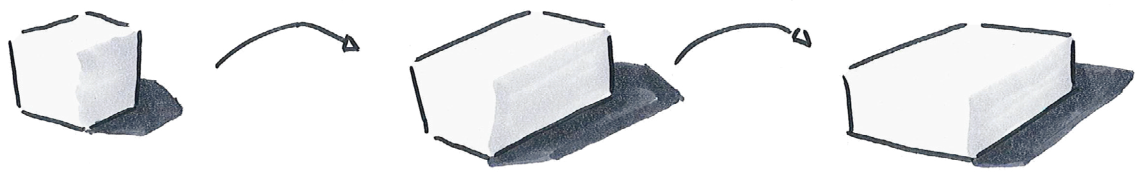
When starting ideation on the superstructure we at the same time started sketching the inside as well, to gain an early understanding of how the experience of being on board would be. Many of the thoughts from the early phases were brought into the process of detailing the interior of the ferry.

Modular interior

To ensure a flexible design where the ferry can be placed in different cities and countries with different needs and culture, a modular interior design occurred to be a good solution for this flexibility. This was also based on the findings from the work conducted on user journey and passenger flow, that showed that different layouts had different characteristics. Thus, having the ability to make changes to the layout would add value to the overall service.

The interior needed to be simple, flexible and easy to change. It was thought that the characteristic design of the superstructure should be connected to the interior. This was solved by letting some of the elements from the superstructure be repeated in the interior. Since the interior is modular, a vast variety of elements can be developed to comply with different needs. A common design language for these elements was therefore necessary. The most basic modular element for this system was a bench, making it a good starting point to develop the language.

When building and setting up the 1:1 scale mockup of the passenger compartment, we also built six long benches and two small benches. These benches were 450mm high, 400mm deep and 1200mm and 600mm wide. These benches showed that the height and depth of the benches worked really well. The ability to quickly change the layout was practical in the user test, but would also add value in a finished product.

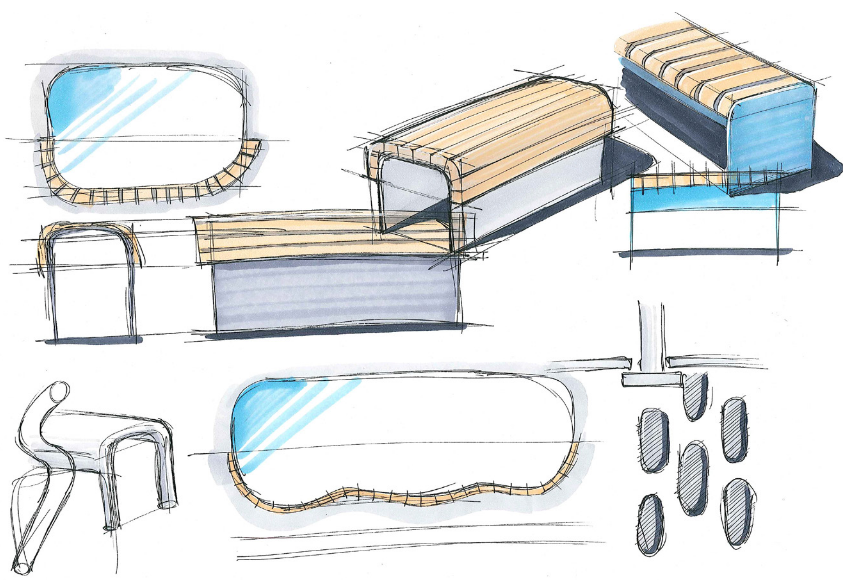


INDIVIDUAL PARTS
INTERIOR

Bench – design language

Starting out with a bench as the defining element for the modular interior was done to narrow the scope to ideate on. A bench was an element we most likely would need anyways in the design. To design a bench, structural challenges and human interactions needed to be solved. As a result, the bench became a description of a design language that was applied onto all the elements of the modular interior of the ferry.

The use of wood as the touch point of the human body appeared early in the process. Wood is familiarly used in benches and public furniture and is transferable to public transportation on waterways. Wood can also be less vulnerable to vandalism than for example textile covered seating.



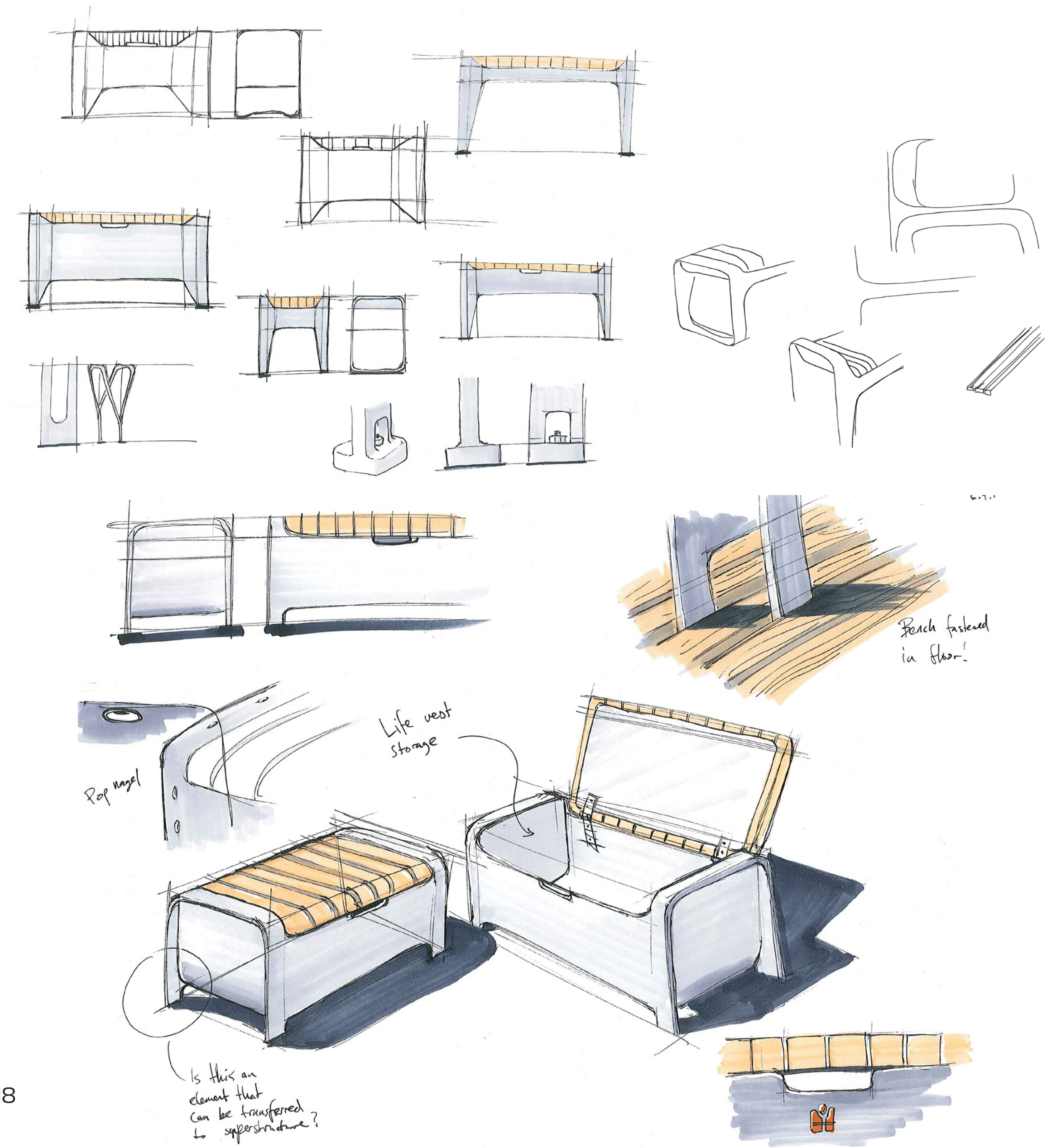

Storage inside
Life wests?
Computers

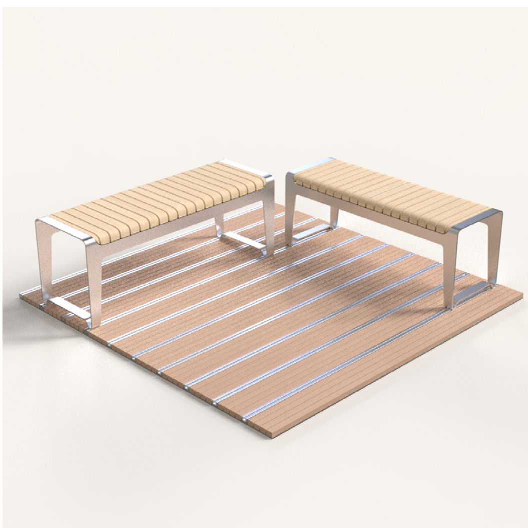
INDIVIDUAL PARTS

INTERIOR

First iteration

To have contrast between the seating part of the bench and the structural part, the structural part was early decided to be made out of aluminium.

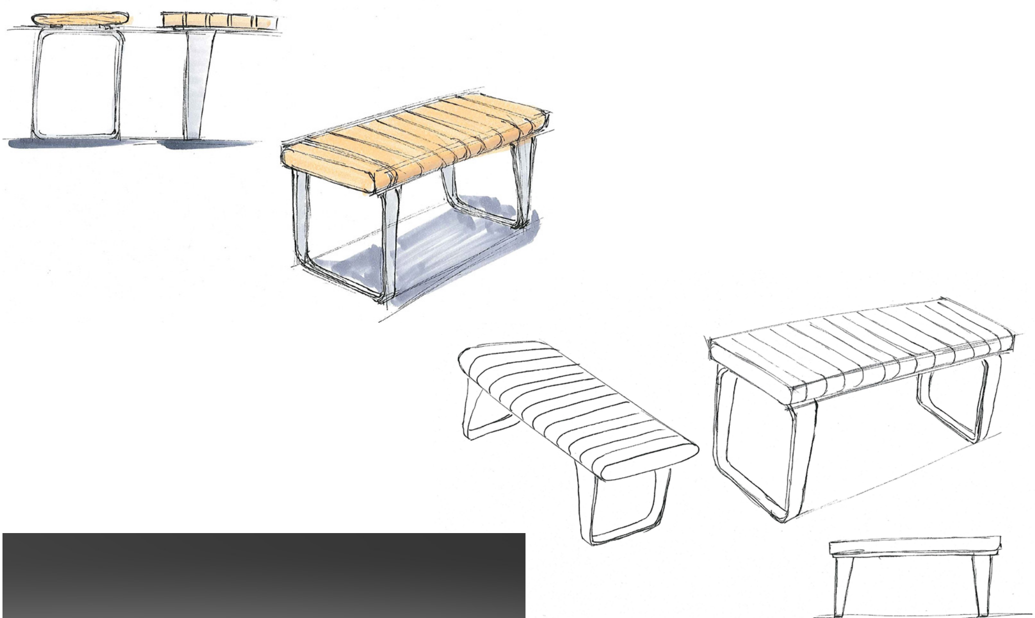


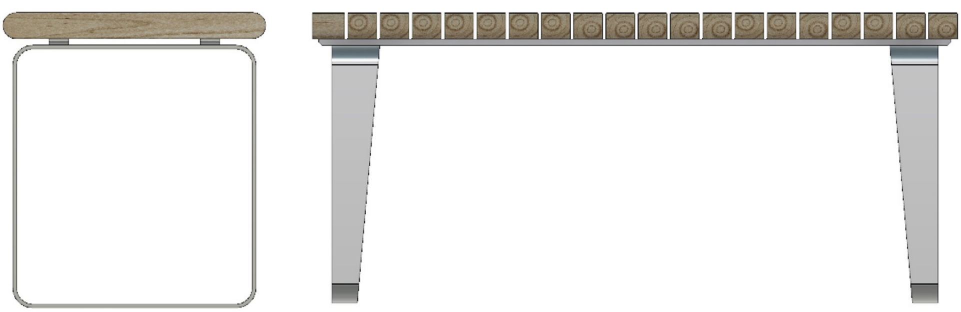


INDIVIDUAL PARTS
INTERIOR

Second iteration

When doing more iterations on the superstructure, we landed on having the side windows angled. To connect this to the interior design language, an angle was added to the feet of the bench. This added structure to the feet, and also gave it more character.



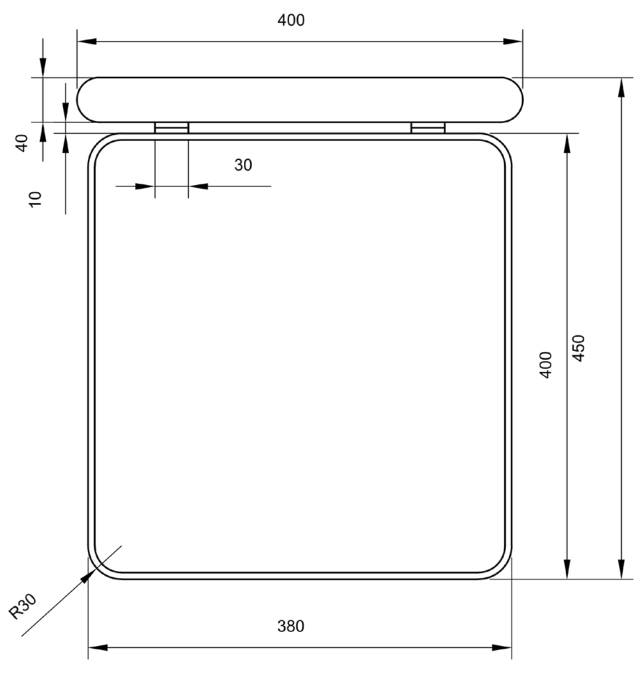


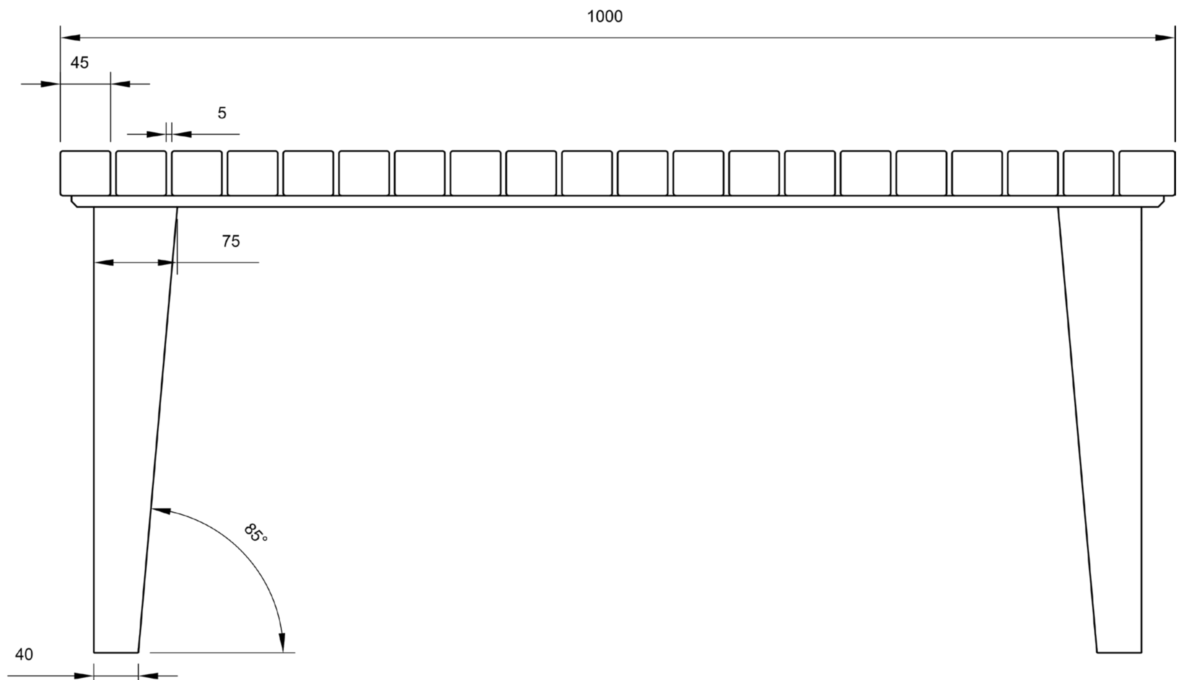
INDIVIDUAL PARTS
INTERIOR

The bench consists of three main parts, the legs, the wooded seating and the supporting aluminium profiles connecting the legs and the seating. The wooden parts are screwed to the supporting beam, and then the beam is screwed to the legs.

The aluminium parts of the modular interior could be powder coated to connect to a given city's main colour or to the public transport provider that is buying the service from Zeabuz.

The design language is defined by the legs, the seating area and space between them. The legs are a frame with rounded corners, and a distinct angle making it wider at the top. The seating has, when seen from the side, completely rounded off corners, making it gentle for those using it. The space in between them, made with the supporting beam, elevates the seating and by that makes the seating float on the frame. These elements were then further transferred onto the other modules in the modular system.



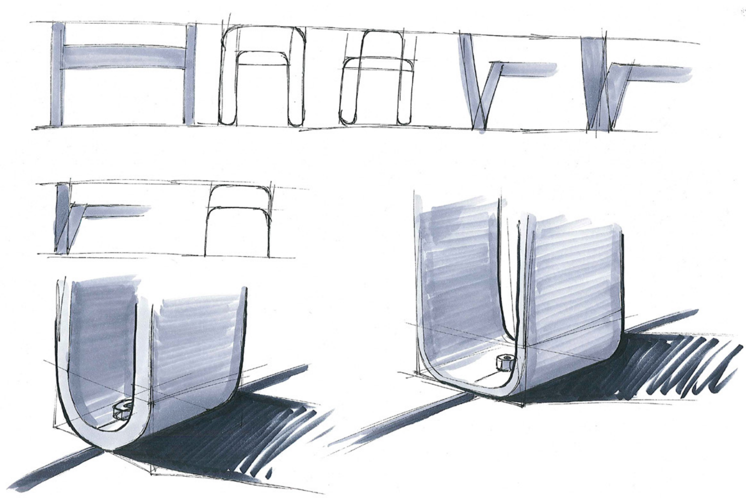

1000
45
5
75
85°
40

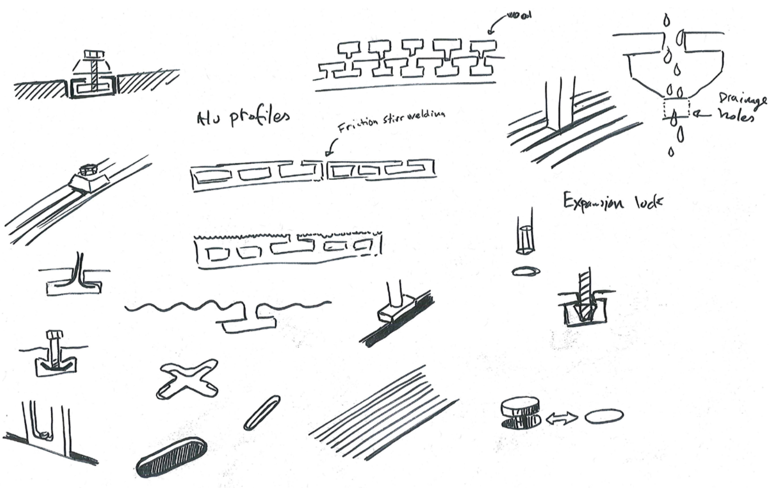
INDIVIDUAL PARTS
INTERIOR

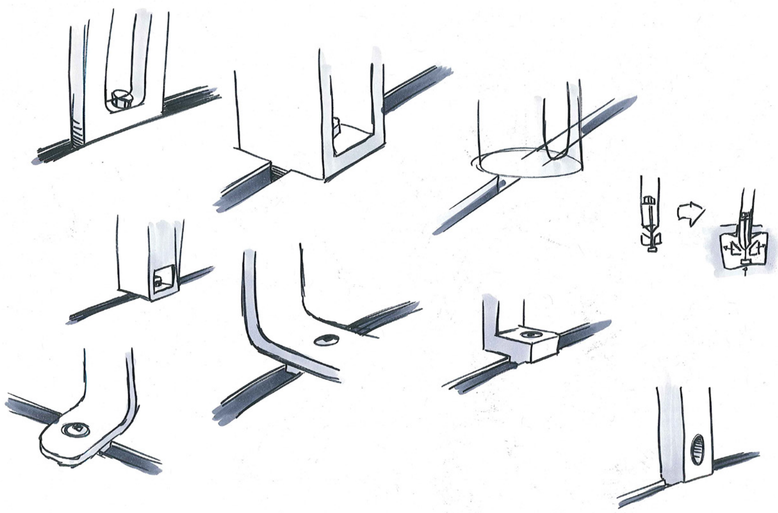
Railing and Floor

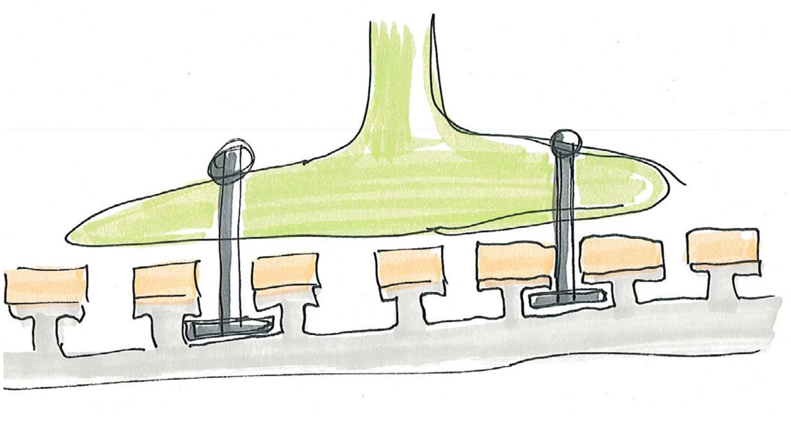
Interior in public transport should be sufficiently secured to be safe during movement and avoid vandalism. It therefore needs to be attached to the structure in a way that it can't be taken apart with your hands. A modular system should at the same time be detachable and it should be easy to make changes in the layout. Aeroplane seating is modular by being connected to an aluminium rail, whereas the seats can be removed or moved back and forth. This was an inspiration for a similar system, as it is cheap to produce, it utilises standard components and makes it easy to make changes. The rails also became a visual element that gave the floor a direction in the driving direction. Other ideas we had, where holes were made in the floor, would not be as sufficient, as it would require machining.

A railing system to make the interior modular would need this railing to be integrated into the floor. The first idea was to make a custom extruded profile with the railing integrated. A problem we saw with this idea was that if the railing should get damaged, a whole section of the floor would have to be replaced.




wood
Drainage holes
Alu profiles
Friction stirr welding
Expansion lock

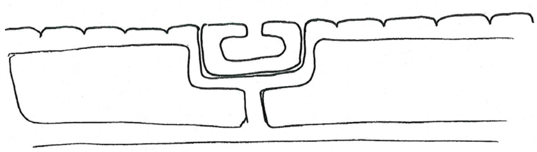




INDIVIDUAL PARTS

INTERIOR

To deal with this, an interchangeable profile could be used instead. By using AluFlex profiles and components, most of the foundation for a modular system is provided. These are well known and well proven systems that are durable and reliable.

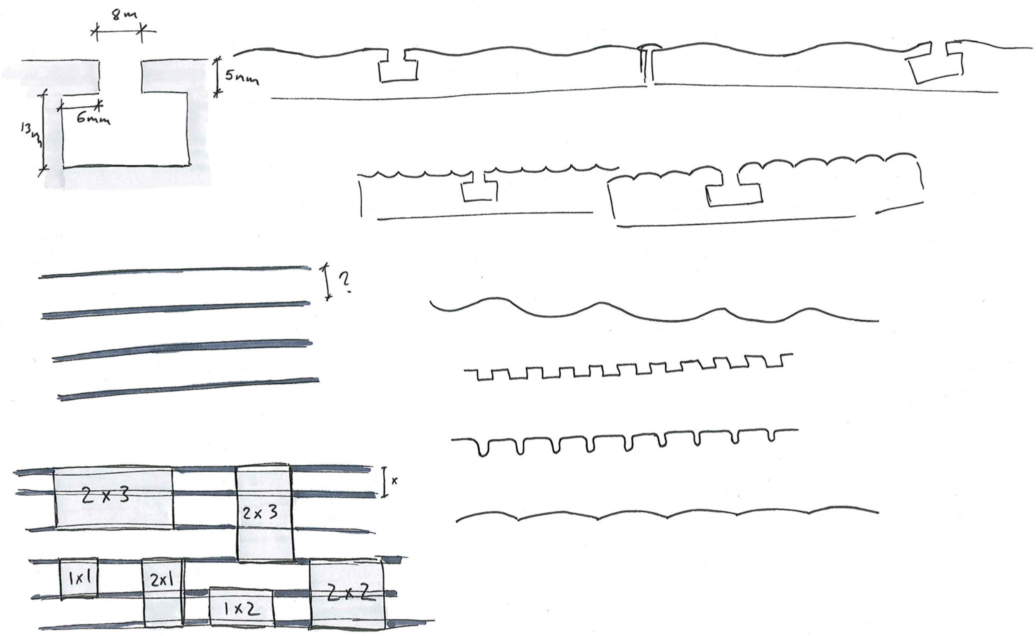


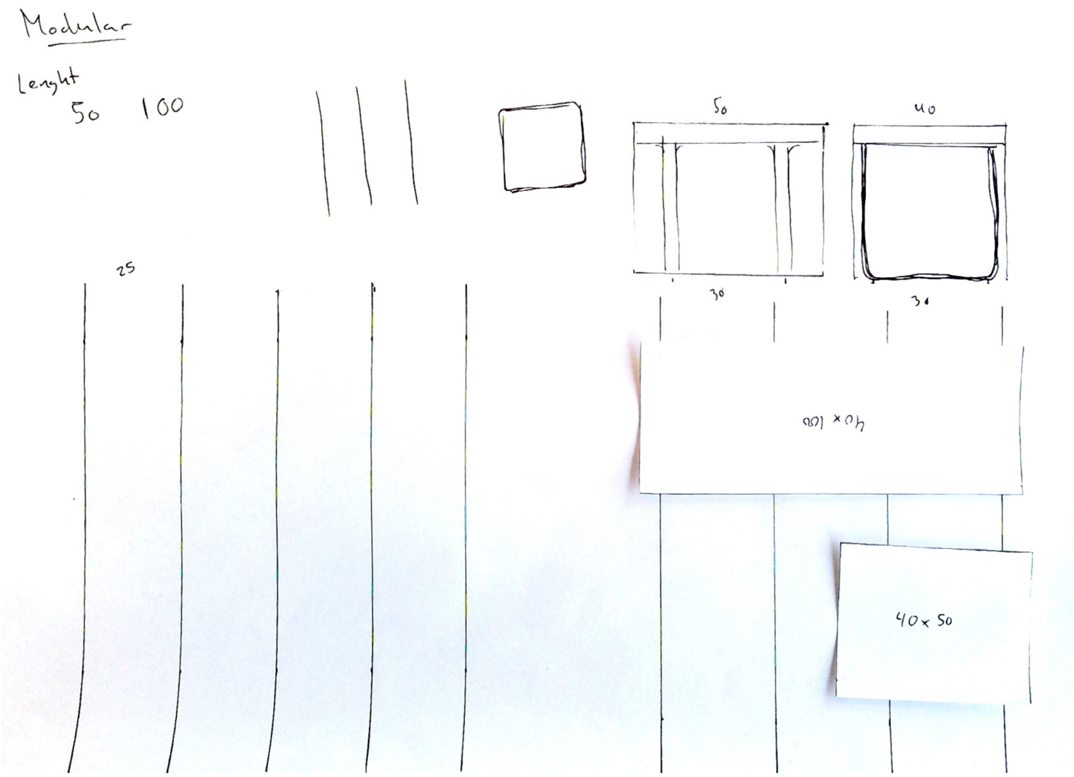


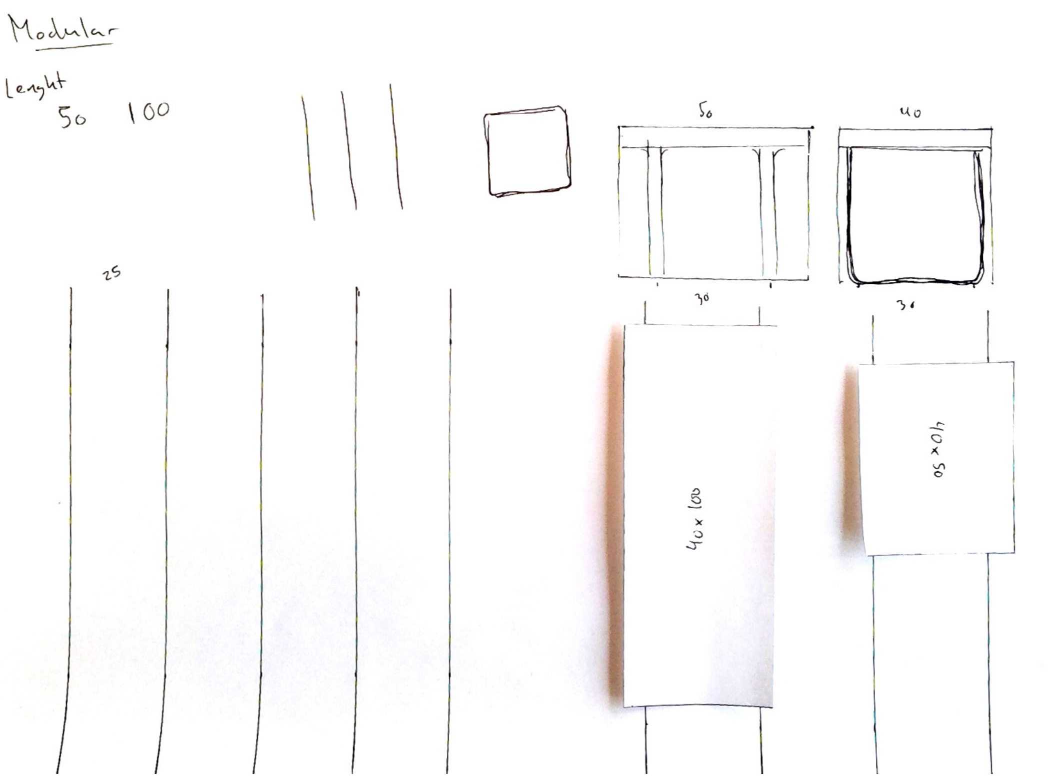
INDIVIDUAL PARTS

INTERIOR

To find an optimal solution between the amount of rails and the distance between them, the standard measurements for seating were used. By cutting out paper seats in the correct scale and trying out different distances, we concluded that having 30cm between each rail was a good compromise.

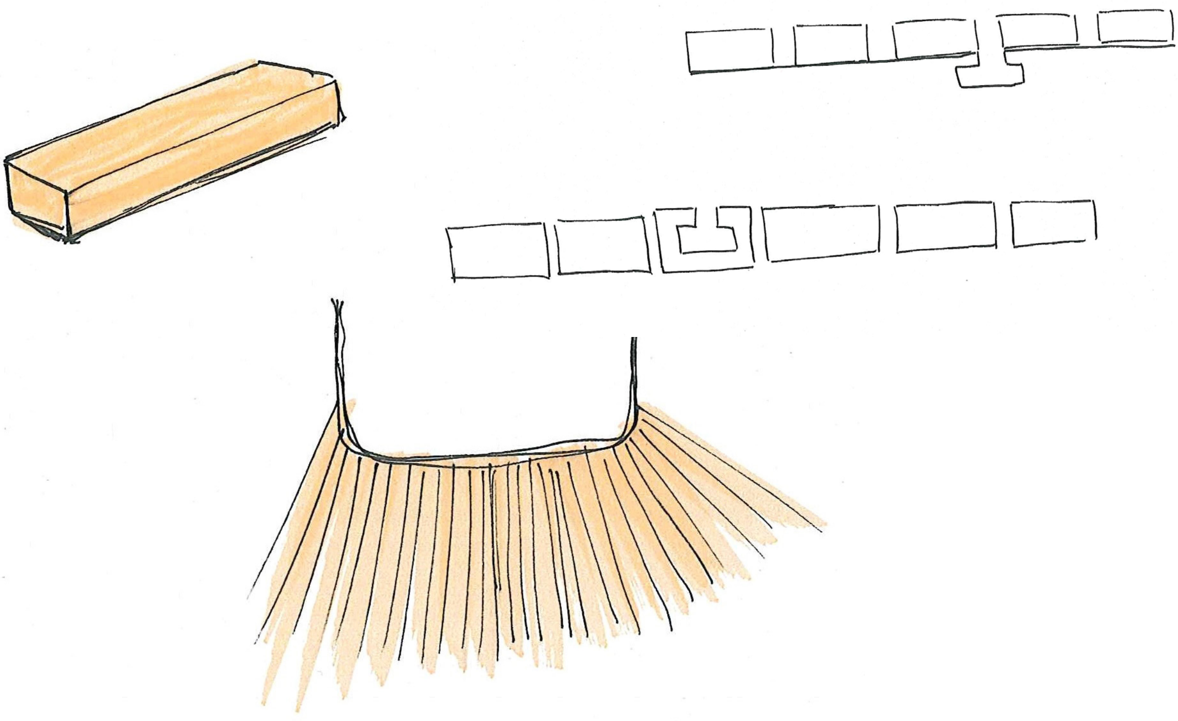


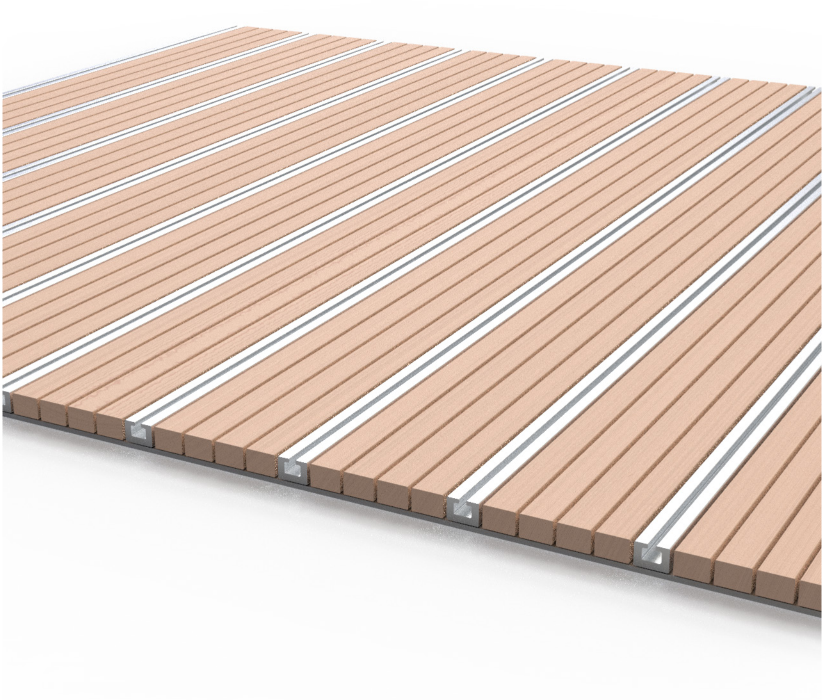

Modular
Lenght
50 100
50
40
25
30
30
40x100
40x50


Modular
Lenght
50 100
50
40
25
30
30
40x100
40x50

INDIVIDUAL PARTS
INTERIOR

Another idea we worked with was to use wooden bars as floor. This would hide the rails, but still make them accessible. However, as we had decided on using wood in the touchpoints of the interior, a wooden floor would not contrast the interior elements properly.



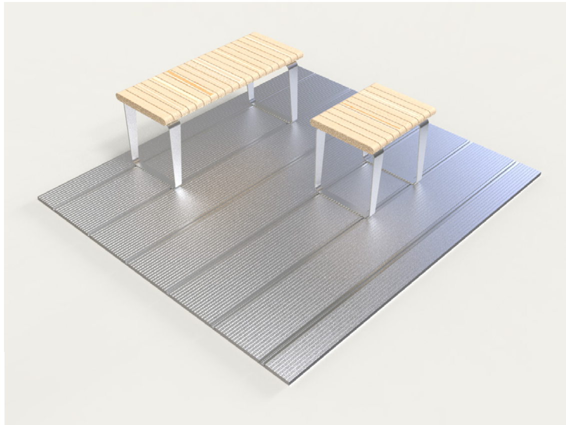


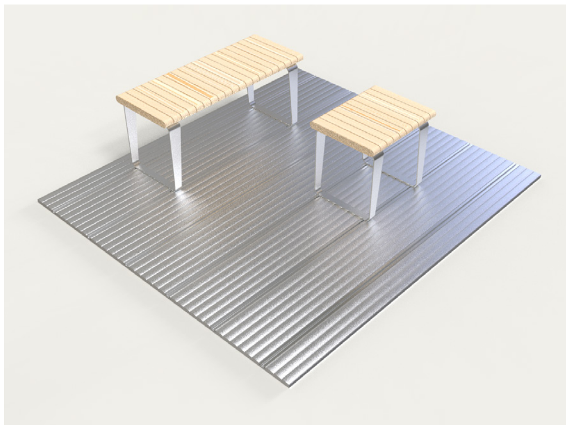
Therefore we decided on having the floor in aluminium. This makes it possible to use a custom aluminium profile with an integrated slot for the railing. Having a custom profile also had the opportunity to create our custom surface and build in functionality.

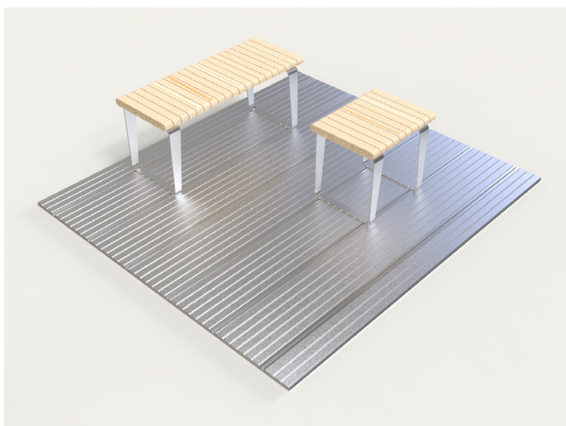
INDIVIDUAL PARTS

INTERIOR

Using the surface as a visual element in the interior design, the floor can give the room direction. Due to the railing being visible and already creating lines in the length direction, the aluminium profile can be made in a way where it echoes the railing. By doing so, the railing becomes a less prominent part of the floor and more integrated. The lines enforce the direction of the floor. Three different profiles were modelled for comparison. The profile mimicking the railing the most was the one that we decided on, because it was less overwhelming and didn't introduce any new curves.

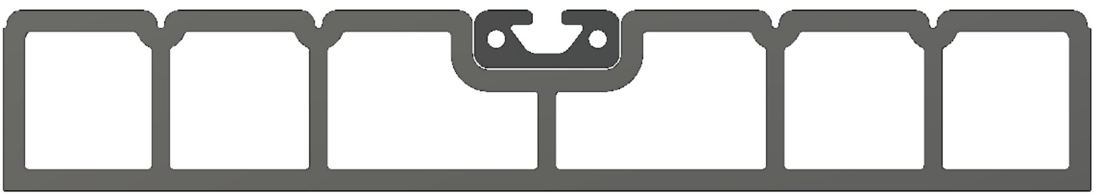




INDIVIDUAL PARTS

INTERIOR

By having a custom profile for the floor, the option to build in added functionality is present. This functionality can be added to the structure, water drainage or cable management. How this should look and also what functionality that can be built into this profile is something that should be investigated further.



The aluminium profile was about 300mm wide, and the thought is that these profiles should be friction stir welded together. As the weld will leave a small bump, an indent will be made in the profile right where the weld will be. The alignment of the profiles will not be perfect, therefore the modular furniture is designed in a way that allows for some variations in the width between the rails connected to the floor.

To comply with the regulations and follow the recommendations (Universell utforming, 2020), there should be a sufficient contrast between the floor, walls and elements in the room. Surfaces the passenger is touching are made out of wood, since it's warm and soft material in contrast to aluminium. As the floor is extruded aluminium profiles covered with anti-slip texture, which might need to be reapplied after wear, this surface is kept as raw aluminium. Depending on which type of wood is used, this gives adequate contrast to the floor. For the walls, a light paint could be a contrast to the grey/silver on the floor and the wooden seating and railing.

INDIVIDUAL PARTS

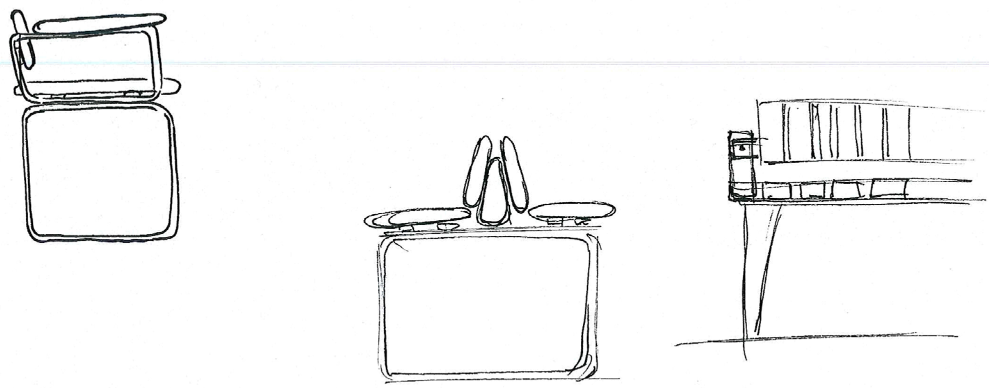
INTERIOR

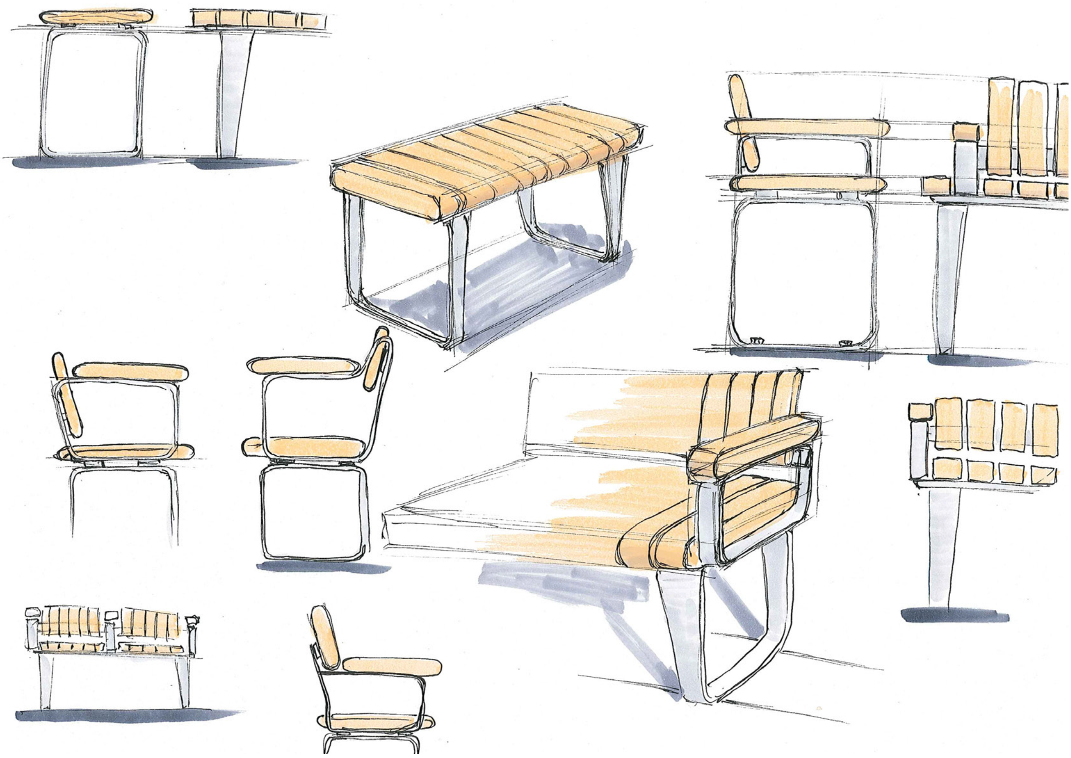
Modules

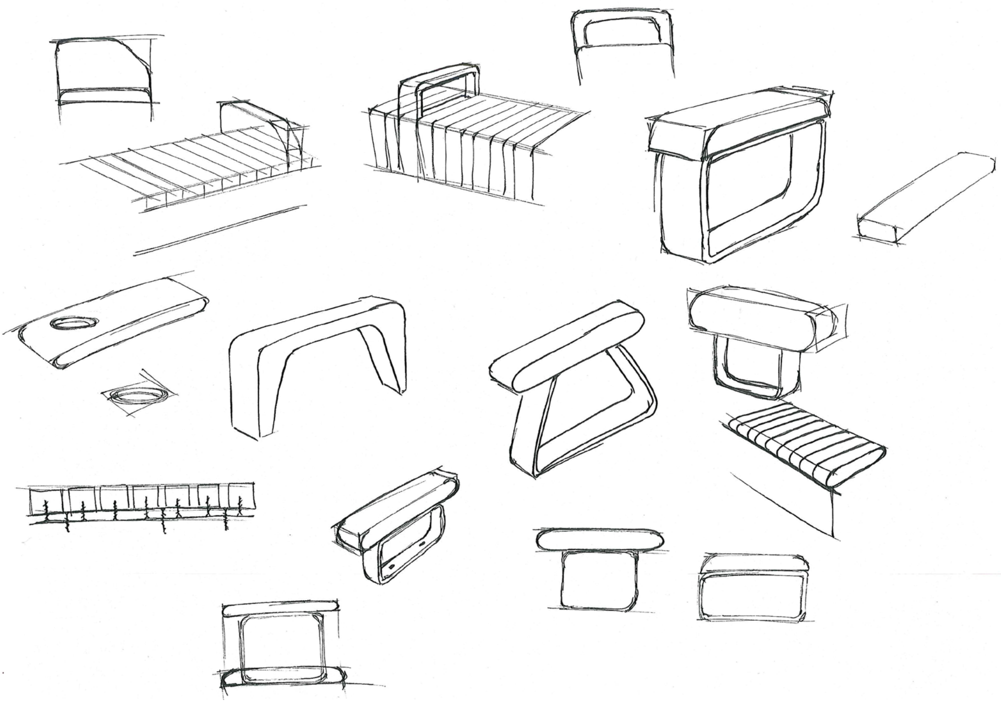
By using the design language developed with the bench, modules were designed to fit into the modular system. More modules can be added, using the same principles of the design language.
The selection of modules developed, emerged from the insights conducted with the work done on passenger flow.

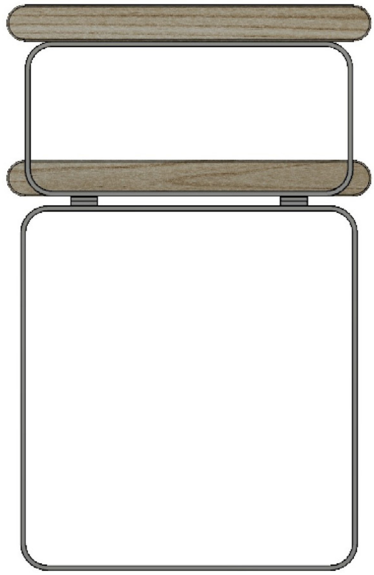
Benches

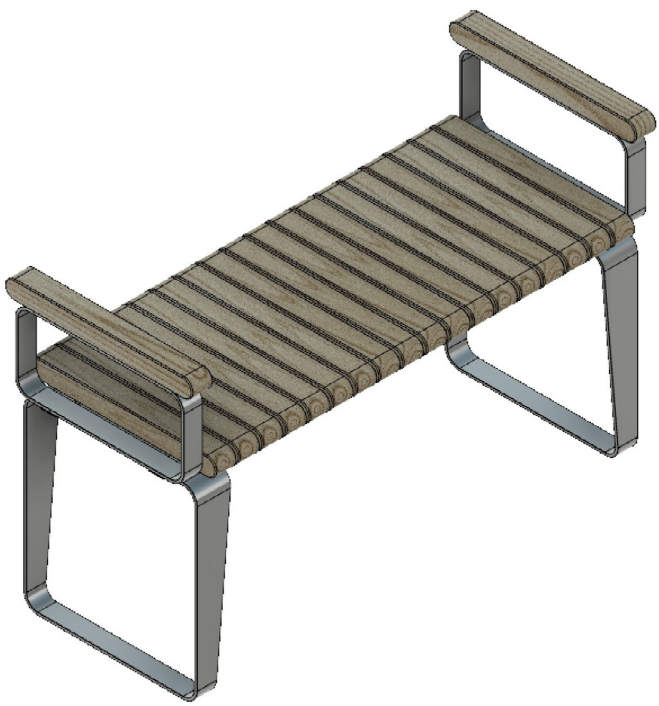
Versions of the bench have been extended with multiple additions. An armrest and backrest has also been developed to comply with the needs of different solutions. The armrest is good for elderly sitting down or getting up, and can also be suitable for dividing the seating areas, giving it more structure. A backrest is not included in our layout of the interior, but with different needs and layouts, the request for a backrest might arise.

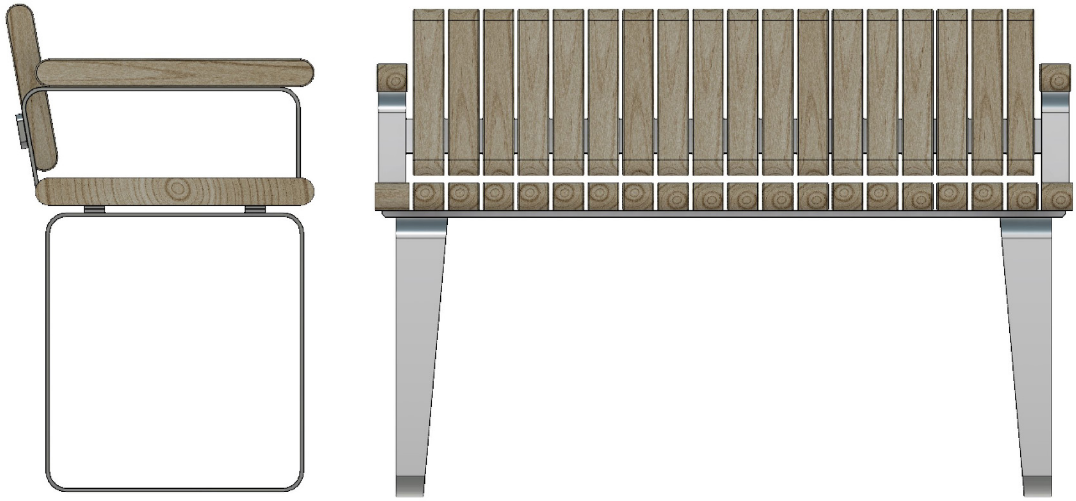








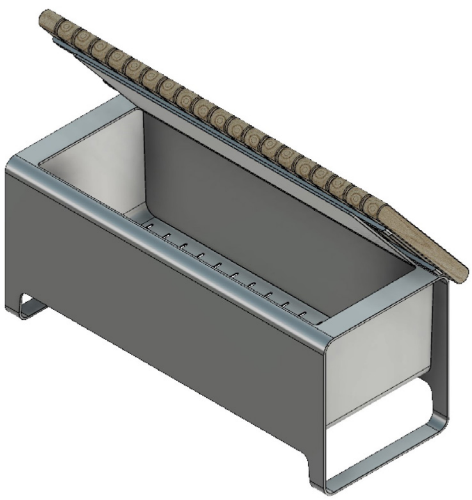
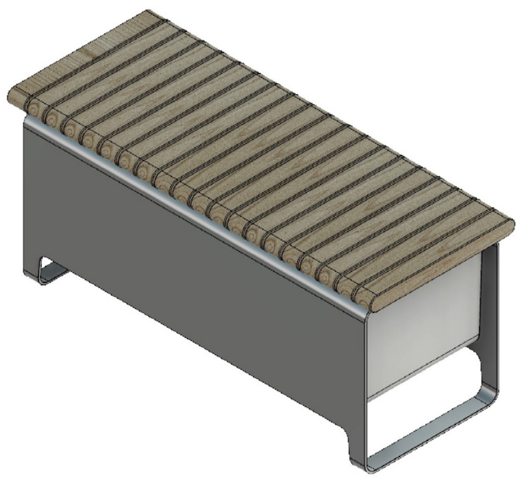




INDIVIDUAL PARTS
INTERIOR

By adding volume underneath the benches, this would allow for storing life vests. By lifting up the floor of the volume, air holes can be made to ensure proper ventilation of the life vests. To ensure passengers understand that life vests are stored in the benches, a sign must be added. The volume underneath the window benches is space that serves well as life vests storage, but also the free-standing modular benches can be taken advantage of as storage area.

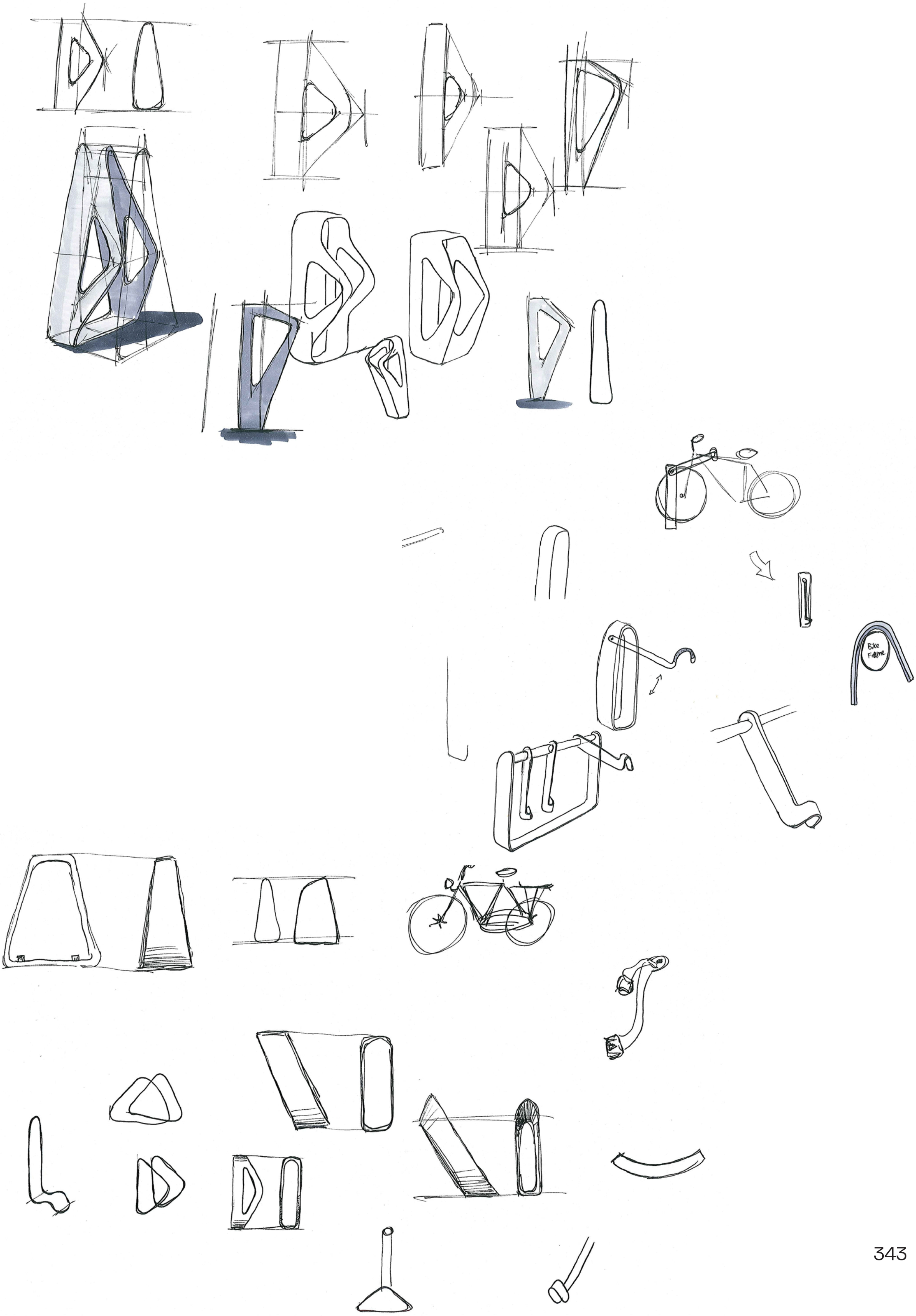


INDIVIDUAL PARTS
INTERIOR

Bike stand

As our service will serve commuters and others travelling by bike, having bike stands on board will be of good use for those wanting to sit down during the crossing. It also dedicates space for bikes and makes it obvious where the bikes should go. During ideation some more innovative ideas on bike stands occurred, but these were not pursued.

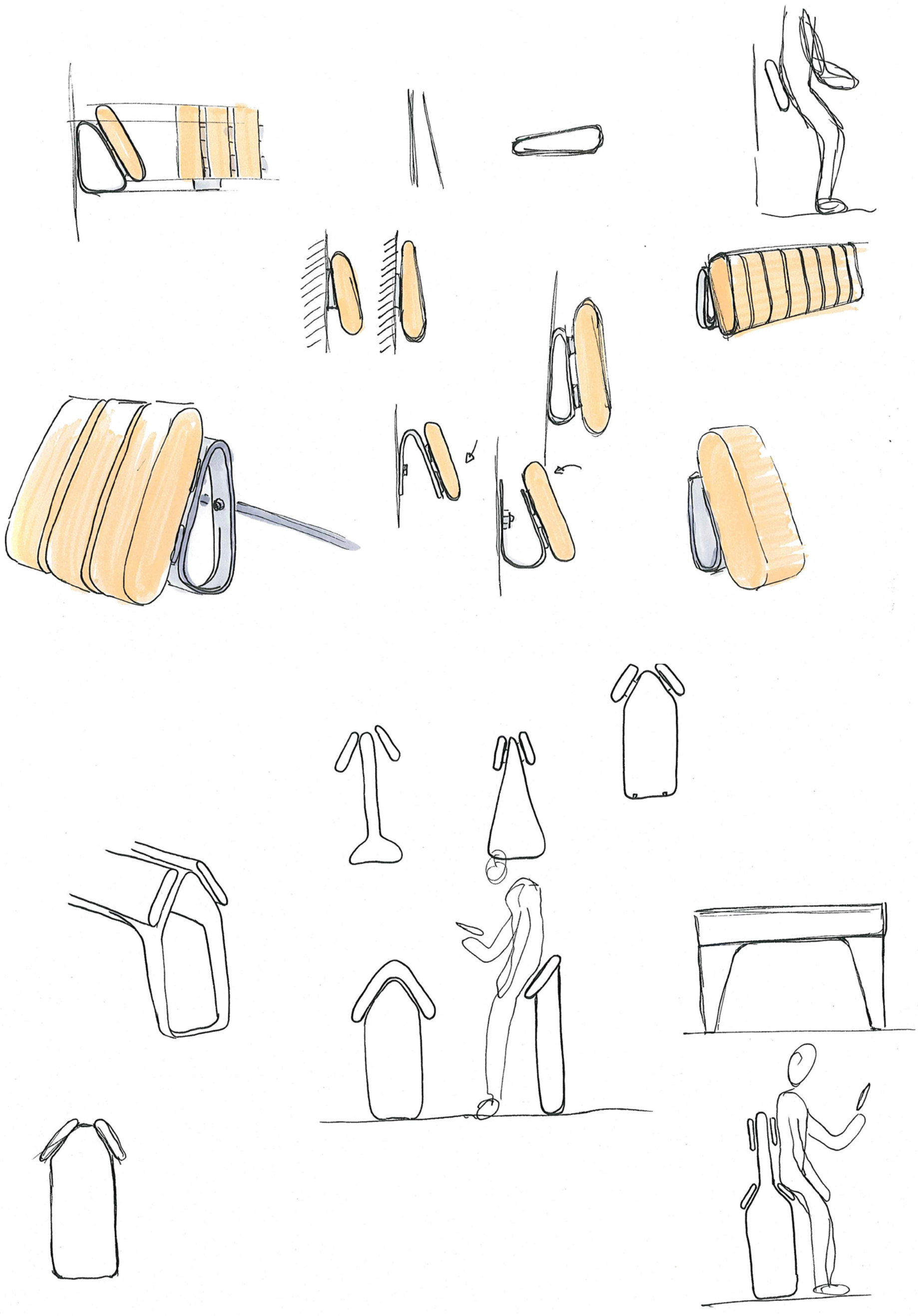

Bike Frame

INDIVIDUAL PARTS

INTERIOR

Lean Bench

To accommodate different seating options and the ability to further increase passenger quantity, a lean bench was developed. As the crossing is a rather short trip, having a dedicated spot to lean into may be enough. This solution is not connected to the floor and would need the same type of railing system integrated into the wall section. Having one or two rails on the four walls would allow for a lot of added flexibility for adding further modules. The lean bench follows the same principles of having wood where the user touches the bench.

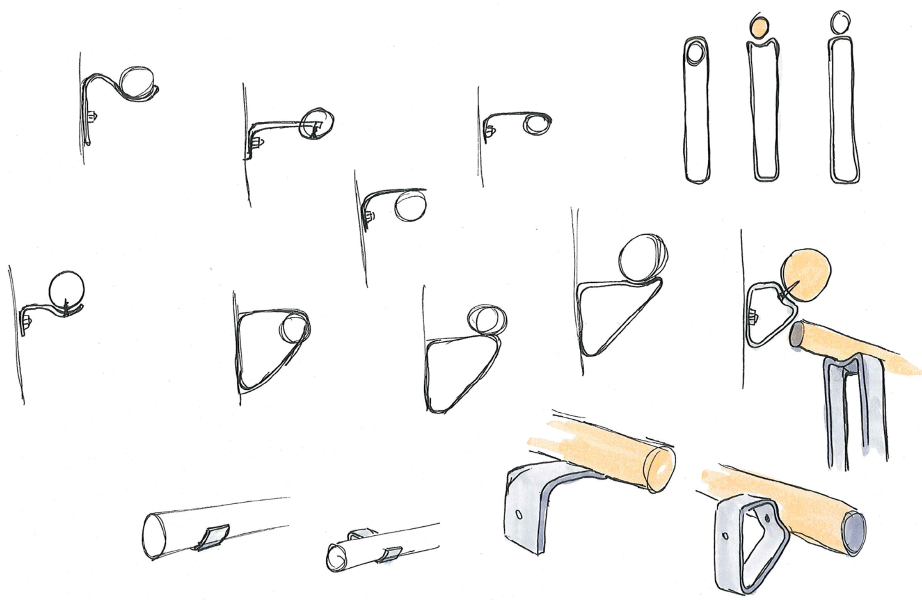


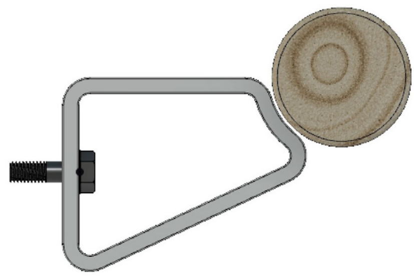
INDIVIDUAL PARTS

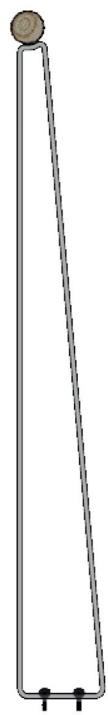
INTERIOR

Hand railing

Having something to hold onto during the crossing can be good for people not confident with ferries and movement in a vessel. It also can be of assistance to elderly people. As there are limited walls to mount the railing to, therefore two different solutions were developed, one that exploits the modular floor and one that uses the same wall railing as the lean bench.





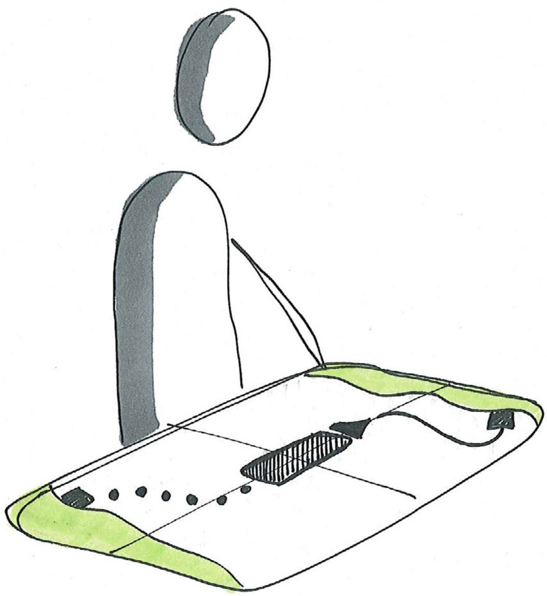


INDIVIDUAL PARTS

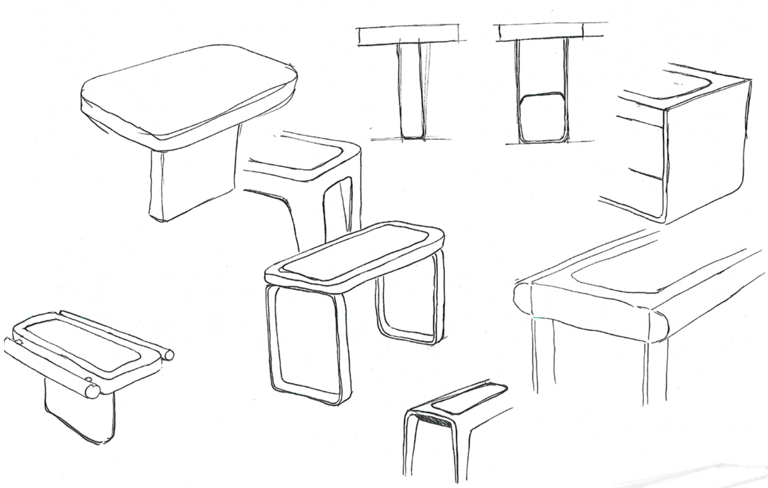
INTERIOR

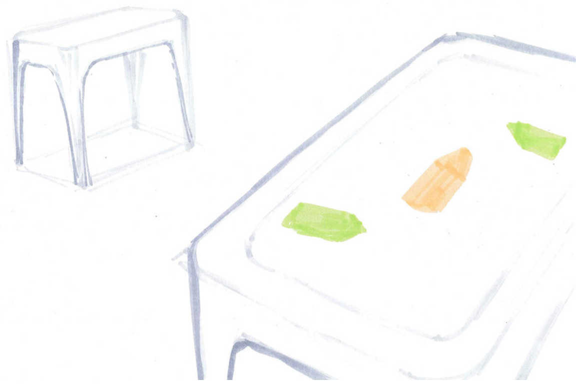
Centre Screen

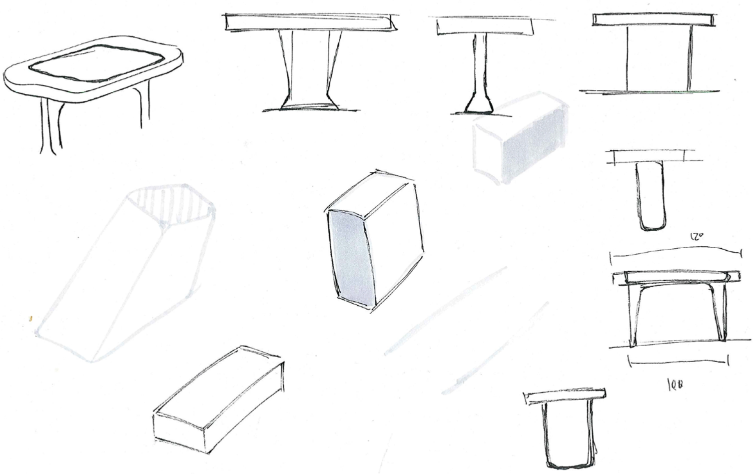
The centre screen serves as the heart of the boat where people can gather around and view information about the ferry's journey, its intentions and recognized vessels.



These early ideas came with discussions about how the ferry could communicate with the passengers. After building the 1:1 mockup, when walking "on board", we saw having something in the centre as the natural point to place information.

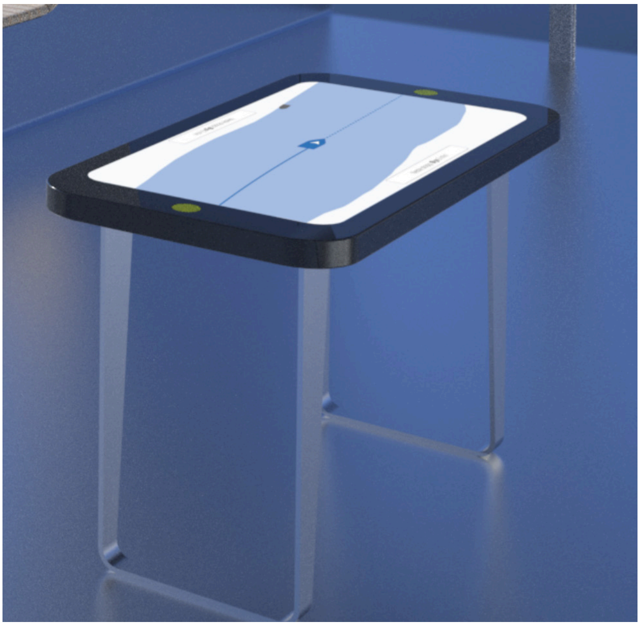


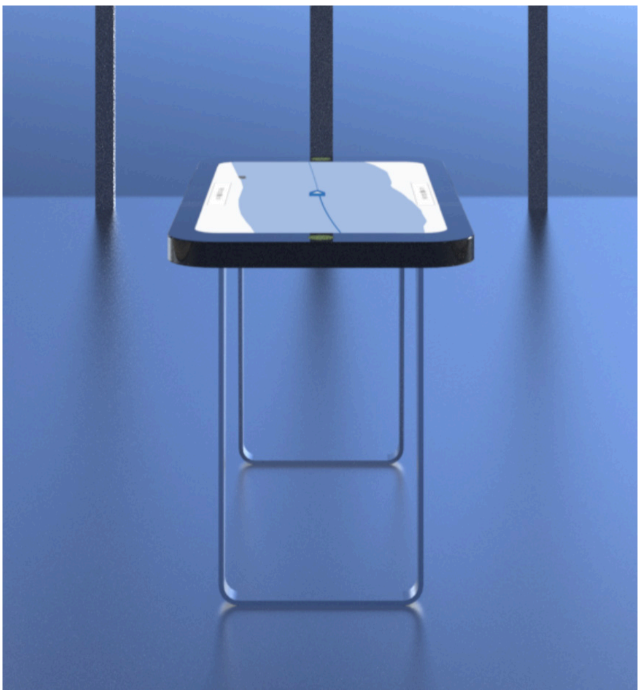




INDIVIDUAL PARTS
INTERIOR

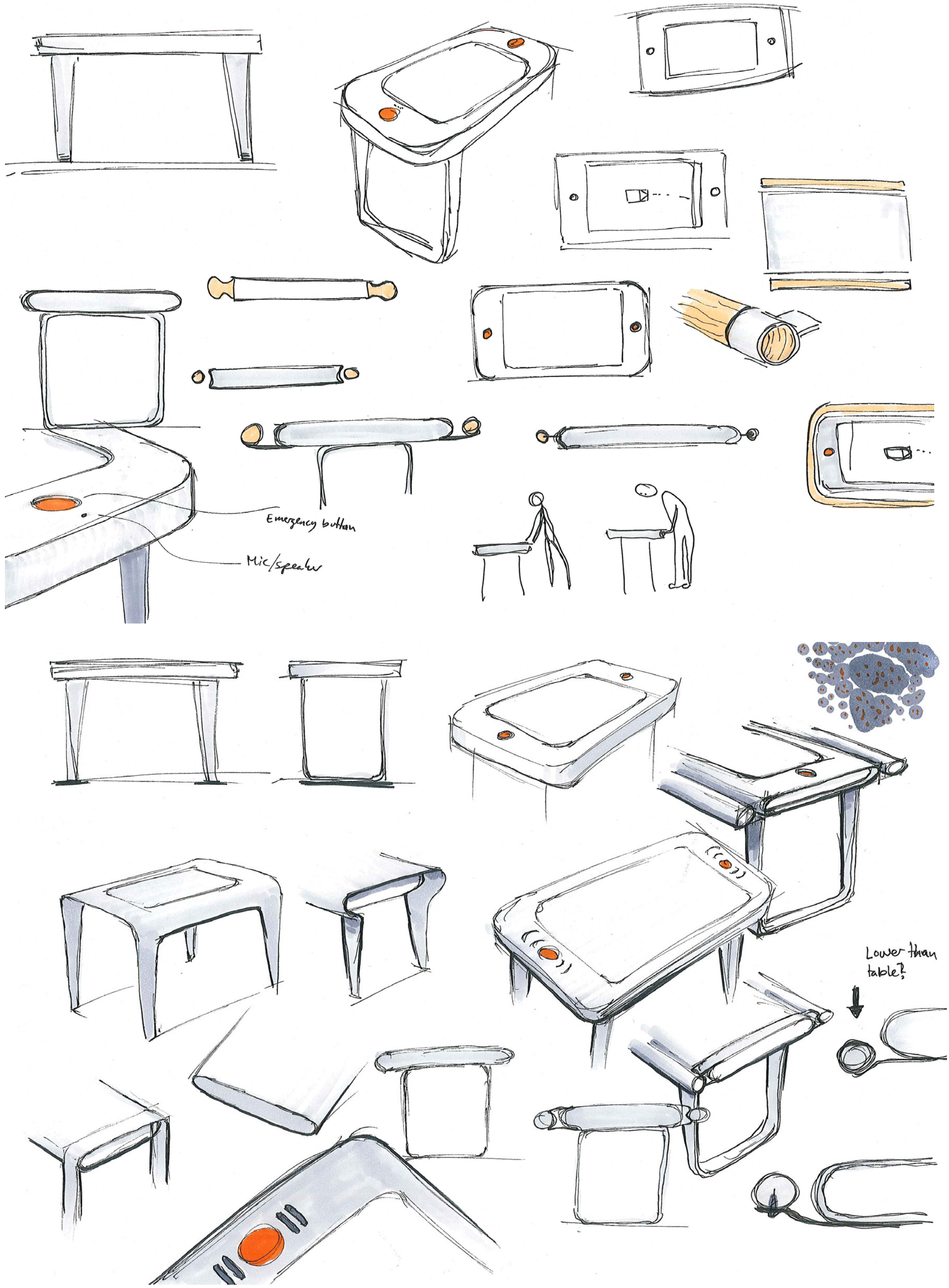
To make it accessible to wheelchair users and kids, it needed to be relatively low and the table legs should not be in the way. Applying the design language and making it fit into the modular system, it still needed some legs in the corners. This reduces the accessibility on the short sides of the table. Having legs also made it feel more stable.





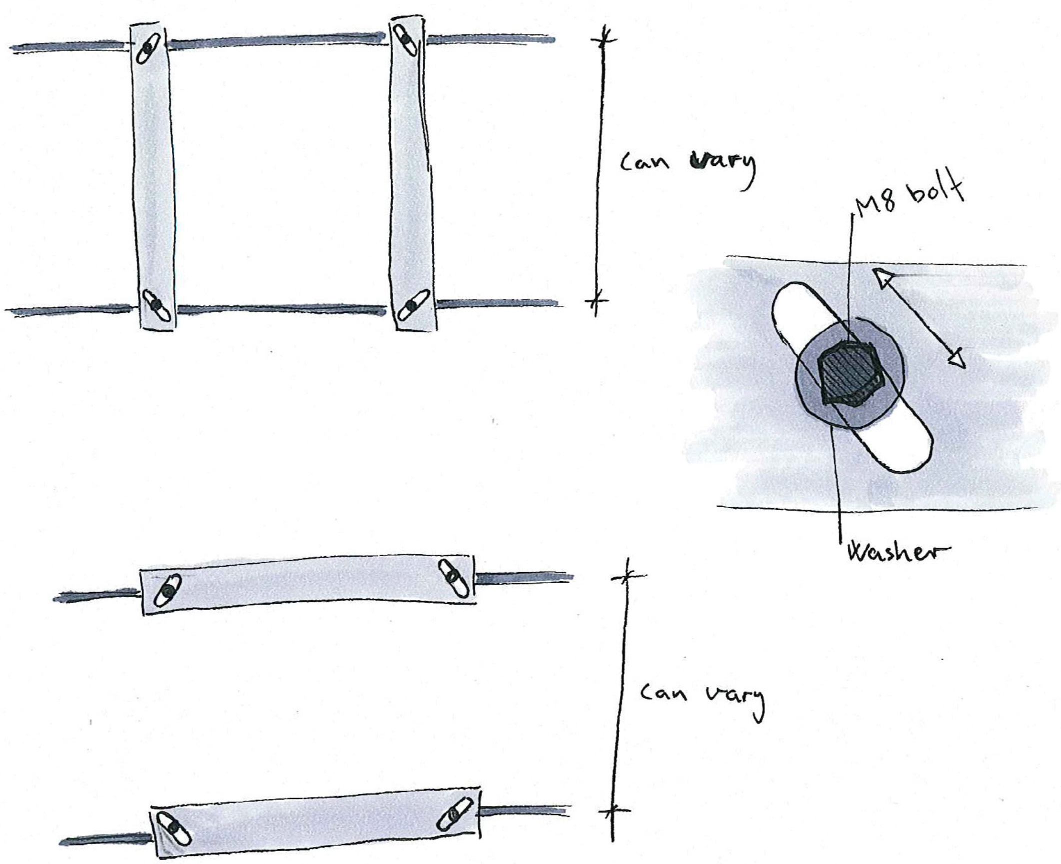
INDIVIDUAL PARTS
INTERIOR

As the centre screen probably would gather people around it, there should be something to hold onto while looking at the screen. Therefore we developed ideas of having a railing connected to the table.


Emergency button
Mic/speaker
Lower than table?

Attaching the modules to the floor

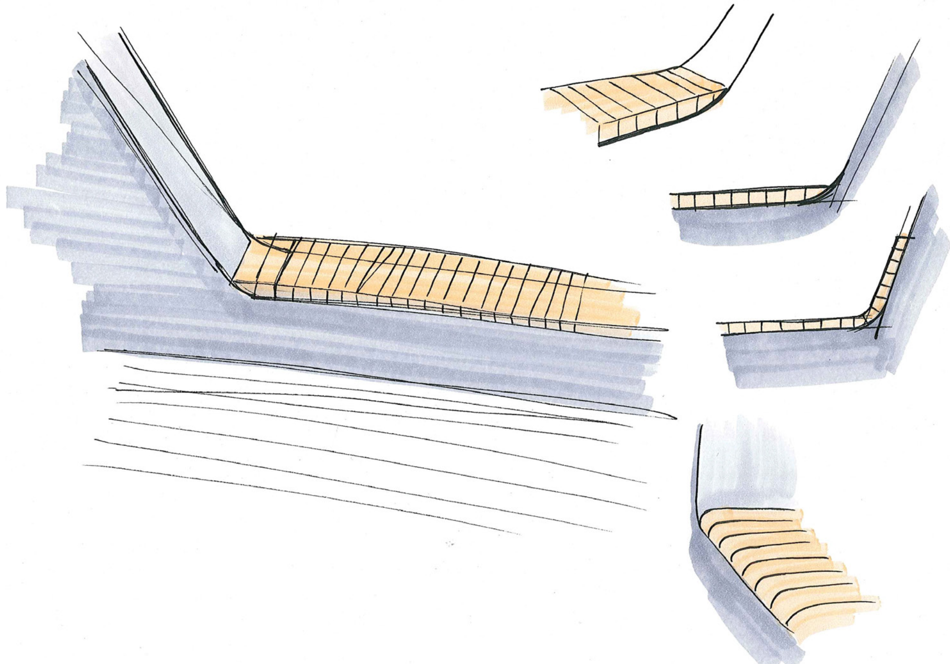
To attach the modules to the railing, a bolt must go through the lowest part of the frame and fastened on top. As the floor might have some inaccuracies from being welded and to make sure that the module can be connected to the rail, the cavity on the bench should be an angled slot. The slot needs to handle some inaccuracy in the width of the rail. Additionally, it needs to be angled to handle the same inaccuracy when the module is rotated.

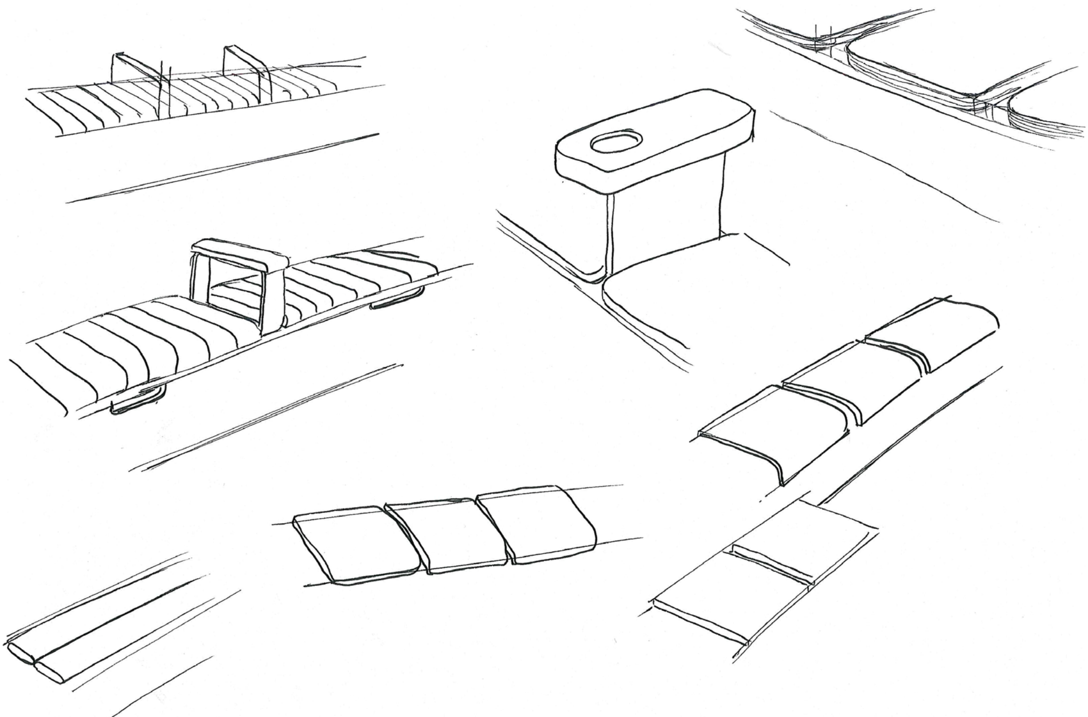

can vary
M8 bolt
Washer
can vary

Windows Bench

Benches along the sides were discussed already when ideating on the superstructure, regarding if it should be a closed or open structure. With milliampere2, an argument for not having benches along the sides was the fear of kids climbing over the fence. They therefore placed a bench in the centre (Egil Eide, 2022). Having a mast in the centre as well, this becomes an awkward seating solution. As we converged towards a closed superstructure with large windows on the side, and a concept that had a large wall thickness, it was an opportunity to place benches in the walls, next to the windows. The integrated window seat was introduced with the swath hull concept. When reiterating the swath concept, some of the changes made were the angle on the windows. This allowed for an even better seating experience, where the window walls could be used as back rests.

The first sketches of the idea, the window bench was an integrated part of the wall. For the layouts tested in the passenger flow user test, there was a layout with no window bench, only modular benches perpendicular to the side window. This is a setup where the modular floor is extended all the way to the window. Having this flexibility made sense where solutions without window benches was desired. The window benches are therefore also modular, but have a design that integrates them into the wall but still share the same design language as the rest of the furniture.





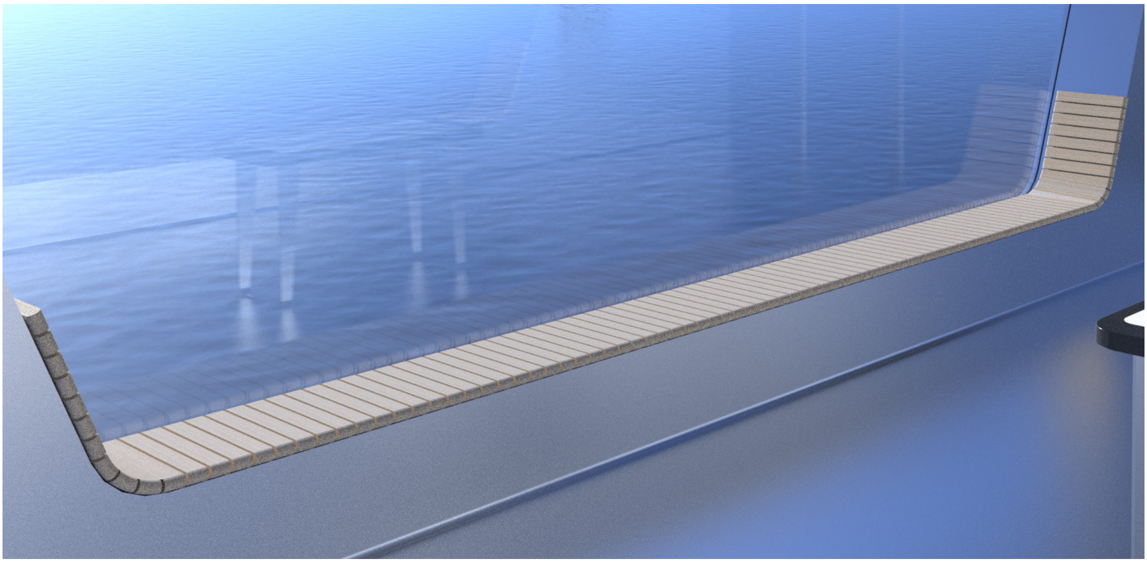
INDIVIDUAL PARTS

INTERIOR

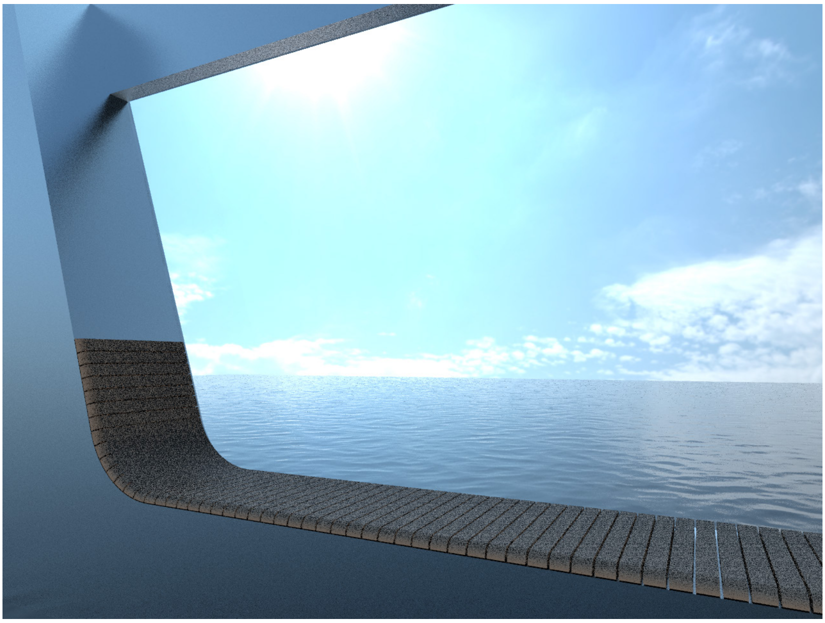
By setting up a cardboard box on a raisable table, we were able to test out the depth of the window bench.

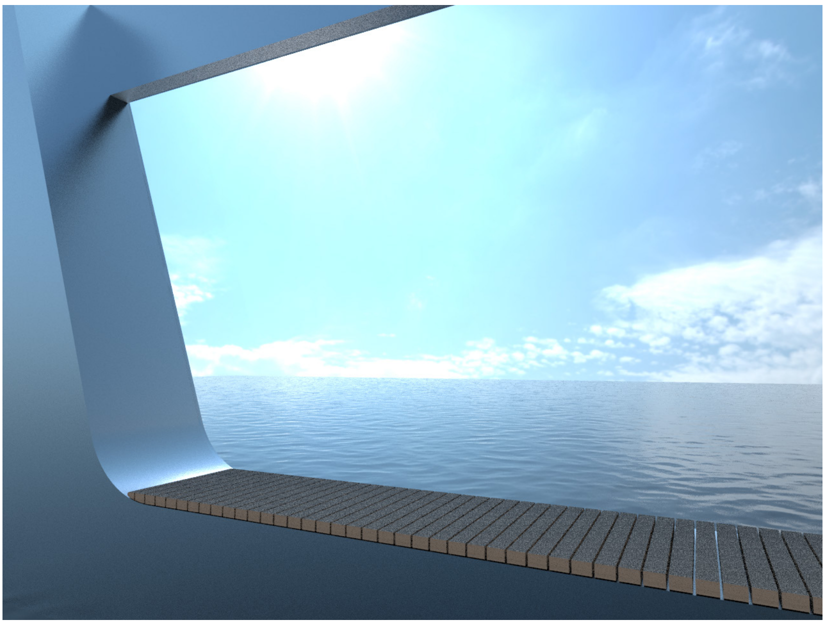

C5522QT
DELL


DELL



Different iterations of the window bench

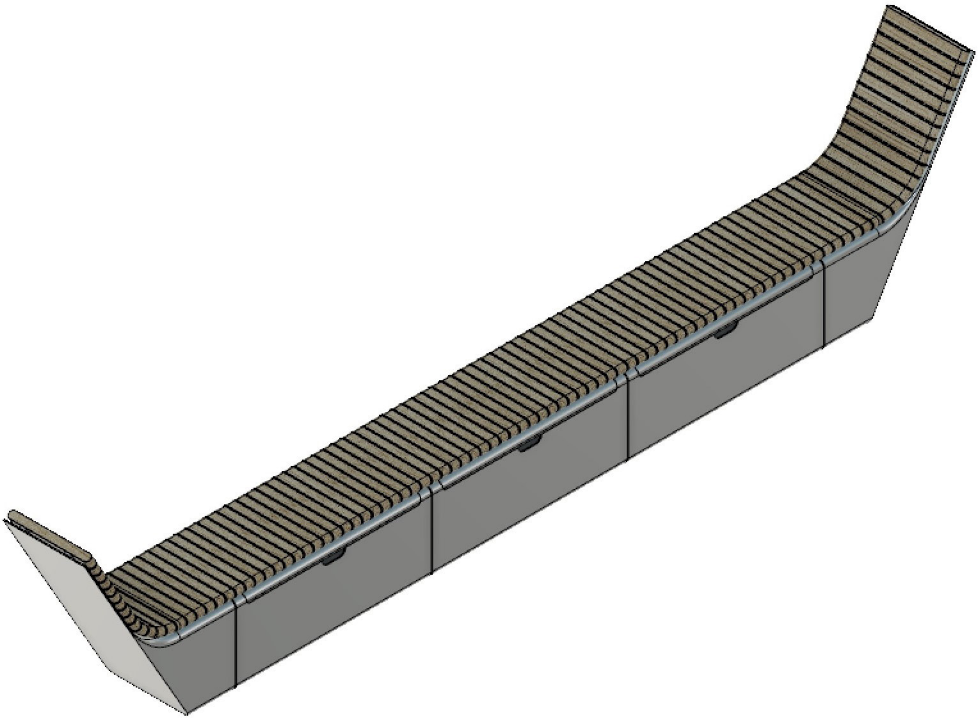


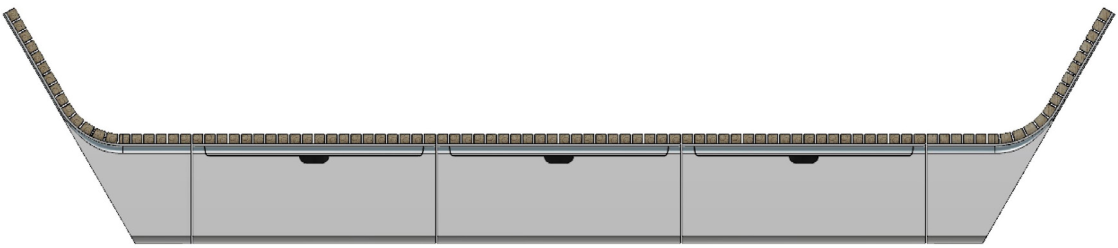


INDIVIDUAL PARTS

INTERIOR

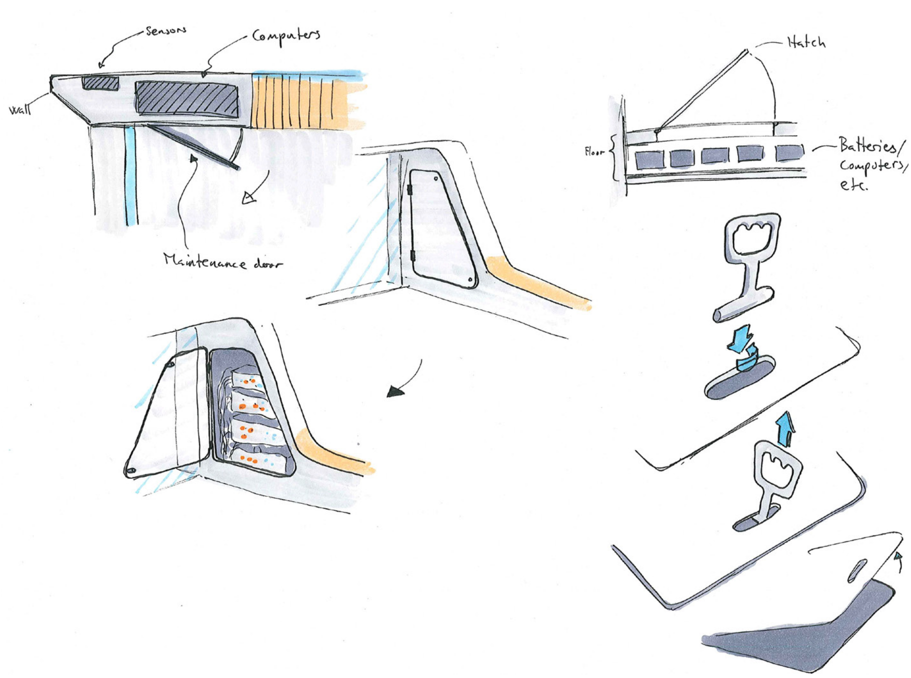
The modular version consists of three identical benches in the middle. On the sides, a module adapted for the angle is inserted, making the walls usable as backrest. They all connect to the existing railing in the floor.

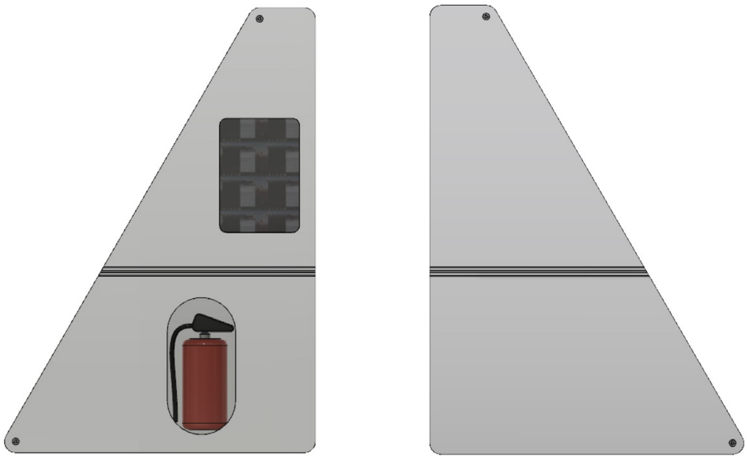


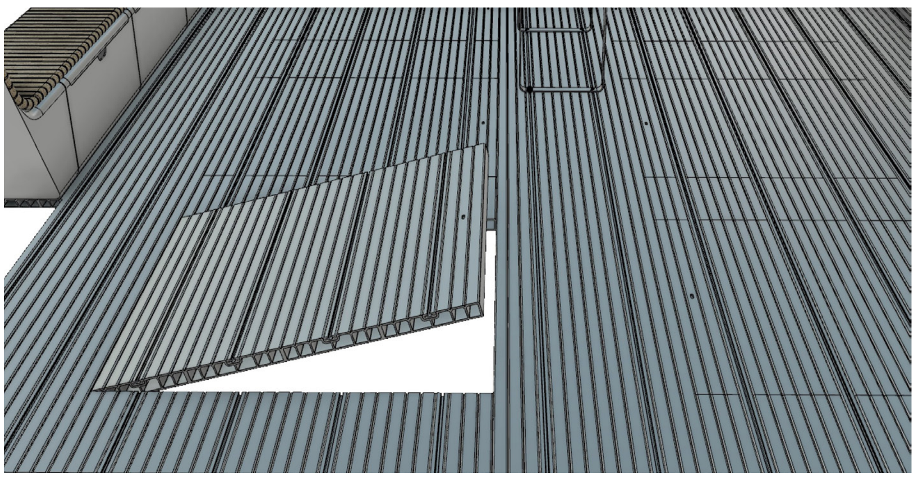


Access to batteries and electronics

With the chosen concept, having a swath hull and a closed superstructure, it must be possible to access batteries and electrical components. For instance, the floor can be used for storing batteries and computers. Likewise the wall sections in each corner can be made use of for electronics and computers. As the walls would be accessible with a service door, this is probably where the components needing the most maintenance should be placed. This is also where the most of the sensors will be accessed. In the maintenance door there was integrated a section of the AluFlex railing, to be able to add hand railing or a lean bench. The floor compartment can be accessed through eight hatches in the floor.

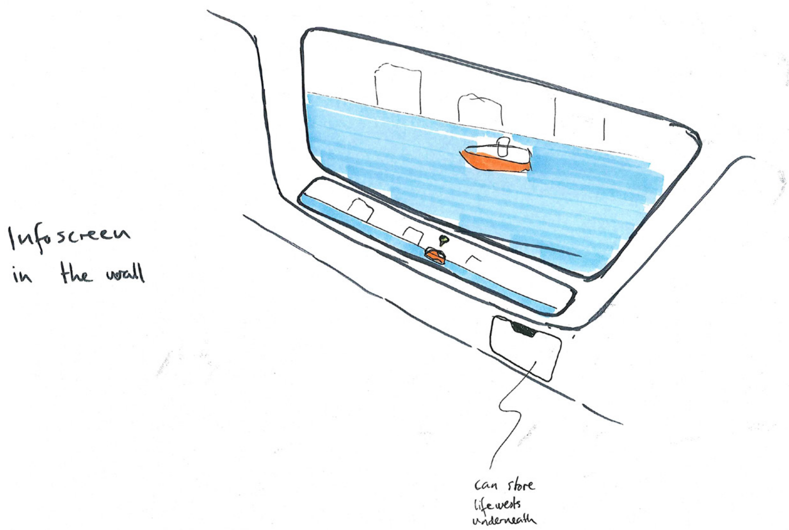






Interaction surfaces

As identified in the work with the user journey, interaction surfaces for the passengers was a necessity. We tested different placements and what information it should contain. For the two layouts we tried out in the user test, we had two different solutions. The first one was the centre screen presented in the modular interior section, where a flat screen was integrated into a table, showing the ferries position in relation to the shore and other vessels. Feedback from the passengers was that when sitting on the window bench, the information wasn't accessible. In the second layout we presented the same information on the windows on the sliding doors on the driving direction side. The test passengers had different opinions on this solution too, complaining that the information would reduce the view and be difficult to see in bright light.

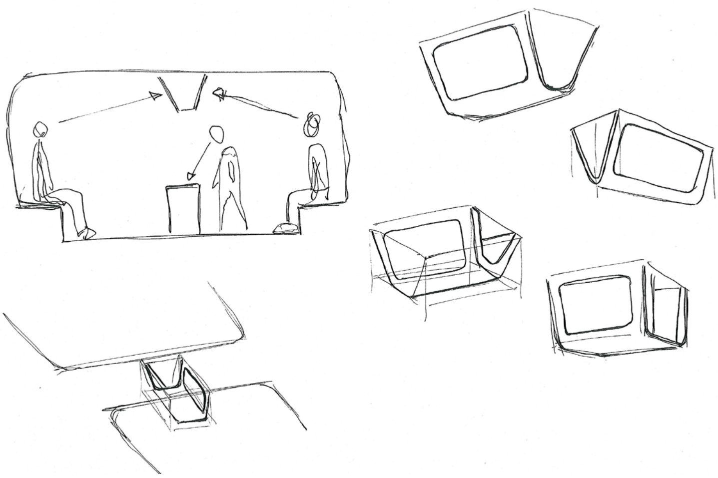


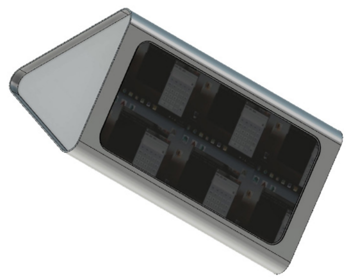
Instead of having benches in the windows, it could present information instead.

Photo credits: Business Wire

The idea of projecting information onto the glass of the sliding doors can be solved in two ways. Either way, the glass would probably need to be frosted where the information should be shown. Having an actual projector projecting light onto the glass is problematic since the glass would probably reflect most of the light. The second option is technology where a screen is built into see through glass.

Something we had discussed and also came up as an idea during the focus group was displaying information on the roof on the first layout. This could be different information then what the centre screen displayed. To be visible from the window benches, these screens should be tilted towards the side windows.





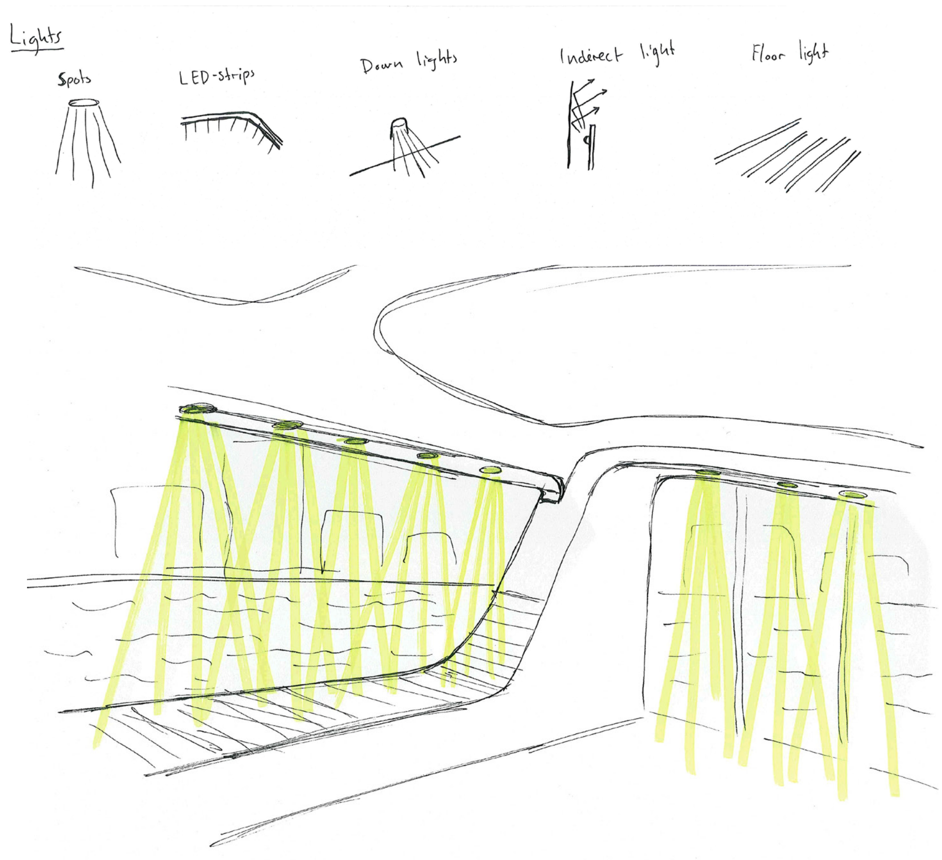
Instead of having the centre screen table, an idea was to have the same information projected from the roof onto the floor. This would make it more visible to more people on the ferry. An unfortunate issue with this idea is that people standing on the floor under the projection, would cast shadows on the floor. This would make it less attractive and informative to look at.

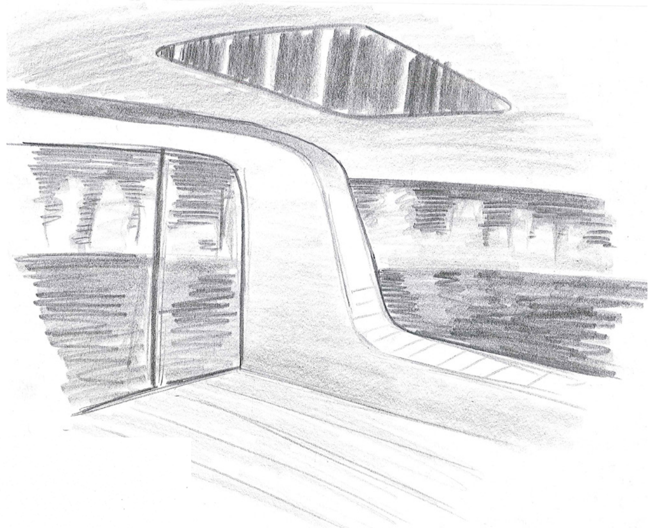
An idea that came up during the focus group was using lights to dynamically allocate dedicated spots on the ferry to what passengers were boarding. A camera connected to AI could calculate how many bikes, wheelchairs, and suitcases were brought on board. From that, a lights system would indicate where the bikes should be placed and where the suitcases should be stored. We think it's an interesting idea that could be investigated further.

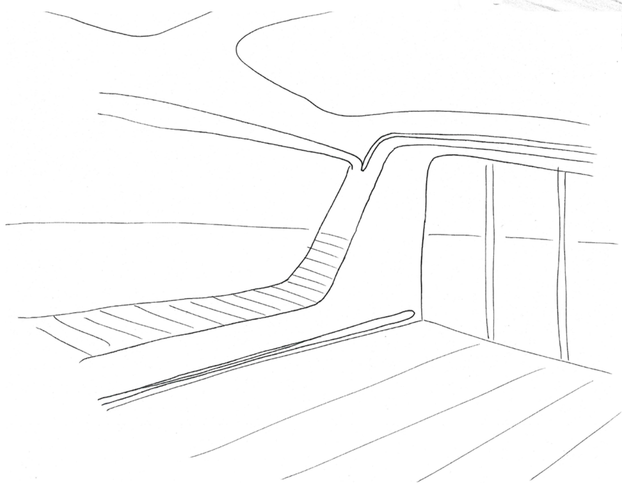
INDIVIDUAL PARTS
INTERIOR

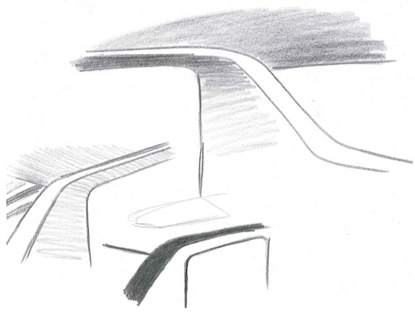
Lights

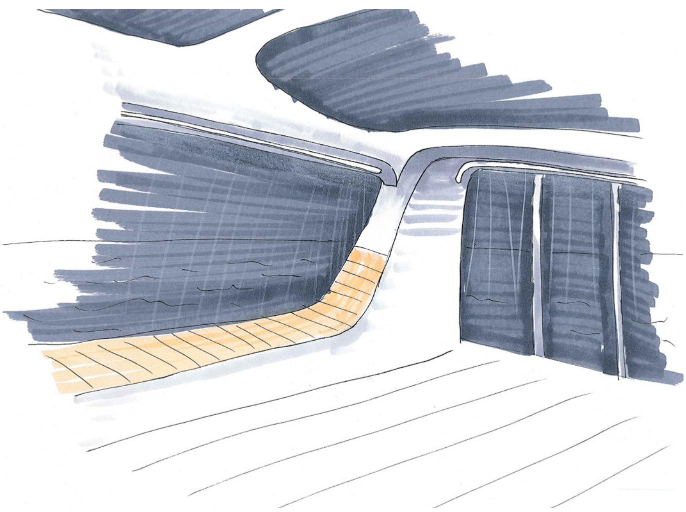
Taking the ferry at night-time should be a safe and good experience. A well-lit interior can make for a comfortable atmosphere, contributing to feeling safe. By identifying what different light sources could be used, it helped when making different solutions to how the interior lighting could be solved. These different light sources were then put into different set-ups, first sketched out and later rendered. The shape of the inside of the ferry has lines that we wanted to emphasise, to strengthen the direction of the ferry and to make interesting contrasts.

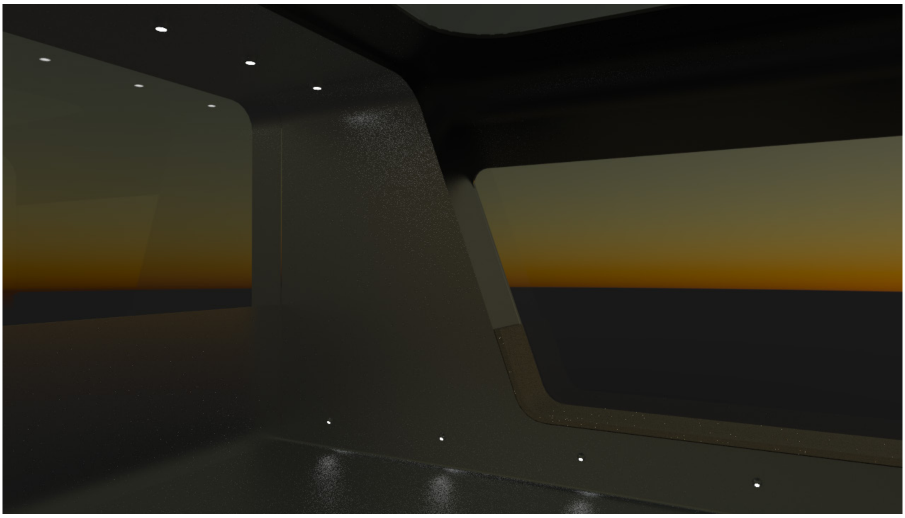


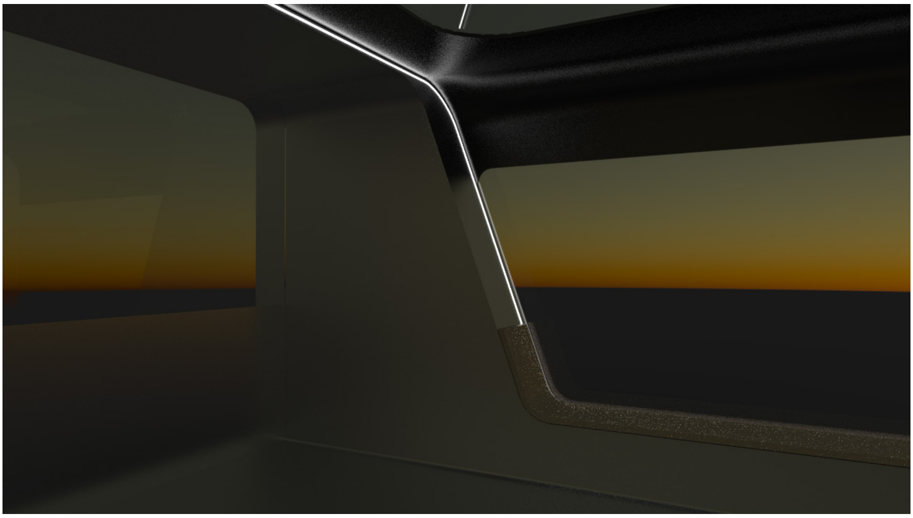


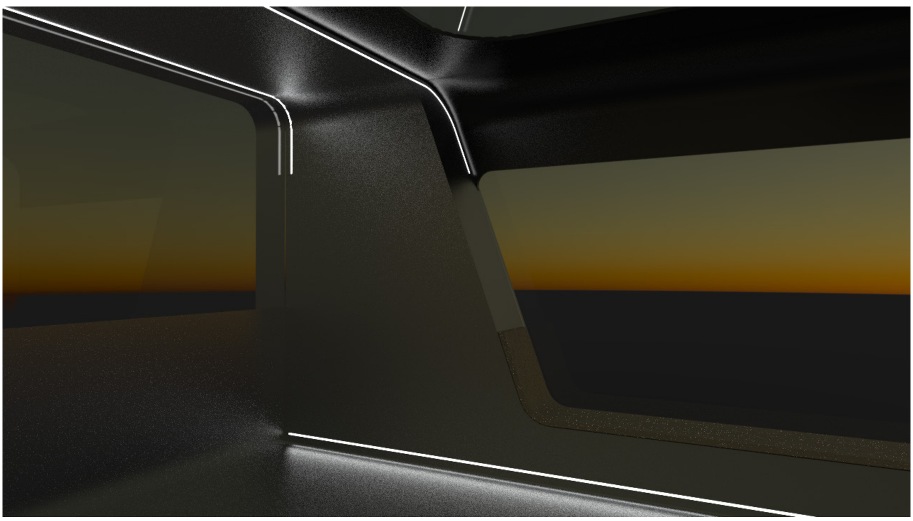


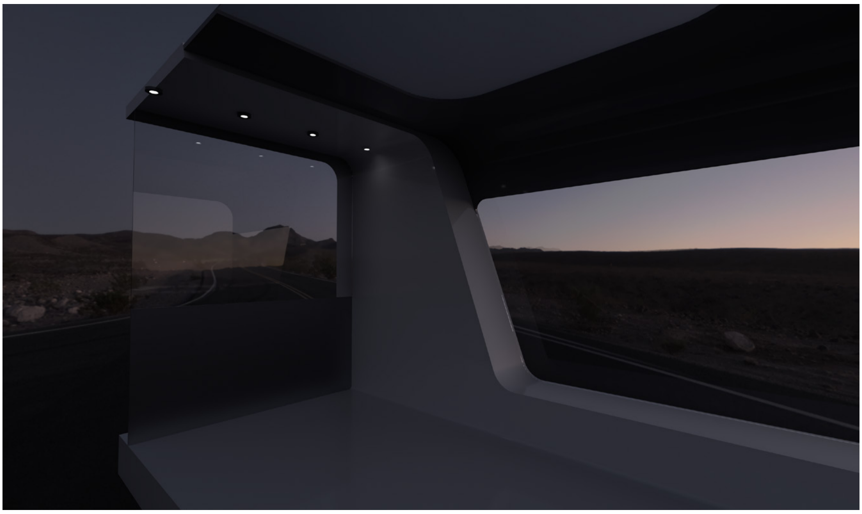


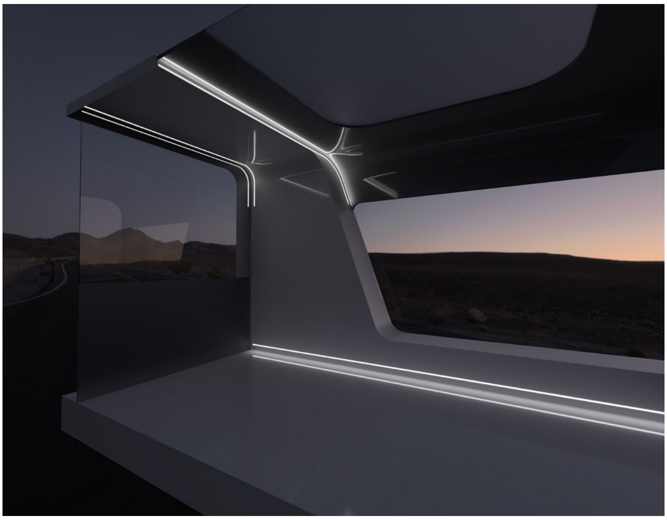


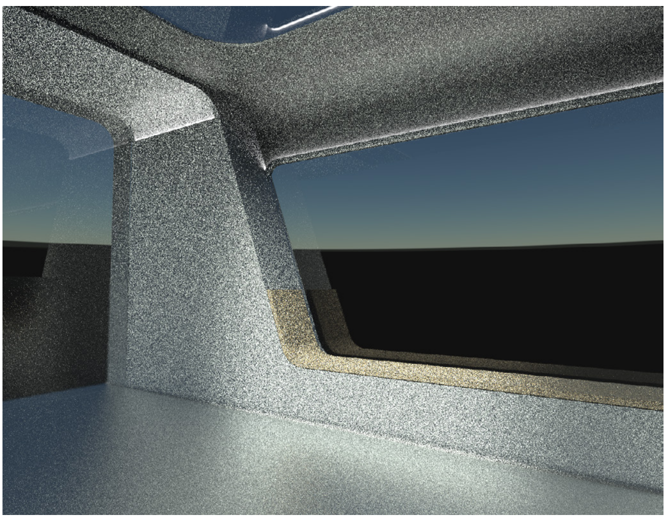










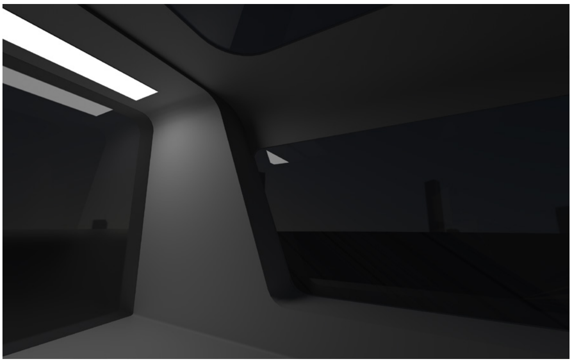
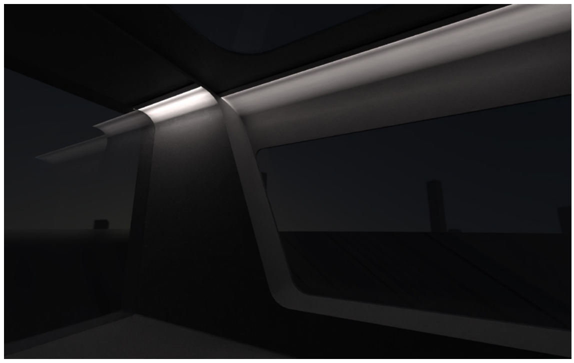
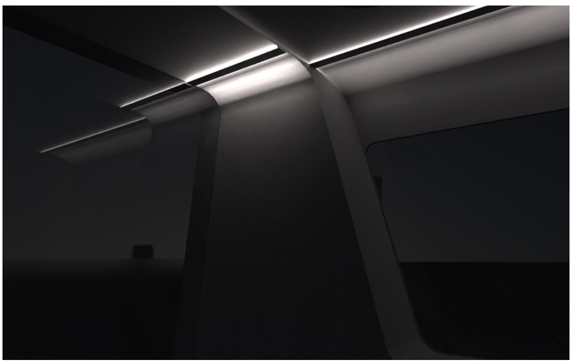
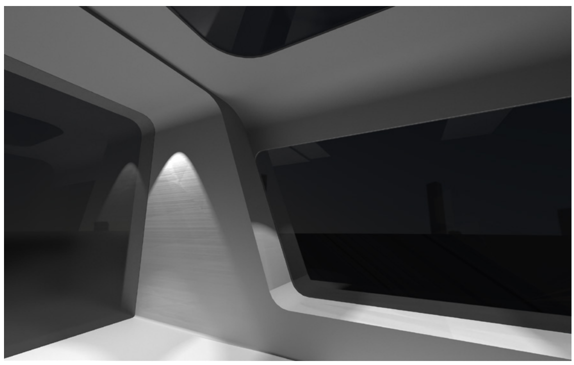


INDIVIDUAL PARTS

INTERIOR

Having LED-lights with the possibility to change colour; functionality or communion can be built into the lights. For example can one colour(“mood”) be the idle situation, where the ferry is docked and waiting for passengers. When undocking and starting the crossing, the “mood” can change to a more dynamic colour. This also applies to emergency situations, where passengers must be alerted. As Zeabuz has pointed out several times, the crossing needs to be of “low cognitive load”. We therefore suggest that the changes in colour and moods should be subtle and minimal.

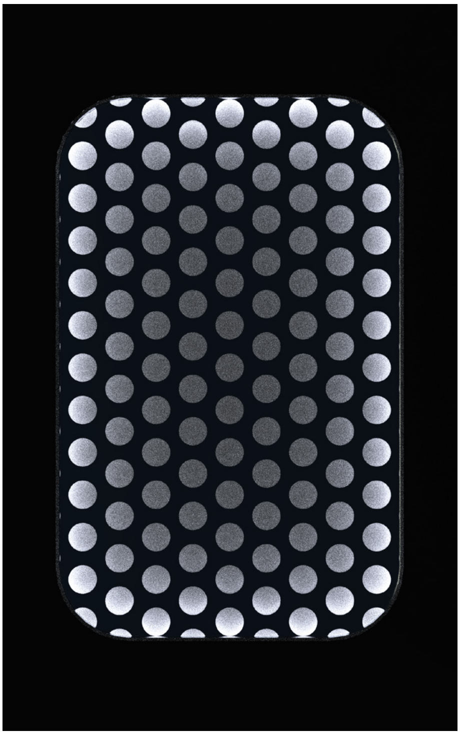
In the last iteration of lighting, a setup with spotlights, LED-panels and LED-lists was tired out. In the rendering, the spotlights gave the best results considering illuminating the room. The LED-list was intended to be reflected in the curve in the roof, but does not light up much of the rest of the compartment.

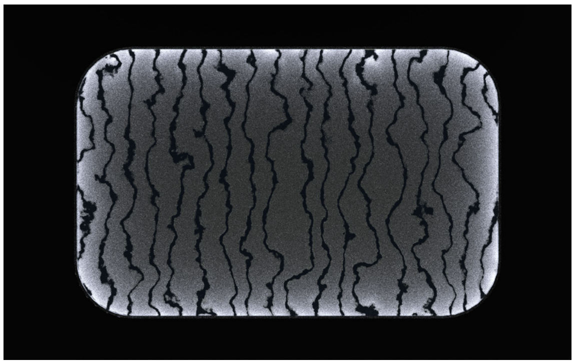





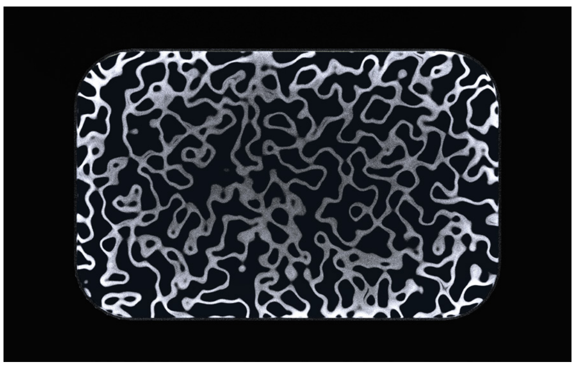
INDIVIDUAL PARTS

INTERIOR

As our design has a lot of window area, the lights must be put on the non glass surfaces. Nevertheless, by having dynamic frosting of the windows in the ceiling, and having a light source surrounding the edge of the glass, the frosted part of the glass can be lit up. Since the frosting is dynamic, it can show different graphical elements. This is something that can be unique for each city or even each boat. This element can also be animated, so it indicates speed or movement. To test this, a scene in Keyshot was made. By controlling how and where the frosting would appear with different textures, this created different solutions to the frosted part being lit up.



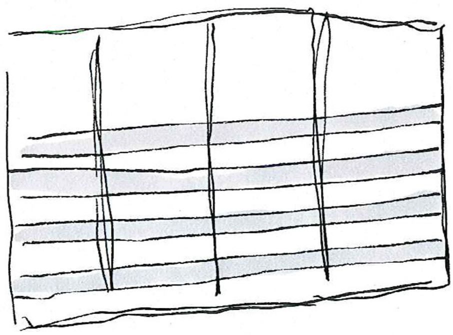


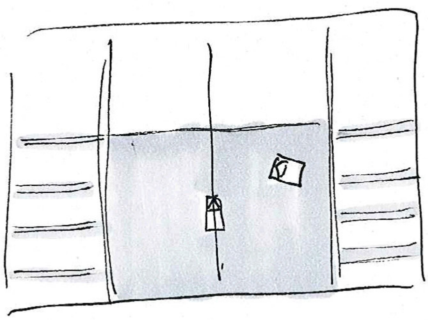


INTERIOR

Sliding Doors

The concept of the superstructure we had decided on, had sliding doors on each short side of the boat. We added sliding doors to make it a smooth experience boarding and unboarding. Having glass on the short sides also meant that you would retain a good view in the driving direction. Furthermore, to comply with regulations regarding visually impaired people, there needs to be some sort of graphical element in height of vision to make the glass visible. We first thought of having frosted glass up to standard railing height, to have a sort of virtual fence, aiming to make it feel more safe. Making the frosting go all the way up to height of sight, it defeats the purpose of having glass sliding doors. We therefore looked into solutions where the frosting is perforated and can be changed dynamically.

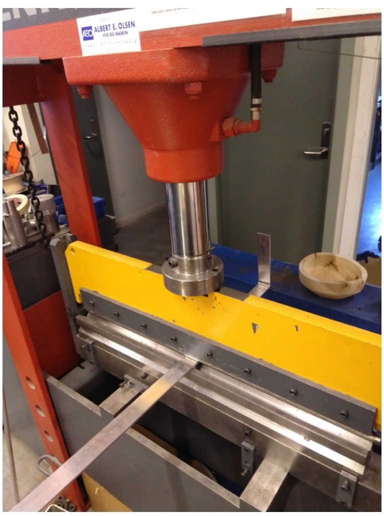




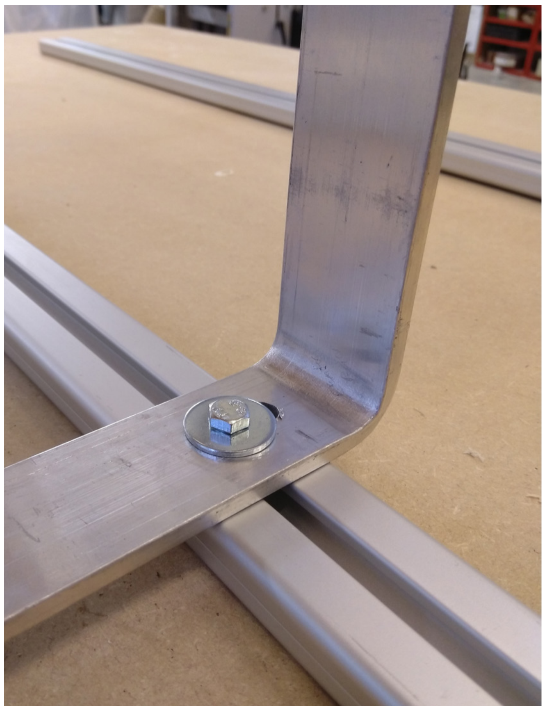
Prototype

To validate the concept of the modular interior, a prototype of the smallest bench was built in the workshop. We wanted to see if the frame was solid enough and how it connected to the railing system. Another reason was to get an impression of the looks and aesthetics of the modular elements.

For the prototype, the correct railing provided by Aluflex was used as well as quick connectors used to mount the furniture to the rail. For the frame, a 6x40mm solid aluminium profile was bent using a hydraulic press. The radius that the press produced was smaller than in the envisioned model. The wooden part was simplified and was made out of plywood, just to have the seating provided.





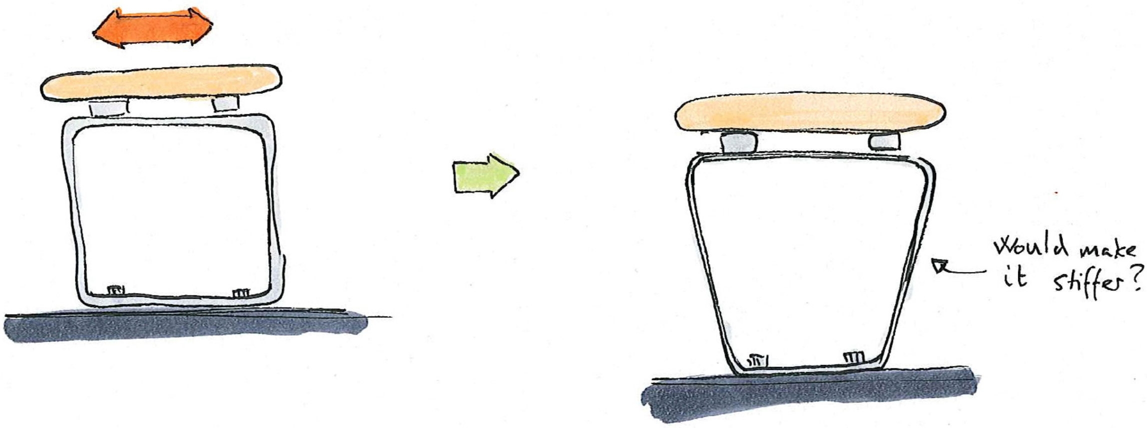
INDIVIDUAL PARTS

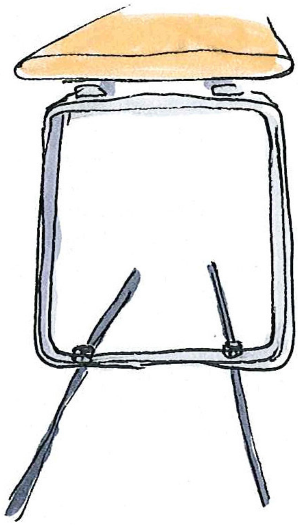
INTERIOR

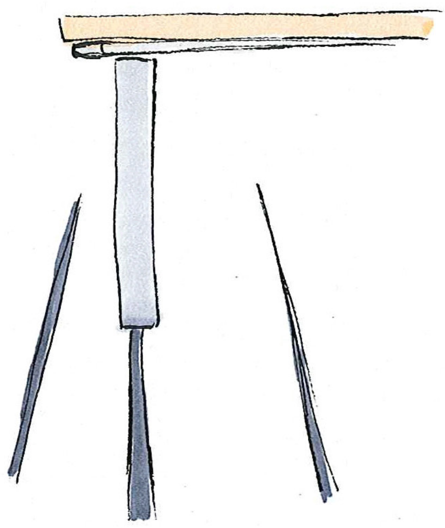
One of the concerns about the bench was that it would not be strong enough. As the frame is a rectangle, we feared it would parallel shift on the top. Judging the prototype, this happens, but far less than feared. Adding an angle to the vertical sides, making it an trapeze, would prevent this. When connecting the bench to the railing it stiffens up a lot in all directions.

The frame connects easily to the railing thanks to the connectors provided by Aluflex. Thus, making changes to layout would be a quick action. Having the ability to rotate the bench 90 degrees, provides a huge amount of flexibility.

The bent aluminium frame visually interacts with the railing in a way where it's an added element, but at the same time speaks to each other with shape and material. As the frame is only 6mm seen in one direction, it makes the bench almost floating. However, when rotated, it affects the openness the frame gives in the direction of the rails.


Would make
it stiffer?

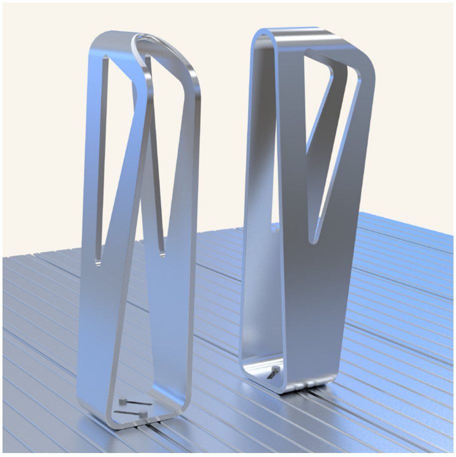


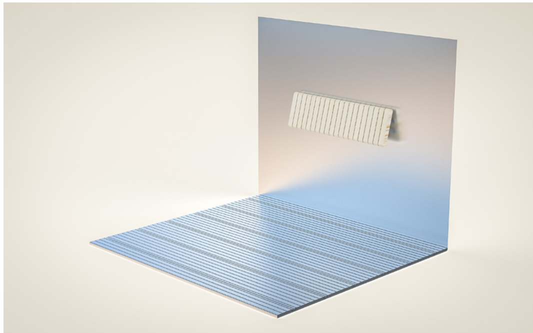


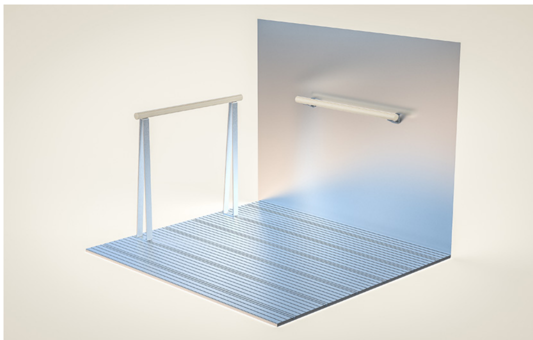
Chosen Interior

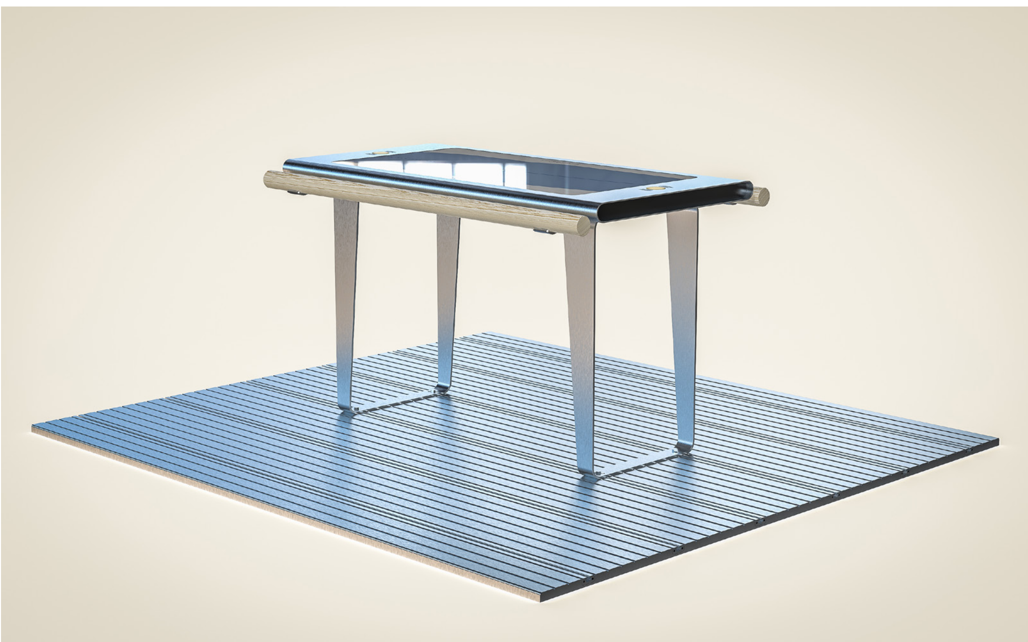
Modules

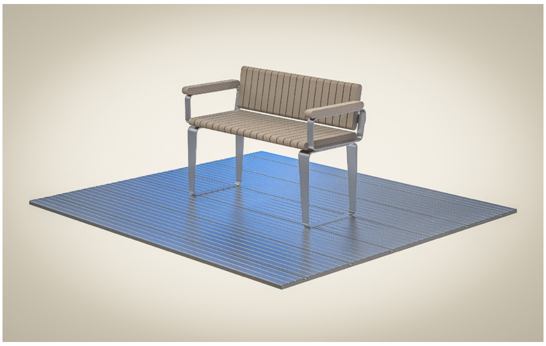
Here the different modules are presented, a family of elements that all share the same expression.

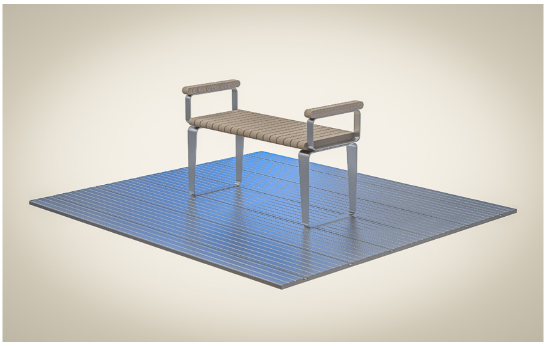


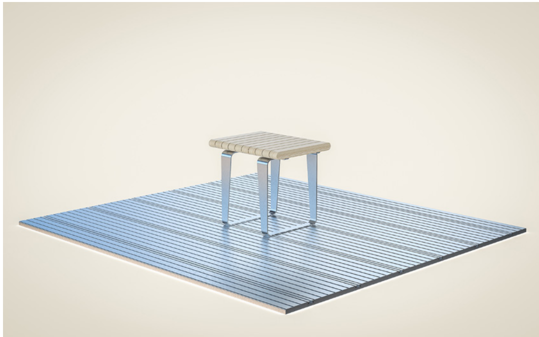


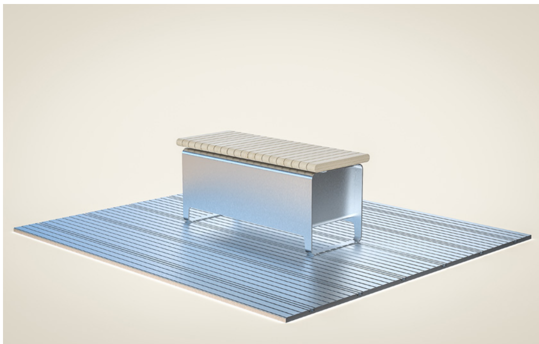


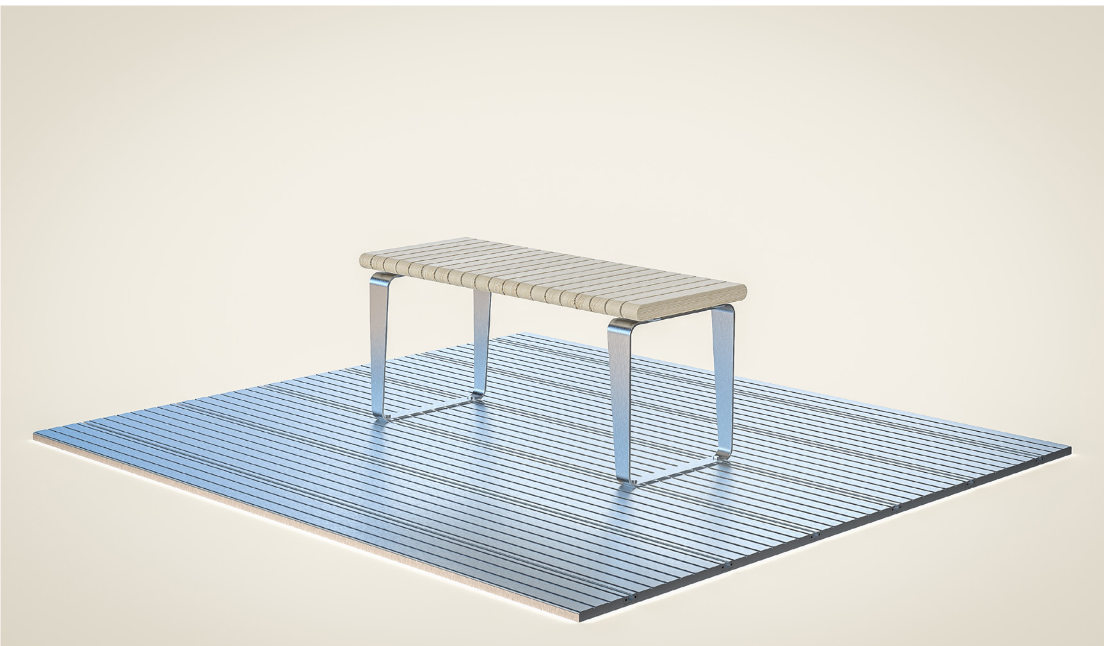




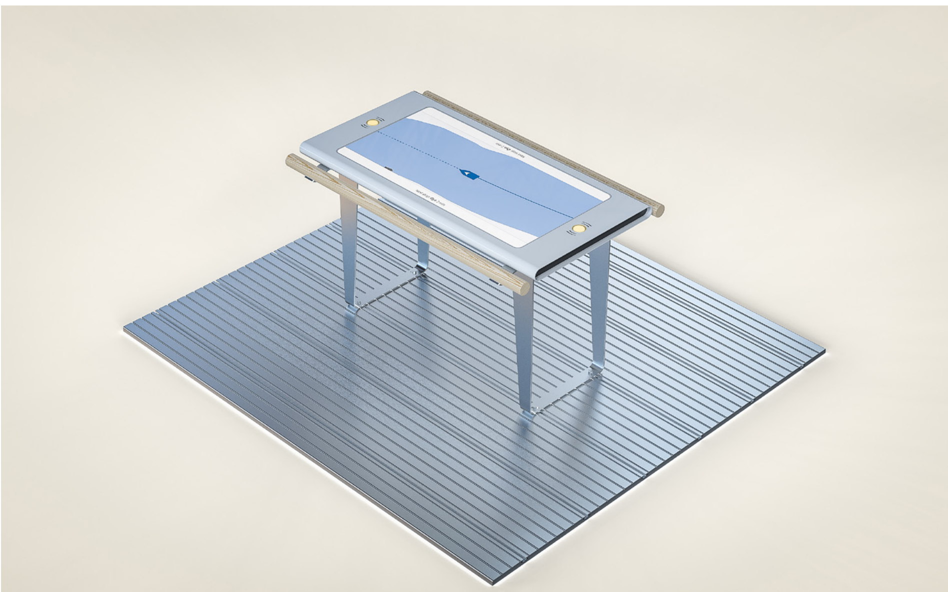


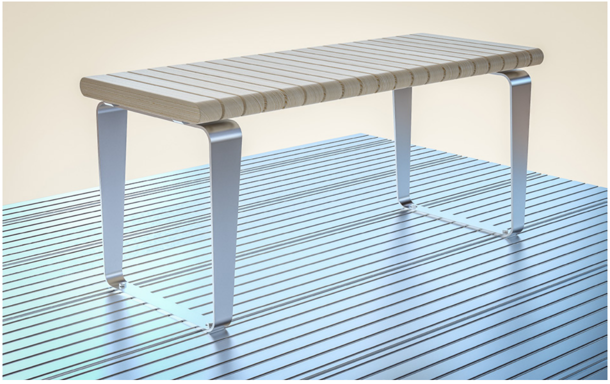
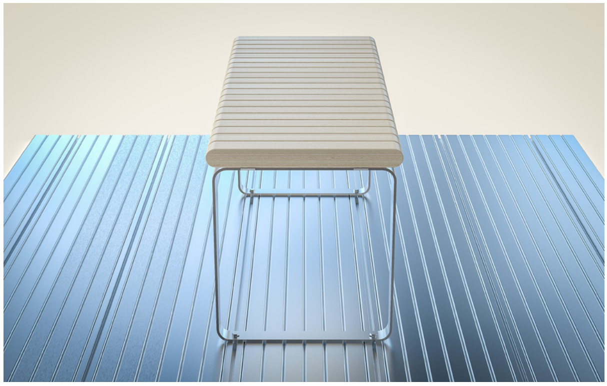
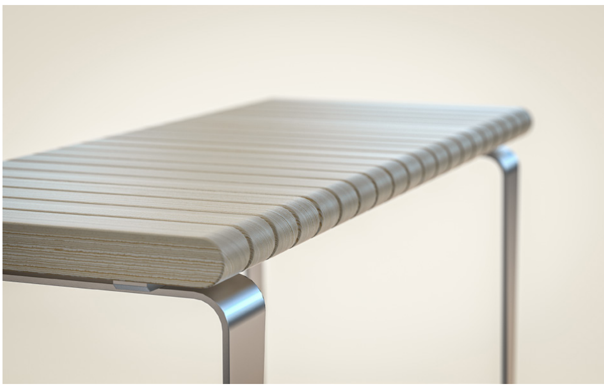
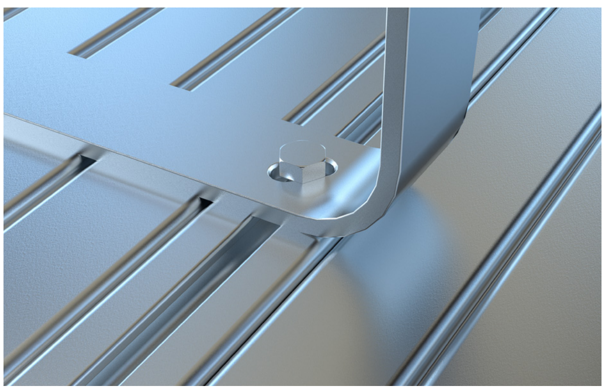






In addition, three colour examples that were tried out on the bike stand.

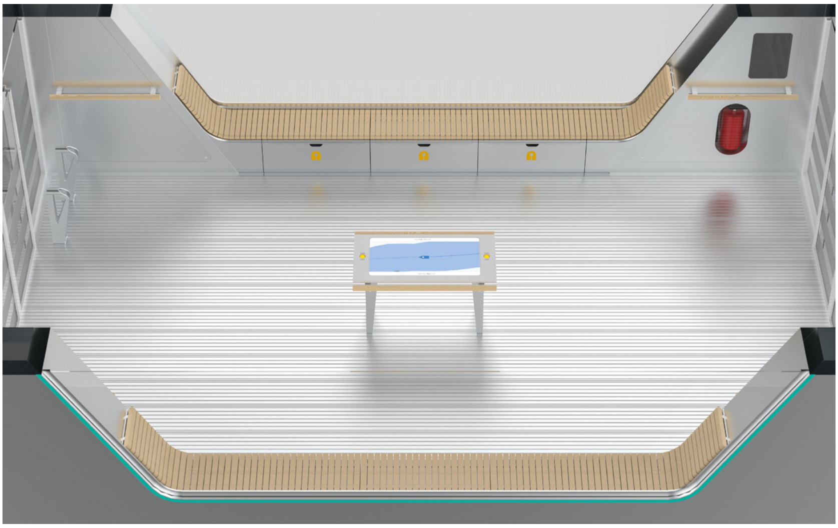


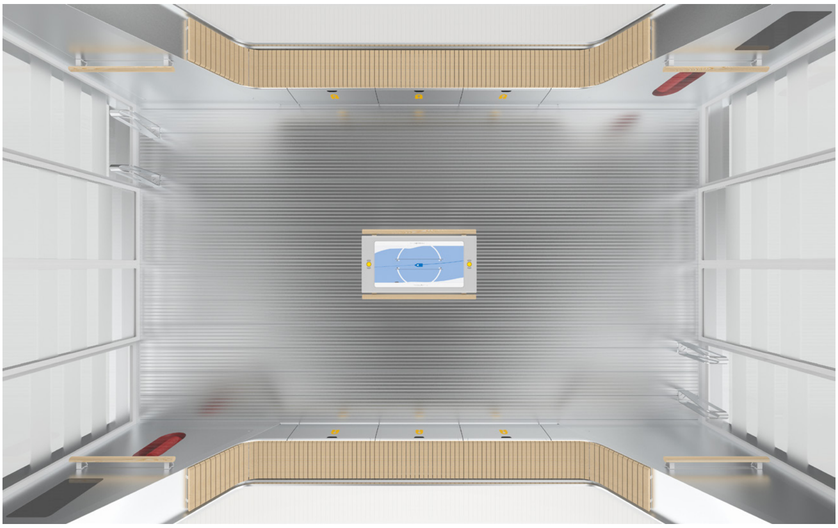





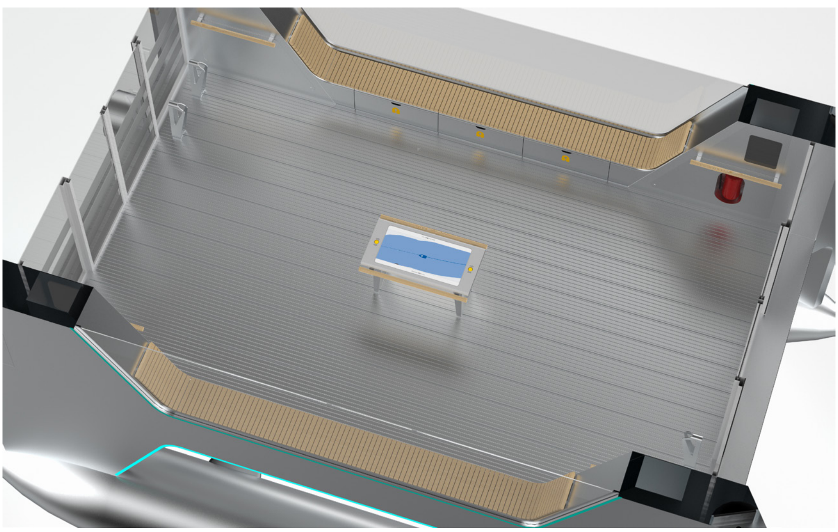
INDIVIDUAL PARTS
INTERIOR

Chosen Layout

From the insight gained from the user test, we developed the layout further. Still keeping it as clean and open as possible, but adding some functionality. The chosen layout consists of window benches, centre screen, top centre screen, four bike stands and hand railing.

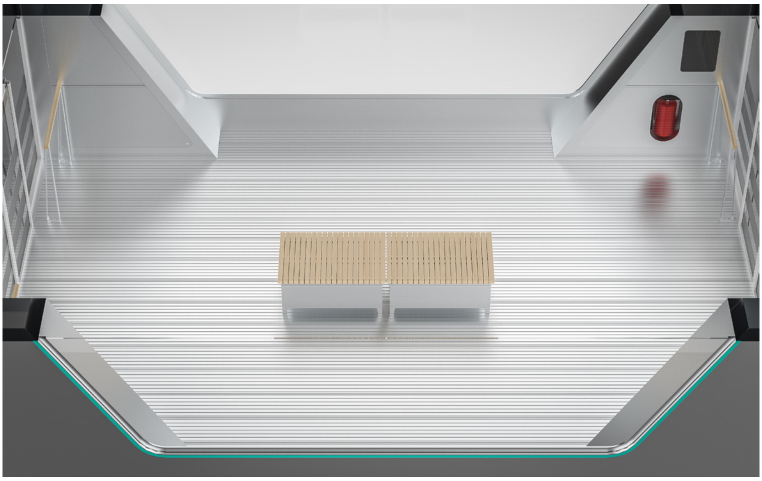


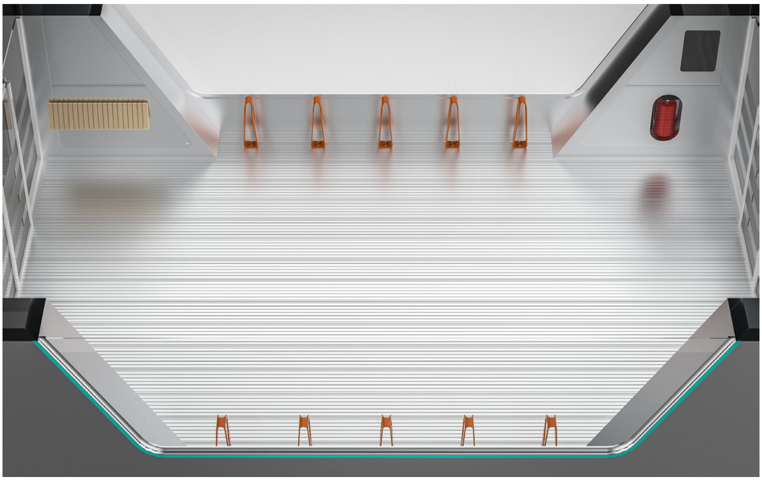


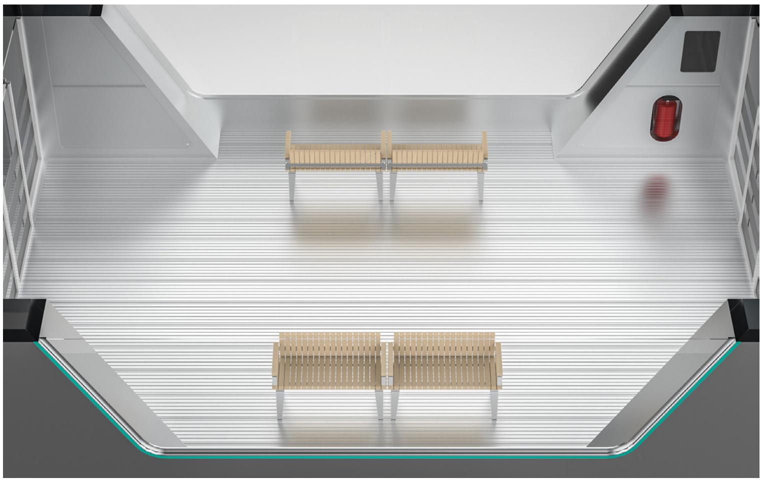


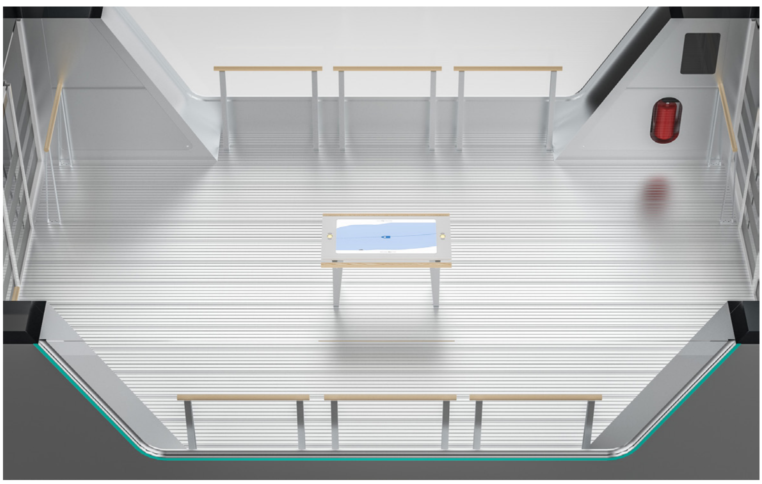
Other Layouts

As the modular system adds a big amount of flexibility regarding functionality, we here present different layouts that could suit different needs. Looking at for example Amsterdam, a layout which emphasises functionality for bikes would be relevant. Or where the ferry might be used for inshore sightseeing, a layout focusing on having good seats that are facing outwards would be preferred.







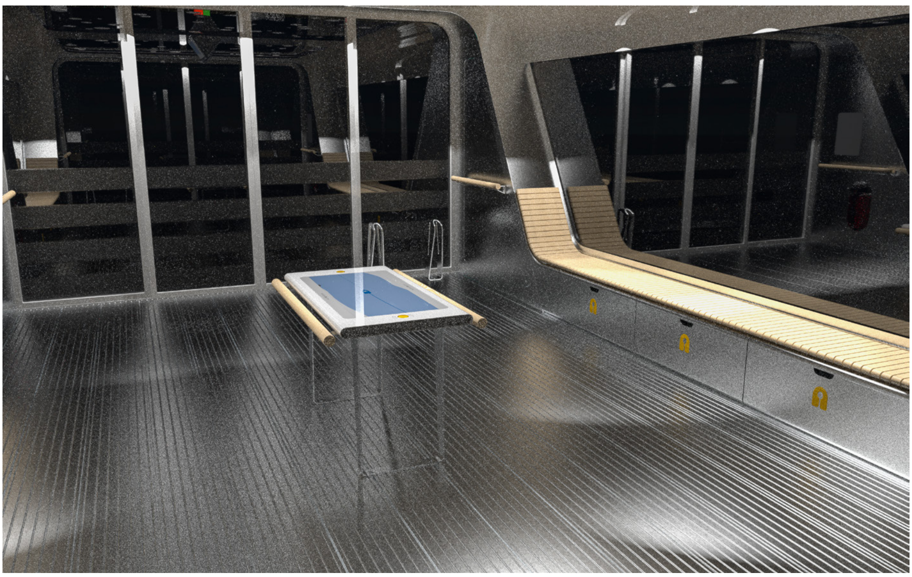


INDIVIDUAL PARTS

INTERIOR

Lighting

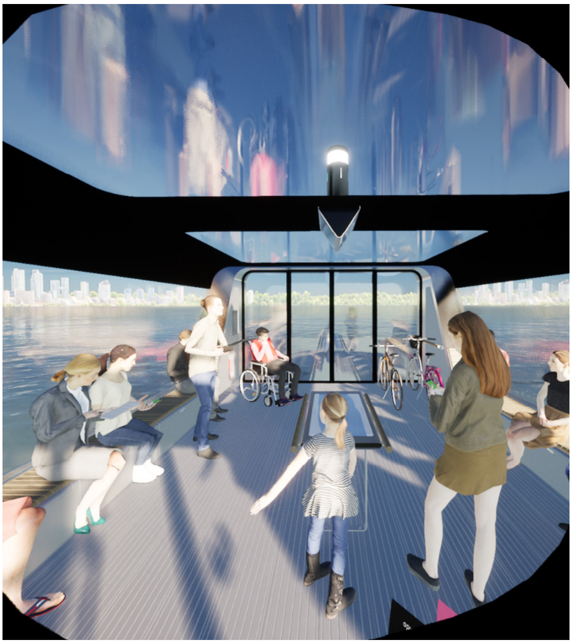
For the interior lights, it has been difficult to find a solution that is both elegant and discrete. The way of visualisation through Keyshot also had its limitations, when it came to giving the right impression of the light. We therefore will not conclude on the interior lighting set up at this point. For visualisations at night time of the ferry, a set up with spot lights in the roof was used, as this gave the best sense of how the interior light could be.



Evaluation in VR

To get the experience of being on board the ferry and to evaluate the interior design, we found a solution to bring the ferry to VR. Using Twinmotion in combination with Oculus Link on a computer we were able to view a scene built up in Twinmotion on a Oculus Quest 2 headset. With Twinmotion we also could add basic functionality to the scene, like moving sliding doors and having the ferry move on a route. This gave us an impression on how it would be to be inside the ferry, and see the viewing angles and layout of the interior. It also gave an impression on how it would be inside the ferry with 12 passengers on board.

The solution with Twin Motion and Oculus Link was not as "plug-and-play" as we thought it would be, dealing with admin rights and finding the right cable to connect the VR-headset. But when the set up was done, being able to sit on the bench and have a look around or looking at the centre screen, it gave a good impression of how it would turn out.



Discussion

Throughout this chapter we have discussed the different choices made to arrive at the finished result. Developing the bench as the direction for the rest of the interior gave the opportunity to develop the looks and solve the details without having to think about every use case of the modules at once. Settling on a railing system to attach the furniture to the floor, also meant limiting some of the flexibility in placement of the different modules.

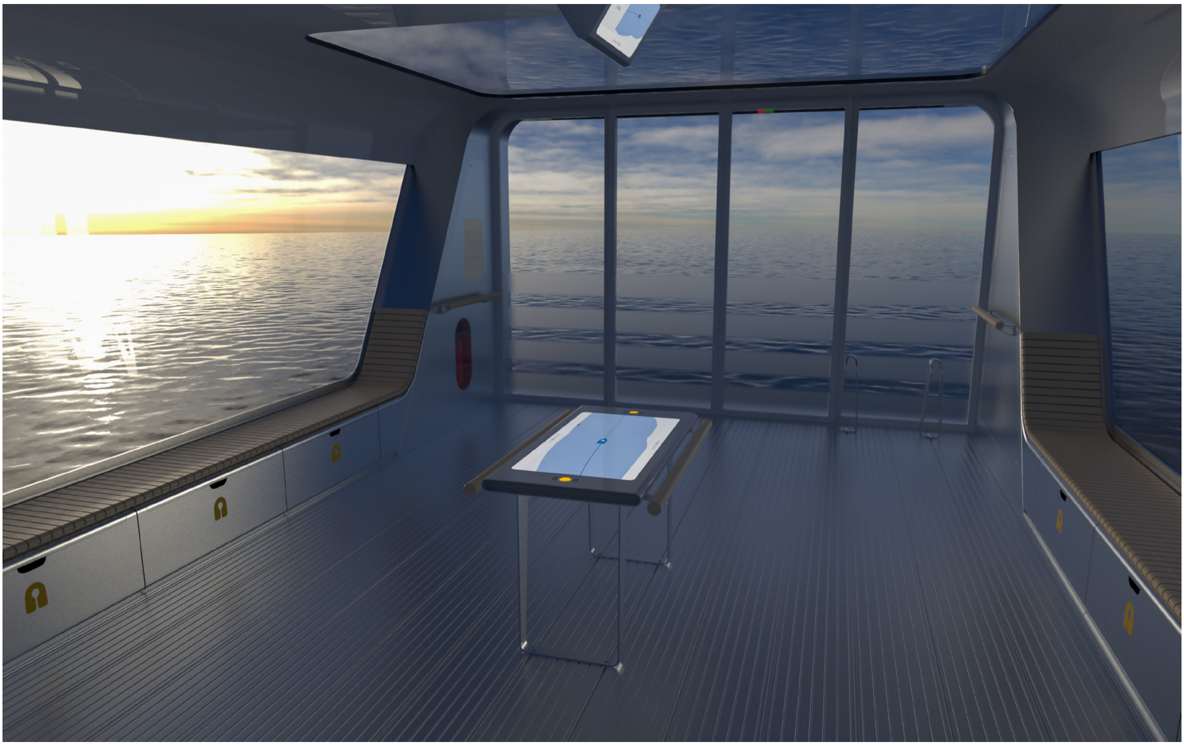
The interior consists of many elements, and they all have to work together as well as complying with legislation. Making some of the interior modular was a way of dealing with this complexity, as it can be adjusted to fit a specific city's laws and needs when it is to be used.

The ferry has a lot of glass covering most surfaces except the floor, this affected and restricted the placement of lighting to a great extent.

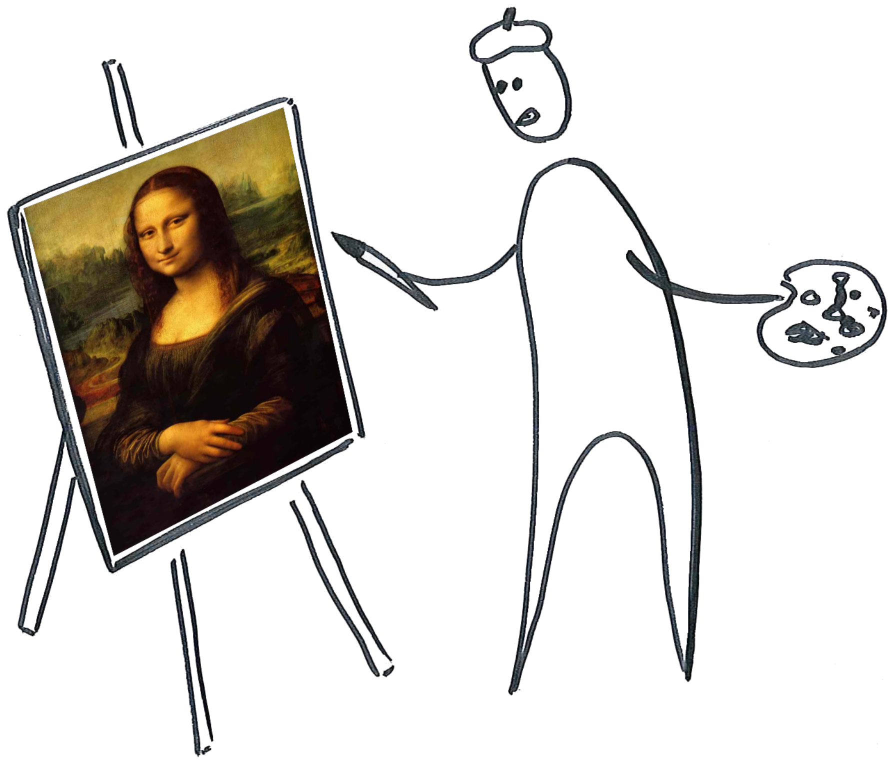
Conclusion

For the interior part of this project, a modular furniture system was developed to accommodate the different needs the ferry might facilitate. The modular system includes the floor for attaching the modules to and different modules that can be in the ferry. These modules all share the same design language, which was created through the development of a bench that was to fit into the system. The different modules made were the bench, with variations like armrest, backrest, storage for life vests and a lean bench, a bike stand, hand railing and lastly a table with a screen to interact with the passengers. Additionally, we have looked at how lighting can enrich the experience when using the ferry at night time.

Zeabuz wanted a scalable solution for their future service, meaning a service that can be introduced to different markets. By having a modular interior, the service can be introduced to new cities and its functionality can be tailored according to the functional needs. This adds value to the overall service.



chapter 5



detailing

Along with the process of working with each of our individual focus areas of the ferry, we additionally developed the chosen ferry concept. We reiterated on the concept further and refined the overall design. By modelling the concept in 3D, we all got a common understanding of the shape and size of the ferry. To ensure that the concept would work, we talked to Jarle Kramer about the swath hull, placement of equipment, batteries and propulsion.

REVISING THE DESIGN

Intro

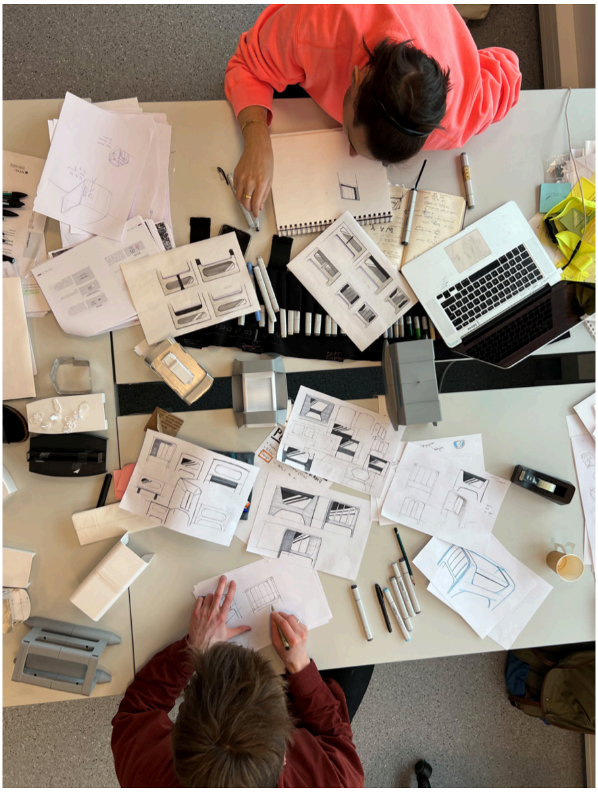
This chapter started during one of the supervision sessions with prof. Hareide where we presented our most recent work and expressed the notion that we felt something was missing. Even though we have chosen a concept we have felt that the visual expression of the ferry lacks purpose and direction. Prof. Hareide suggested we conduct one last creative session in which we try to purify the design and give it the character it deserves.

Creative session

One day was set aside when we sat together and ideated. The creative session started with evaluating the chosen concept. The design was analysed for its proportions from side views. In addition, we evaluated how well it achieved the values from the Value Triangle. We concluded the following:

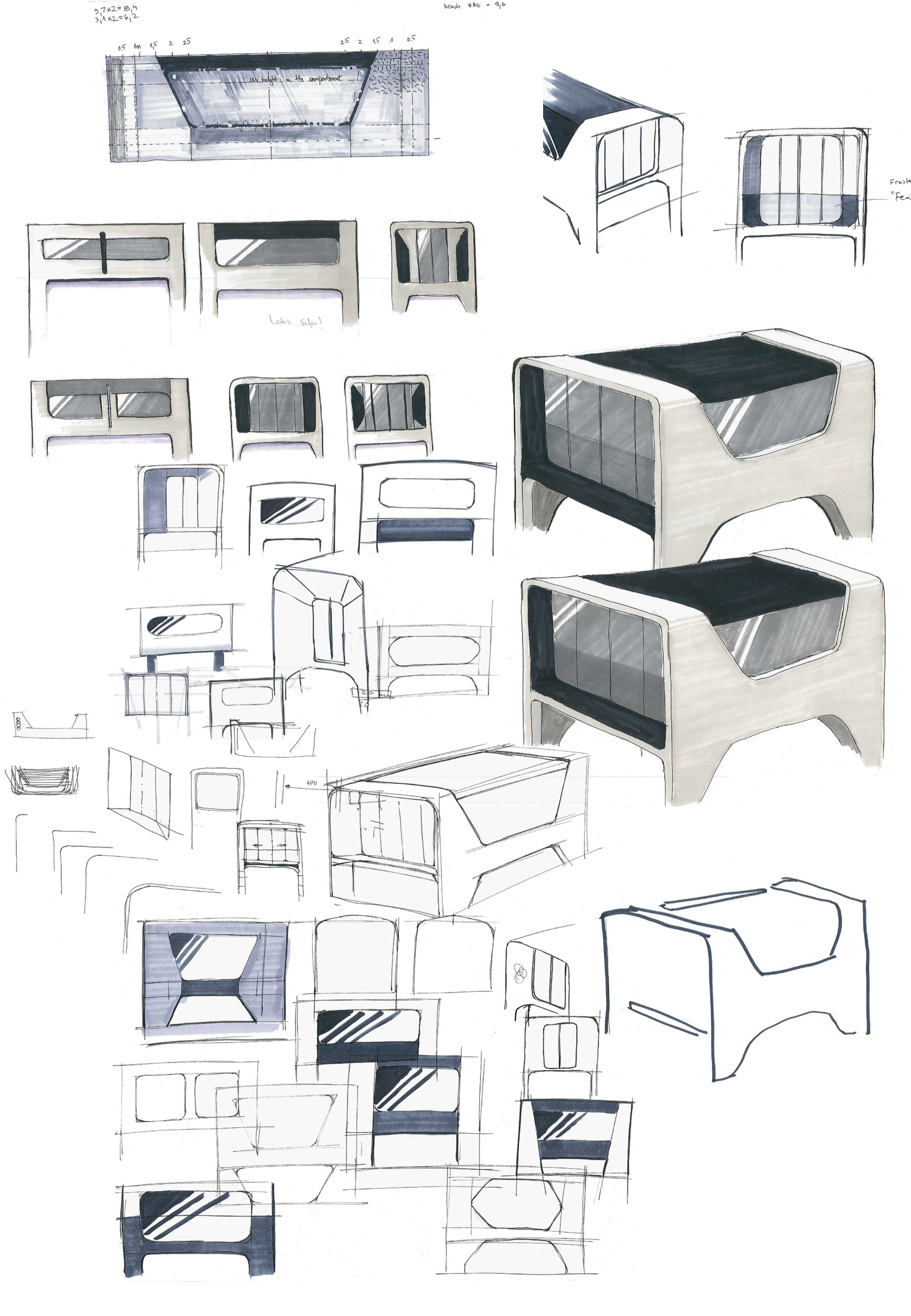
With only horizontal and vertical lines, the design is missing a feeling of direction. Without direction, it feels like the ferry is static and not an object that is meant to move.
The ferry needs more character to be recognized. We felt that the design should have an eye-catching element.

We made sketches of the side views, and tried to make small adjustments such as adding diagonal lines, contrast colours, rounded edges and experimented with proportions.

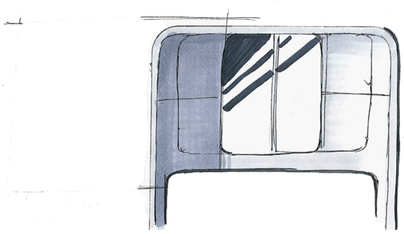


One of the side views sketched caught the attention of all of us. Adding four diagonal lines gave the design a feeling of direction. The shape of the side windows and the negative shape of the feet added the character we were missing. Coupled with a black contrasting roof, the shape of the side windows were emphasised in a nice looking way. The gut feeling of all of us said that "This is the ferry".

Furthermore, we moved on to draw perspective sketches to investigate different solutions for the front and back of the revised ferry design. Here we discovered that we had different opinions on how the lip, the extension of the floor outside the sliding doors, should look like and be integrated with the superstructure. It also gave the opportunity to investigate contrasting colours between the different elements of the superstructure.



9,7x2=19,4
3,1x2=6,2
bench 486 = 9,6
0.5 1m 1,5 2 2.5
2.5 2 1,5 1 0.5
180 height in the compartment
Looks Safer!
400



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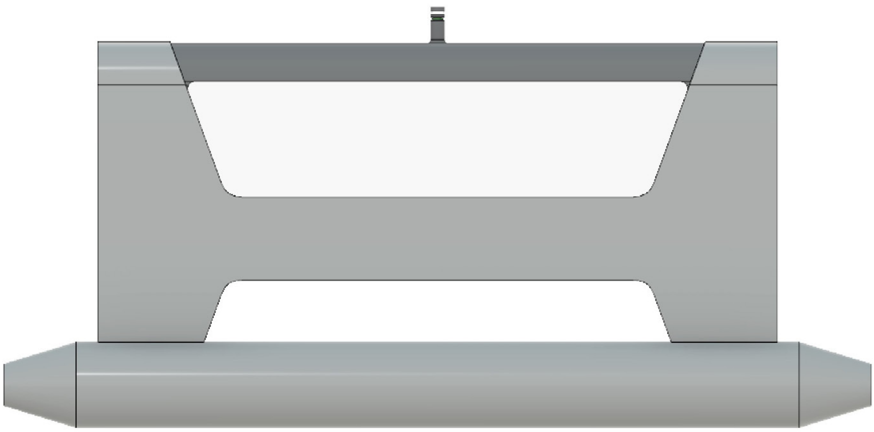
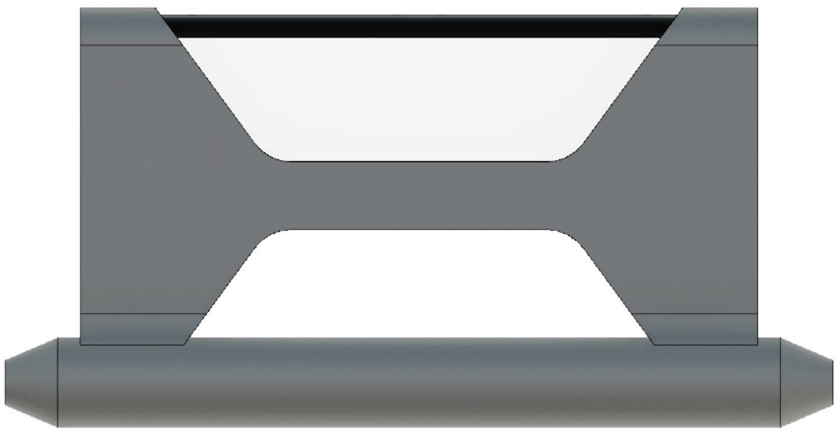
DETAILING
REVISING THE DESIGN





3D modelling

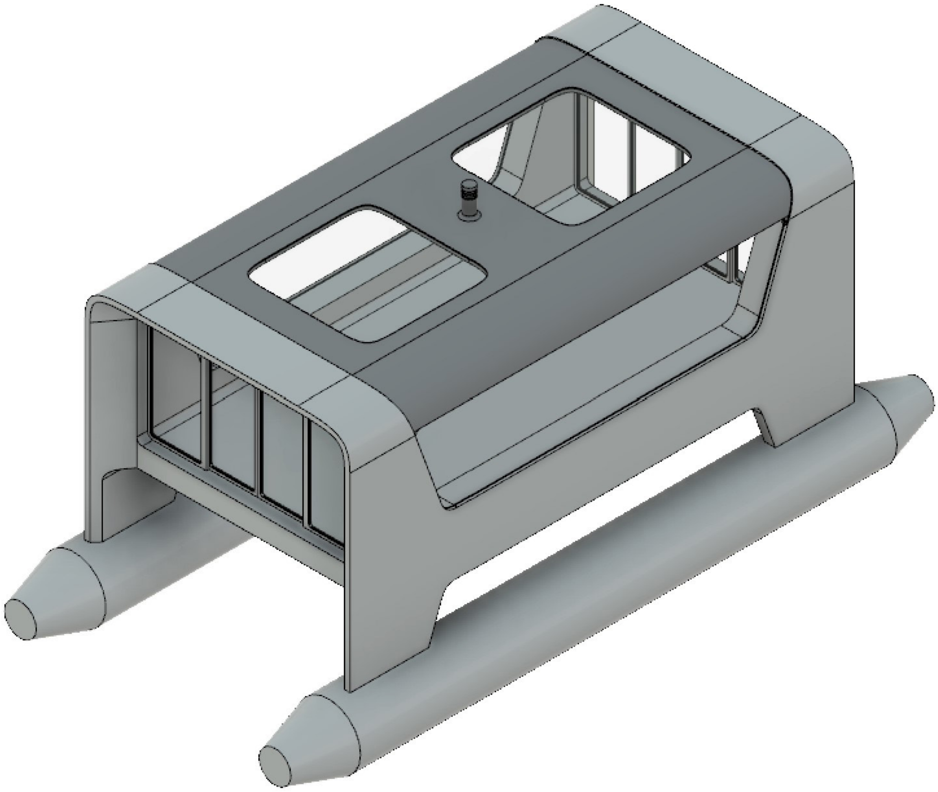
Throughout the project, we have experienced that different ideas arise from different choices of tools. For that reason, we decided that all three of us should move on to 3D-modelling software and model each of our own representations of the new concept iteration. This was to give all three a sense of ownership to the idea, and hopefully explore even more ideas. By doing this, we discovered that we had different interpretations of how the superstructure should be when it comes to dimensions and angles. For example, the window bench in one of the models was very long and looked stretched. In one of the other models, the angle in the side window made the window bench very small.

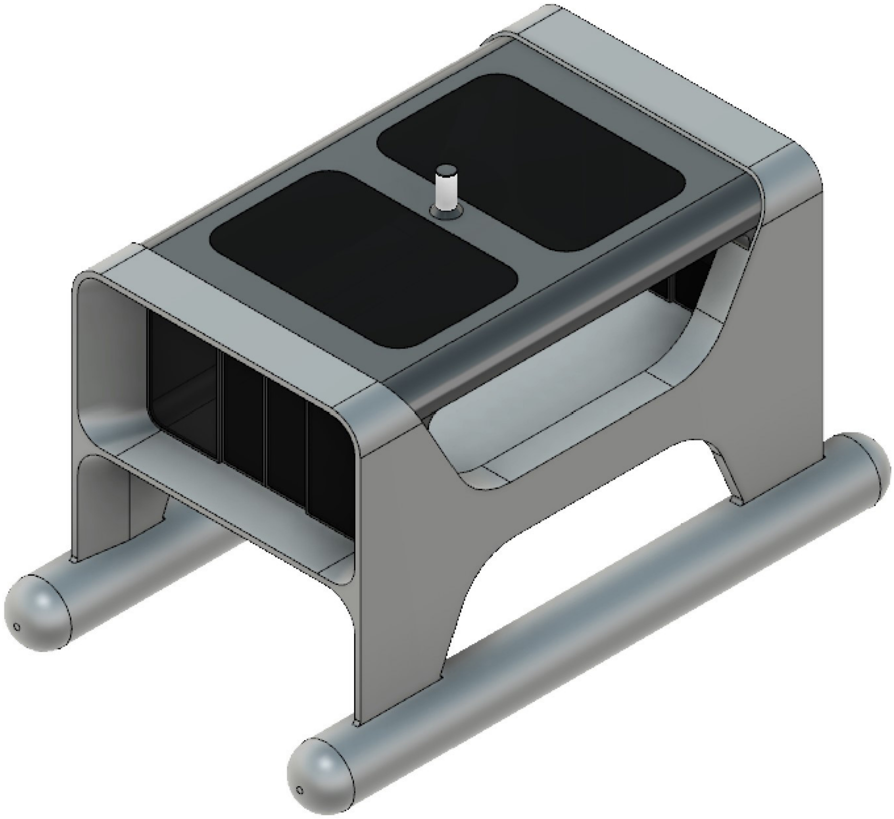
Evaluating final dimensions

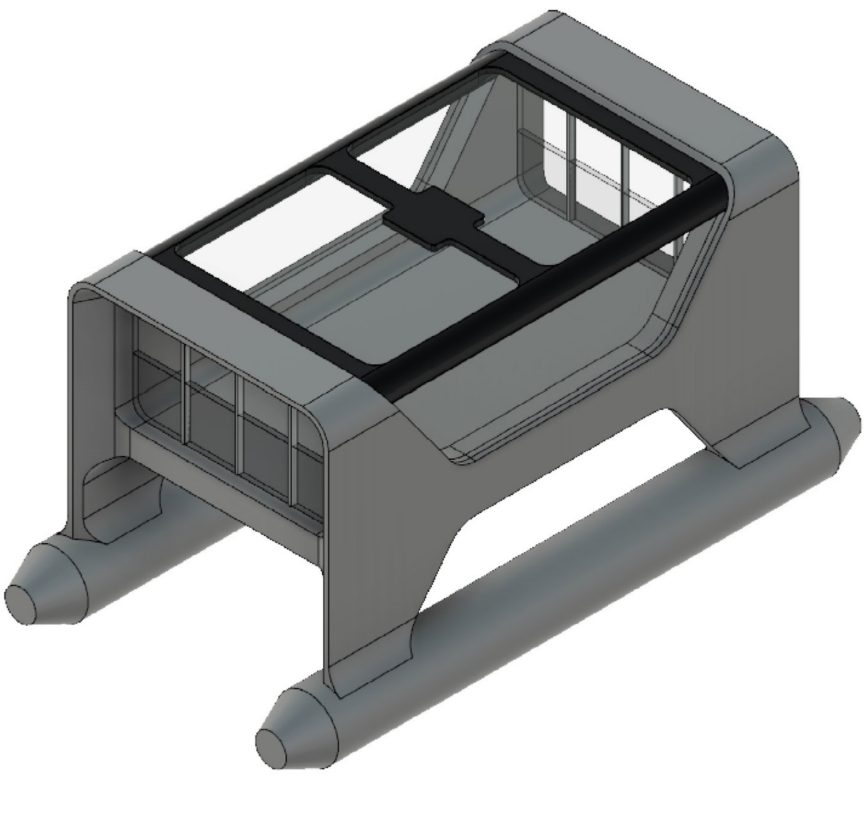
From the user test in the full scale mockup, we concluded the passenger compartment could be made 1 metre shorter without negatively impacting the passengers. In addition, we felt the side-bench area looked too "stretched out" from the side view of the exterior. As a result, this change made the exterior more aesthetically pleasing as well. The height and width of the passenger compartment was shown to be in an appropriate dimension in the user test and were therefore not changed.

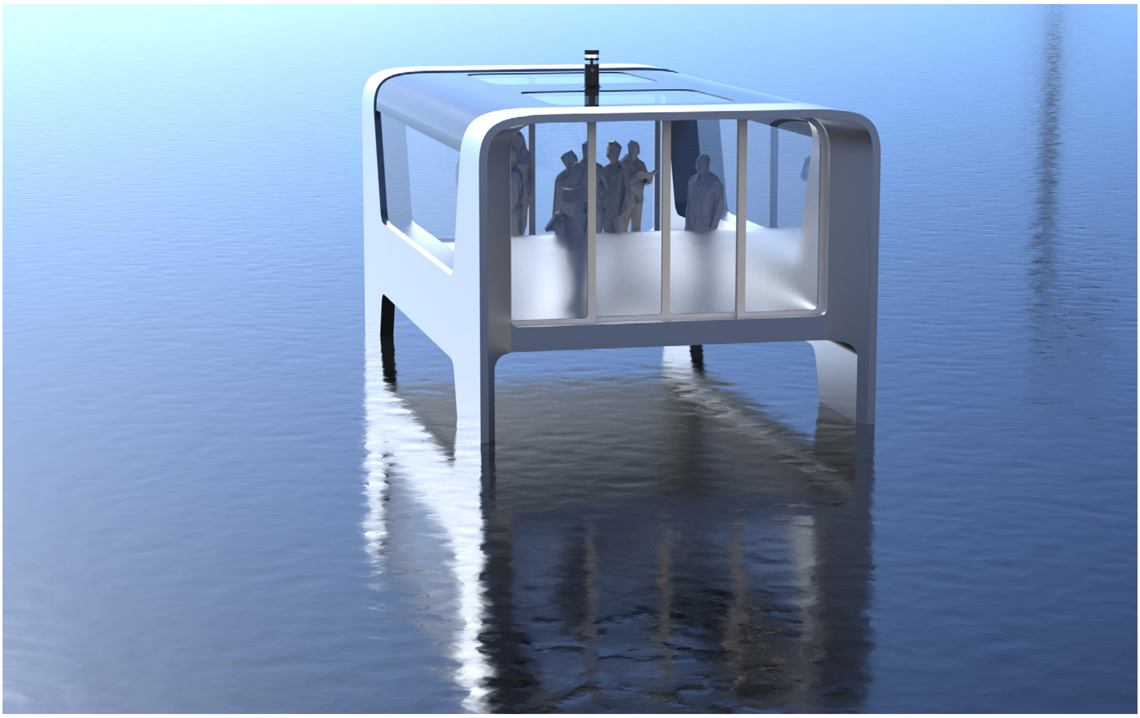
Design conclusion

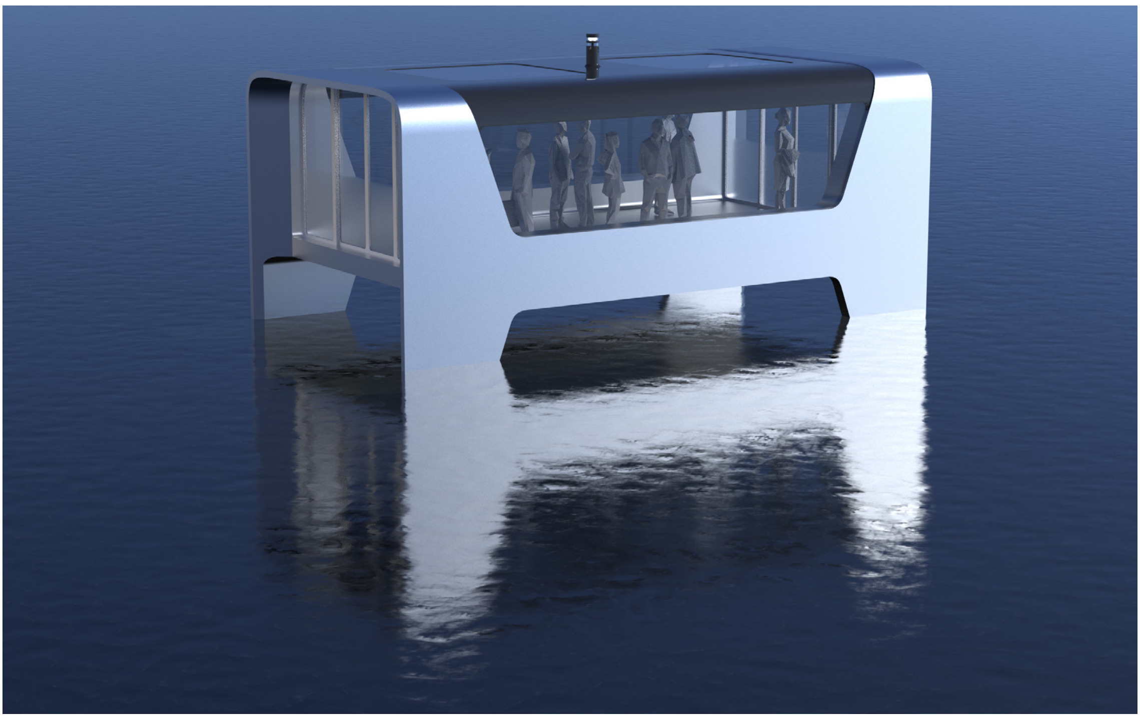
The design adopted a clean shape with angled lines that gave the ferry a true sense of direction. 2 bands in the front and back part of the ship create a silhouette complemented by a contrasting black roof bridging the two shapes together. Looking back, this shape has been part of the sketches throughout our process however only now it reached its full potential. When we had finalised this creative expression we truly felt as if a complete conclusion was made - a vessel that is both visually beautiful and engaging.











As the Minister of Trade and Industry, Jan Christian Vestre, was going to visit the Shore Control Lab, we were asked to make some visualisations of our current concept. Here we also added people inside, to better indicate the vessel's size.

REVISING THE DESIGN

Meeting with Jarle Kramer

We had a meeting with Jarle Kramer, an expert in hydrodynamics at Zeabuz, to evaluate the ferry design by having a look at the 3D-model together with us. We discussed the proportions, placement of equipment, propulsion and the swath hull.

Proportions

Kramer said that the proportions of the main dimensions seemed to look good. To know for sure the hydrodynamics of the design, he estimated that it would take a couple of weeks for one competent person within the field to do the calculations. Because we are designing for 5-10 years from now, and the sizes and weight of the components will most likely be smaller than they are today, we agreed that there is no point in doing the calculations at this point. We suggested making the components of today fit into the hull anyways, to show that the design can be scaled to fit the technology of today and still keep its expression. In that way, Zeabuz will have the opportunity to use elements of our design before the projected time frame.

Swath hull

When discussing the elevation of the swath, Kramer advised us to go for elevation by a water ballast pump. Another option that was discussed was using air pressure, which is also known as SES vessels. Kramer did not recommend this technology, as it requires very high energy consumption to keep the air pressure. In addition to that, SES vessels need huge noisy fans that require extra noise isolation and the hull needs a plastic skirt at front and stern that easily breaks. For those reasons, it was decided to go for the ballast water elevation mechanism.

The ballast water system requires a ballast pump and a ballast tank. The volume of the tank should equal the volume of the feet and hull that needs to be lowered into the water.

The elevation range that is possible to achieve, depends on the length of the feet. There should be some height left at the lowest position, to avoid waves hitting under the superstructure floor. On the other hand, these waves will be very small at the 7 knots speed Zeabuz is planning to operate with. When revising our 3D-model, Kramer suggested adding additional 0.5 metres to the ferry's feet should be fine.

When docking, it is an advantage to not have too long swath hulls in the direction of the ship. On the other hand, having them longer than the superstructure would add more stability. Kramer said that it should be possible to have the hulls at the same length as the superstructure. For the advantage of getting closer to shore when docking, we decided to make the hulls shorter.

Kramer commented that fins need to be added to the hulls for increased stability. The fins should be mounted at front and stern, and should point inwards. In some swath-designs there are rudders at front and stern. Kramer argued that this should not be necessary with the space we have between the hulls. It would be possible to achieve the same functionality with differential thrust, according to Kramer.

Placing of equipment
According to Kramer, using a swath hull for a boat at this size has never been done before. Swaths are usually 30-40 metre long vessels. In the existing swath vessels, there is sufficient space to place batteries for example, in their own battery rooms. For this design, there is less space for placing such components.

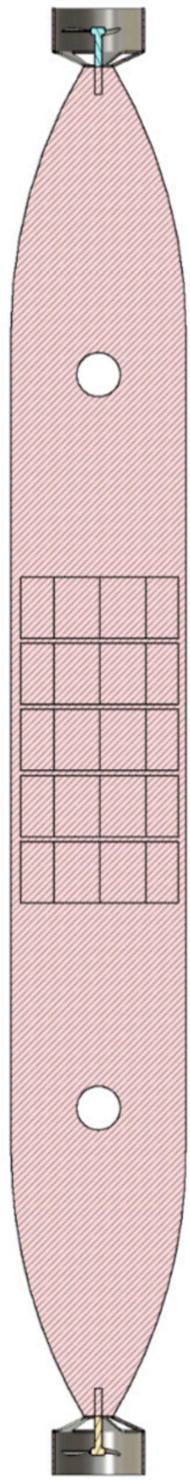
For optimal stability, Kramer suggests placing batteries, water ballast tanks and pumps in the swath-hulls. If there is not enough space, Kramer said that it will also be possible to put those components in the floor of the superstructure. That will require a thicker floor, and will lead to a higher centre of gravity. A thicker floor may lead to shorter legs on the swath. For those reasons, we aimed at putting the components in the hull. The racks of DP-equipment could be placed wherever we felt like. Thus, we decided to place out the heavy components first for good stability, and then place out the equipment racks where there is leftover space.

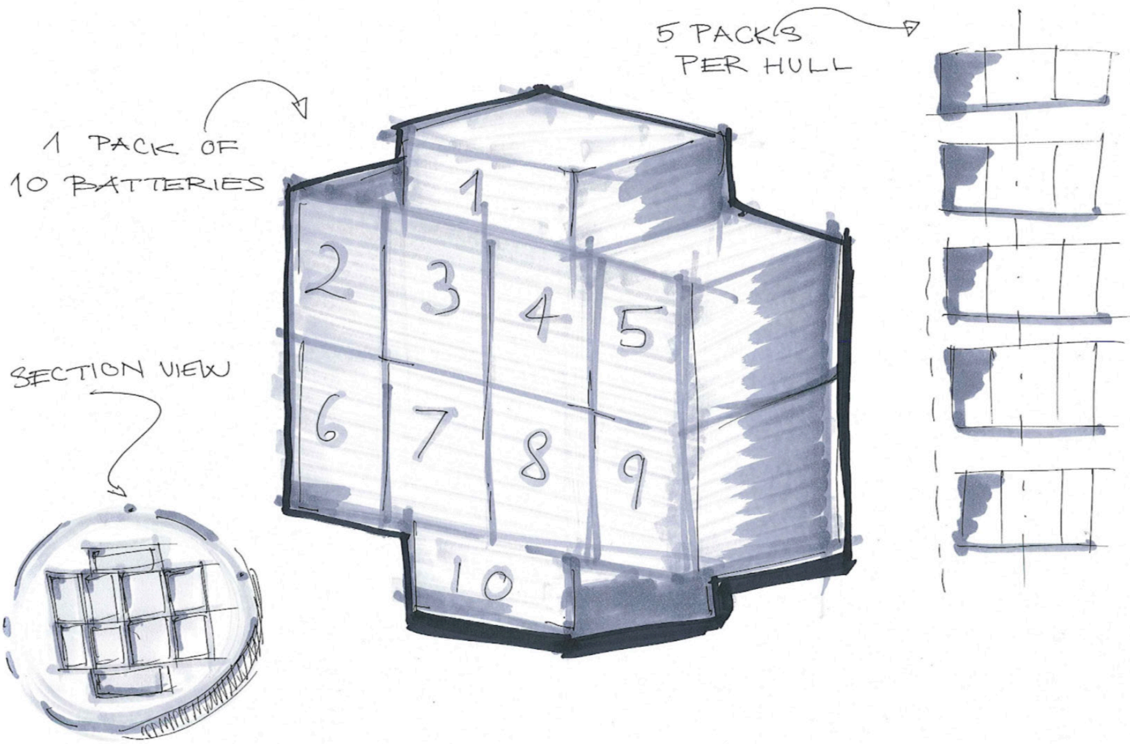
Propulsion
Kramer said a goal for Zeabuz is to use fixed propellers in a couple of years. One reason for this is that fully actuated propellers require complex machinery and larger depth. In addition, swath-hulls with rotating propulsion do not exist to this date as that would require putting the propellers under the hulls. Kramer recommends us to add a fixed thruster at front and stern ends in both hulls. In addition, he suggests adding two side thrusters at front and stern in each swath hull. The front and stern propellers should have variable pitch, to avoid too much drag on the front propellers. In addition, Kramer said protection rings can be applied to the propellers for extra protection. Together with Kramer, we sketched the propulsion on the hulls to get a consensus on how it should look like. We decided to include these recommendations in our design.

DETAILING

REVISING THE DESIGN

A company that Zeabuz had in mind to use as a supplier for their batteries is Super B. Particularly the Nomia 12V210AH, a Lithium Iron Phosphate battery ($LiFePO_4$). Kramer said to take into consideration between 200kWh and 250kWh for the ferry's battery capacity. For reference, the electric car with the largest battery capacity, the Tesla Model S, has a 100kWh battery. One 210 AH Nomia battery has the dimensions of 417 x 227 x 314 mm (Length, Width, Height) which is approximately 30L of volume (29,72L). To get to a capacity of 250 kWh, the ferry would need to house around 100 (99,3) of these batteries, as one of them has about 2.5kWh, totalling 3000L in volume. 50 batteries should be placed in one hull and 50 batteries in the other. If they are to be placed in the most efficient way, to make use of the space (batteries are square boxy, the hull is round), they can be clustered together in groups of 10, like it is shown in the picture. Five of these clusters in each hull would then be sufficient for reaching the desired battery capacity, leaving plenty of space for other components needed to be placed in the swath hulls.




5 PACKS
PER HULL
1 PACK OF
10 BATTERIES
SECTION VIEW
1
2
3
4
5
6
7
8
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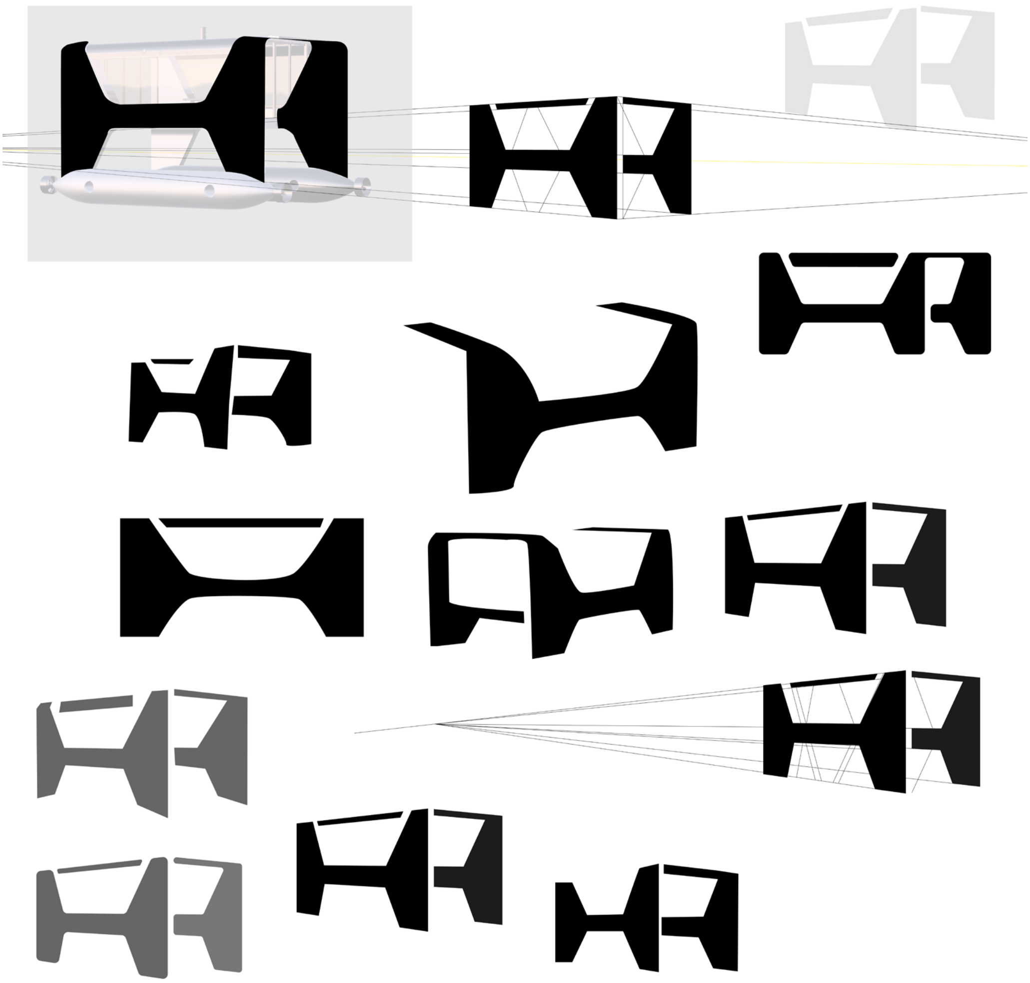
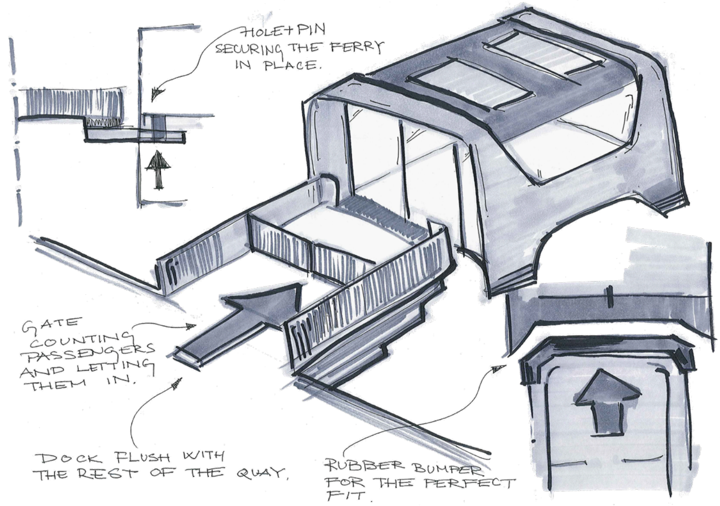
10

BRANDING AND IDENTITY

To give an identity to the project, we have made a logo which represents the ferry concept presented in this report. It is a side view of the vessel, made to show off the distinct angles that cannot be mistaken for anything else. In addition we have decided to name the boat Zwipp. The name comes from the Norwegian verb “svippe”, which derives from the German word “schwippen”. In Norwegian it means “to stop by” or “a quick trip”, therefore fitting the goal of our service well. The S has been replaced with a Z to better fit the brand statement of the Zeabuz identity.

ZWIPP

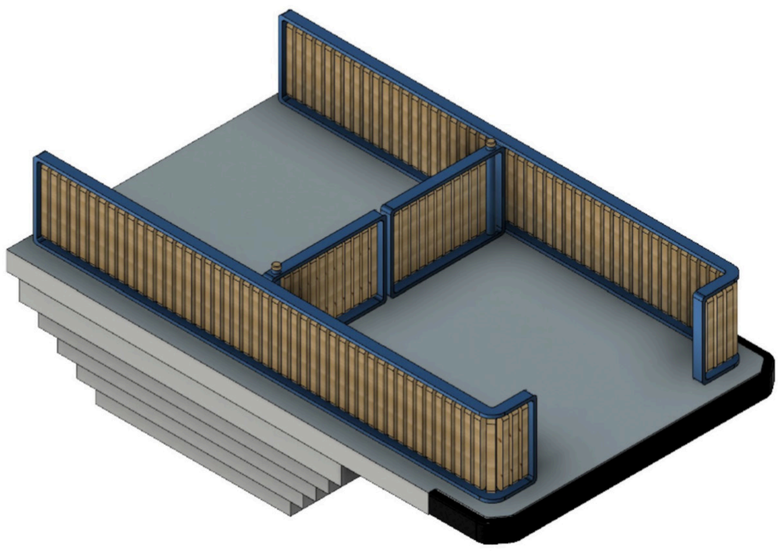




DOCKING

Making a final dock design is outside the scope of this project. However, we have had the docking in mind throughout the design process, as it is a crucial part of the user journey and the services Zeabuz will provide. For that reason, we have sketched an idea for a dock that can be developed further.

An advantage of the swath hull is the possibility to elevate the ferry with ballast water. The range of the designed ferry is 1,34 metres. For cities with tidewater differences within this elevation range, it is possible to have a fixed dock without ramps. The ferry will then be easily accessible for all passengers, no matter the tide differences. If there should be technical issues with the fixed dock, it is still possible to lower the superstructure to just above water level and use a regular floating dock with ramps.



DETAILING

OPERATOR STATION CONCEPTS

Having an operator station or not was a discussion that had been going on since we started this project. This being a concept design some years ahead, we had concluded that an operator on board would not be needed. Even so, we thought it would be nice to have some thoughts about how and where it should look and be, if needed. We found different solutions to this, one where the operator can stand inside the passenger compartment, either with a wireless control panel or a control module connected to a centre screen. Problems with this is that the operator does not have clear sight, with passengers standing in the way, but also the walls in each corner are blocking for the clear sight. A solution to this is to either have the operator on top of the ferry, as an added module in front of the ferry, or an integrated case in the wall.

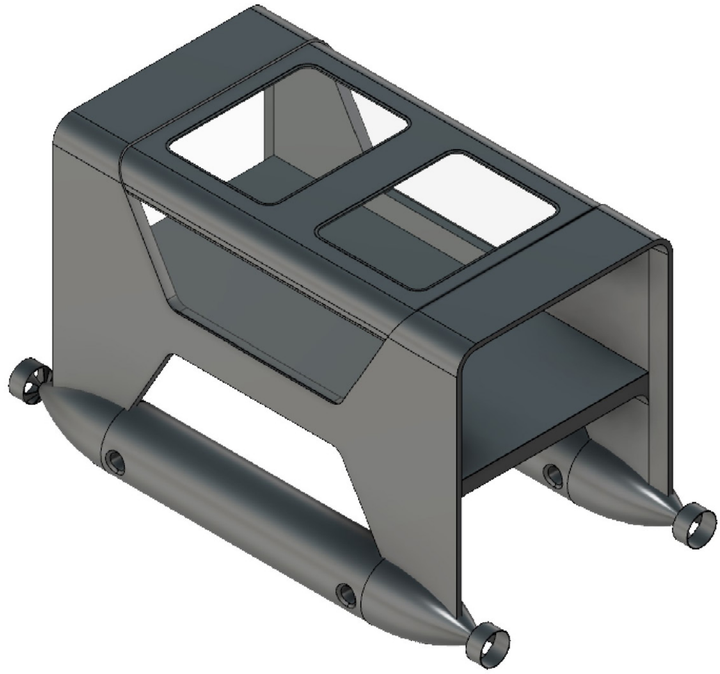

225°

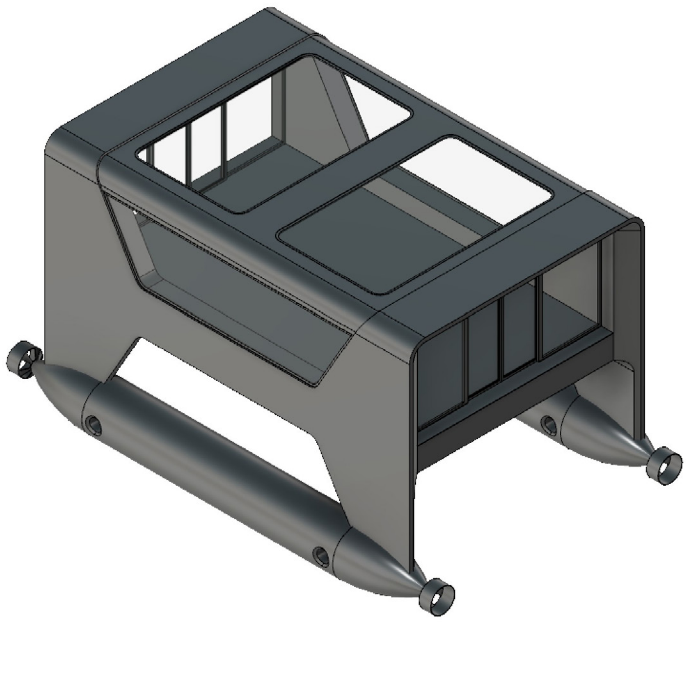
DETAILING

CAD

To make CAD 3D models we have used Fusion360 as our program of choice. All 3 of us are skilled in it so it only made sense to use it as a platform. Fusion360 also supports collaborative working, which meant we could all be working at once, adding on to the final model. To make the final 3D model however, we have decided to sit down together and agree on the final design changes, like dimensions. A big part of this model was also making it parametric, as to later have the ability to change a desired dimension and have the 3d model automatically update.

Parameter	Name	Unit	Expression	Value
Favorites				
User Parameters +				
User Parameter	width	mm	5000 mm	5000.00
User Parameter	swath_radius	mm	1200 mm	1200.00
User Parameter	Compartment_lengt	mm	7 m	7000.00
User Parameter	compartment_with	mm	4000 mm	4000.00
User Parameter	swath_height	mm	1350 mm	1350.00
User Parameter	compartment_height	mm	2500 mm	2500.00
User Parameter	floor_thickness	mm	300 mm	300.00
User Parameter	wall_thickness	mm	500 mm	500.00
User Parameter	roof_thickness	mm	100 mm	100.00
User Parameter	leg_thickness	mm	200 mm	200.00
User Parameter	bench_height	mm	450 mm	450.00
User Parameter	the_angle	deg	90 deg + 30 deg	120.0
User Parameter	bench_lenth	mm	4000 mm	4000.00
User Parameter	inner_roof_height	mm	1600 mm	1600.00
User Parameter ×	lip	mm	300 mm	300.00
User Parameter	door	mm	100 mm	100.00
User Parameter	extesoin	mm	300 mm	300.00
User Parameter	swath_length	mm	9200 mm	9200.00
User Parameter	side_thrusters	mm	300 mm	300.00





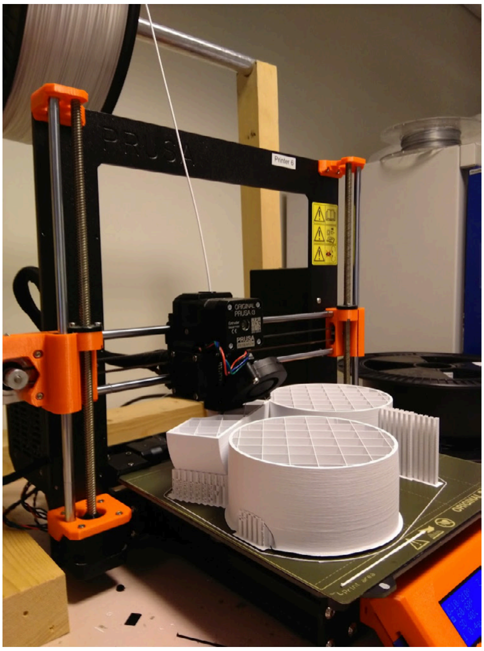
DETAILING

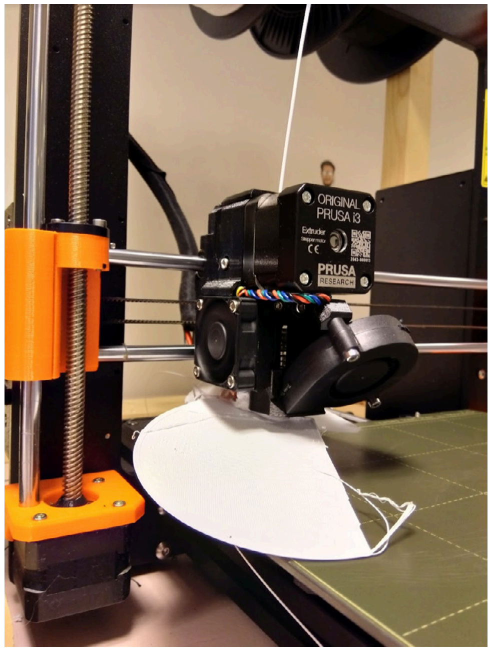
MODEL MAKING

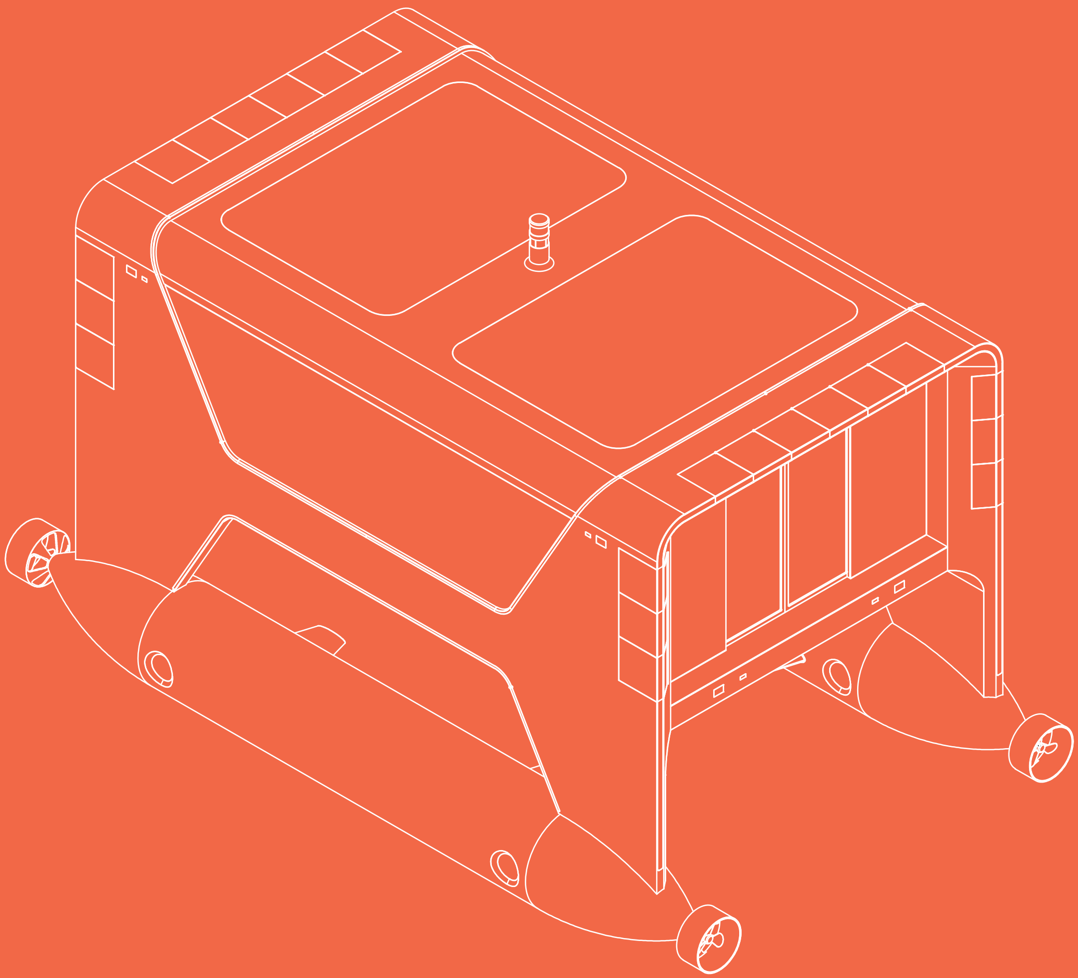
An important part of the project has been to serve as a showcase for a future waterborne autonomous passenger ferry, both for our client Zeabuz and the Design Department at NTNU. In our everyday life at the NTNU Shore Control Lab the last 6 months, we have had weekly presentations to visitors and the Zeabuz team. Through these presentations, we have discovered the enormous power we have as designers to convey our ideas to people with visuals. We have gotten much direct feedback on both renders and 3D-printed models. Especially much attention was received by the physical models, as people could hold them in their hands and study them.

The earlier ferries designed at the Department of Design are made in 1:10 scale models that are exhibited at the NTNU Shore Control Lab. We wanted to make a scaled model of our design as well, to give future visitors a model to study and to stimulate for discussions.

The model was made in a 1:10 scale as well, in case people will compare the size of the model to the other ferry models that are exhibited at NTNU Shore Control Lab. We chose to 3D-print the aluminium parts of the model, and added acrylic for the windows. The parts were glued together, sanded down and painted for the correct colour representations.



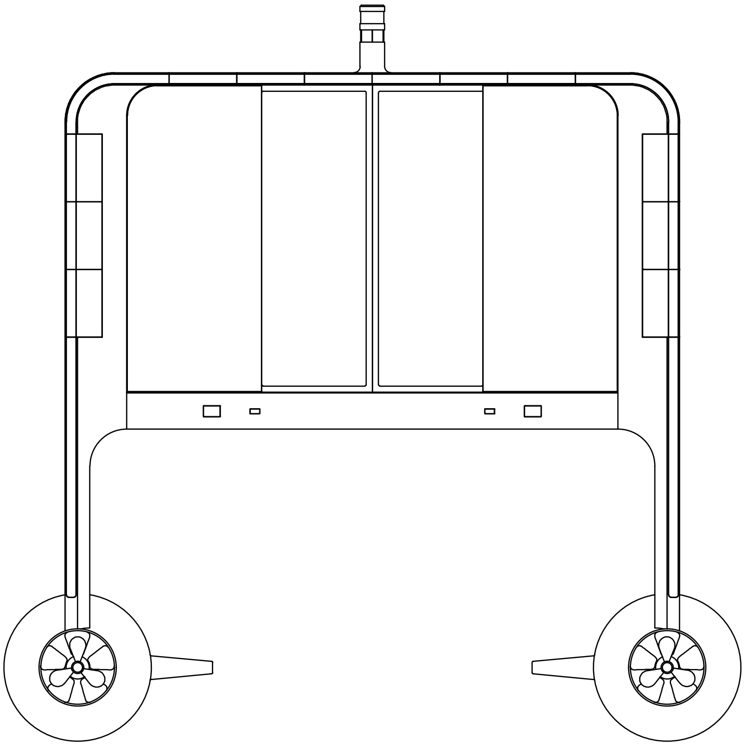

ORIGINAL
PRUSA i3
Extruder
PRUSA
RESEARCH



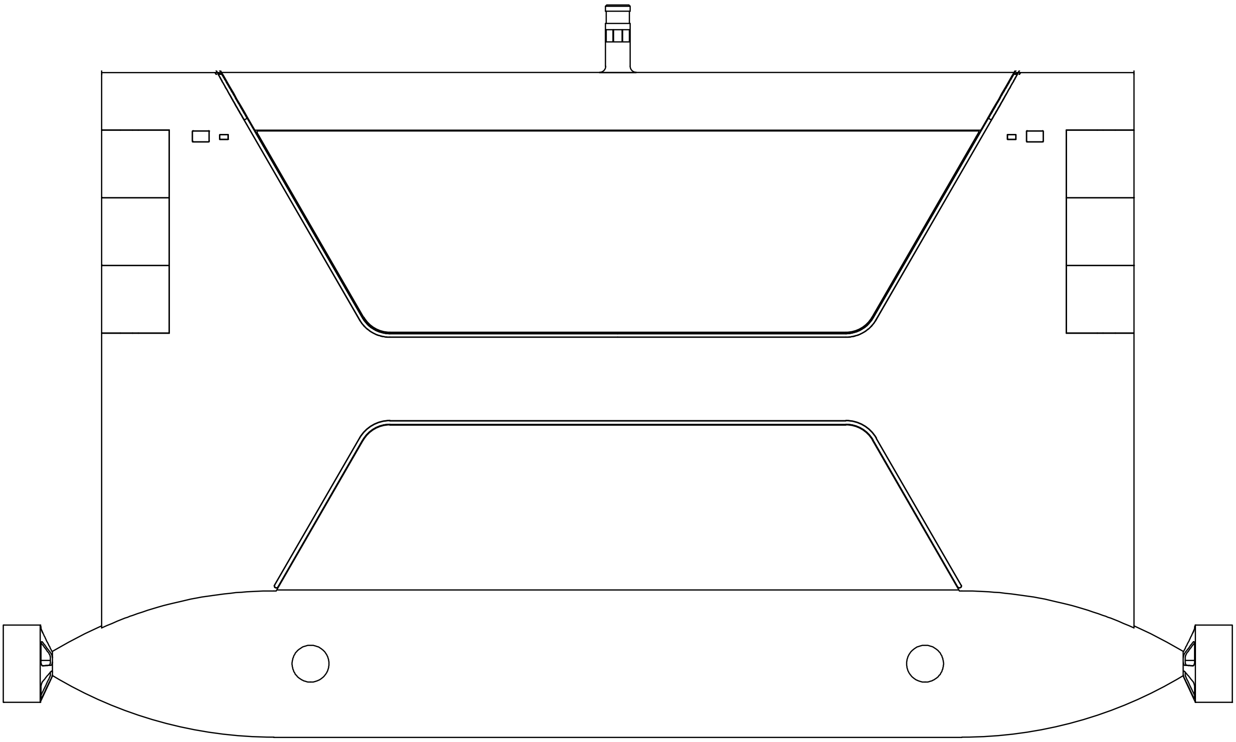
chapter 6

results

The final design of the ferry is the result of a combined effort on the concept and the aesthetics of the superstructure, as well as it includes all parts from the individual work conducted. Hence, the design appears believable and realistic.



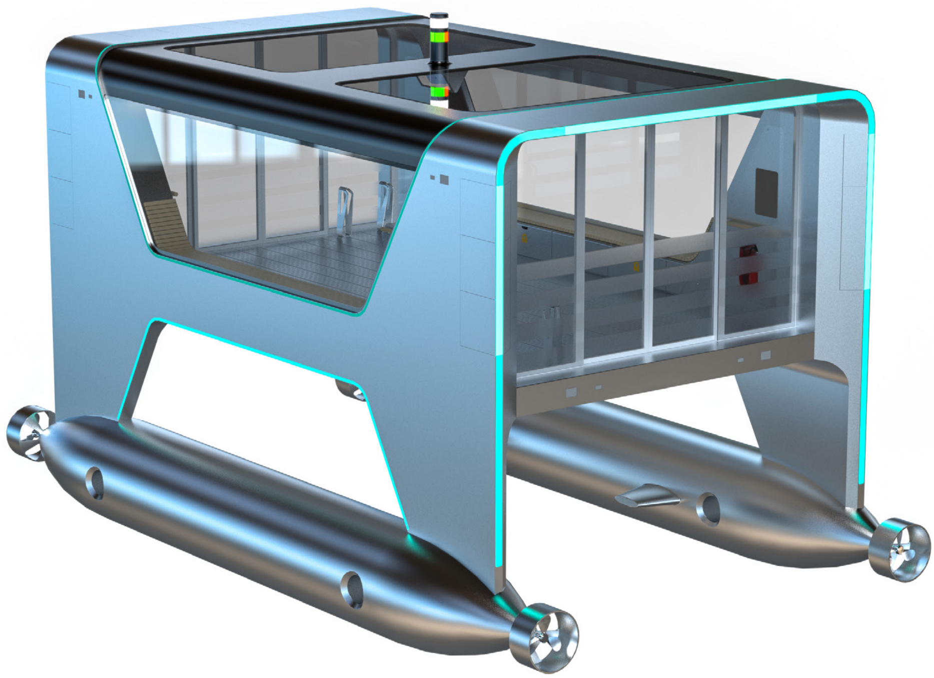
This vessel is based on a swath. The superstructure connects to the hull with 4 supports making a floating appearance above the water. The ferry's design is symmetrical accommodating bidirectional travel. The structure consists of a continuous shape interconnected by a roof. The design is opened up by large areas of glass surfaces, providing an expansive view for the passengers inside. Both ends of the vessel make use of sliding doors that enable easy entrance and exit. The roof, finished in a contrasting colour, ensures complete comfort while travelling in changing weather conditions. This autonomous vehicle is covered by a number of sensors that are integrated into the hull. Paired with elements for communicating intent, lights and physical representation of movement have been implemented into the superstructure.

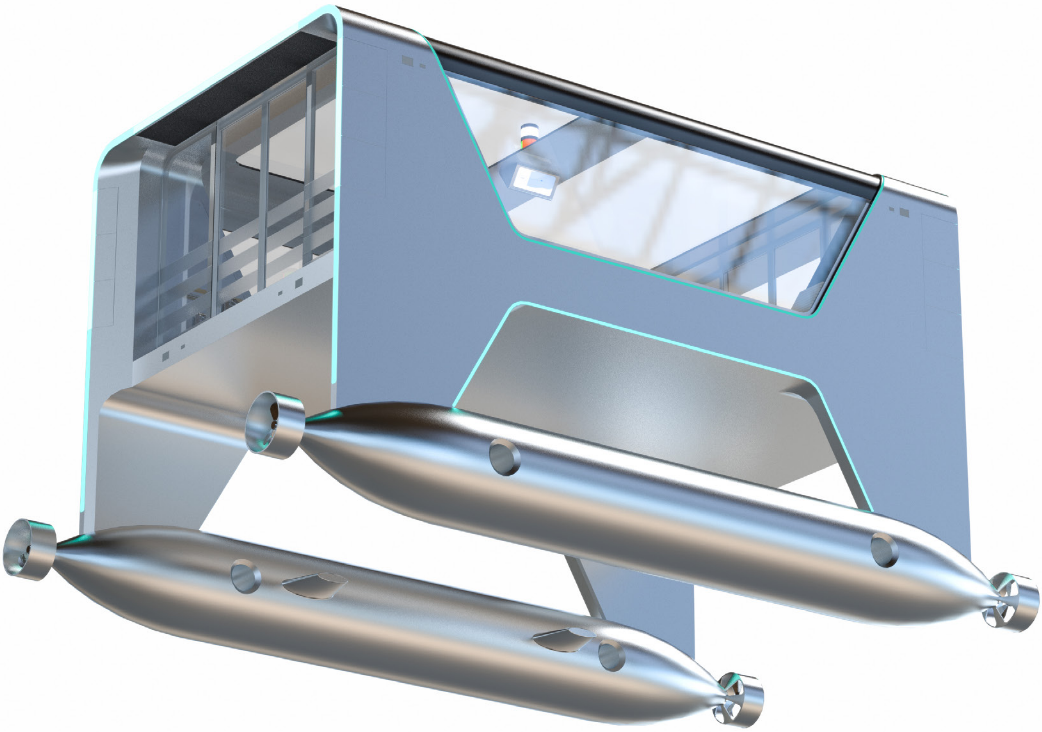


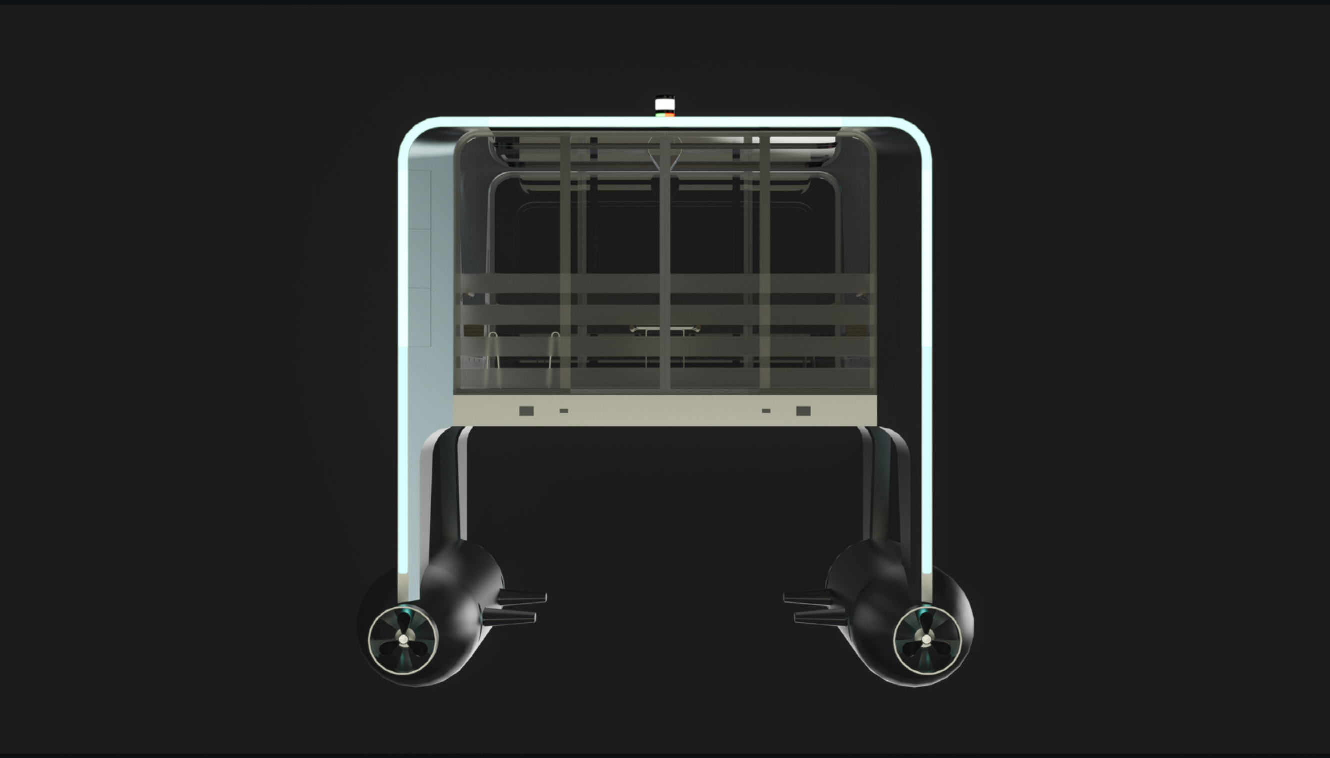
Visualisations of the ferry have been made in both Keyshot 11 as well as in Twin Motion, as they give different results and serve different purposes. The Keyshot renders are made to show the correct materials and colours on the ferry and its interior. The visualisations of the ferry at night time have spotlights as the suggested source of light, as well as the graphical elements frosted on the roof windows.

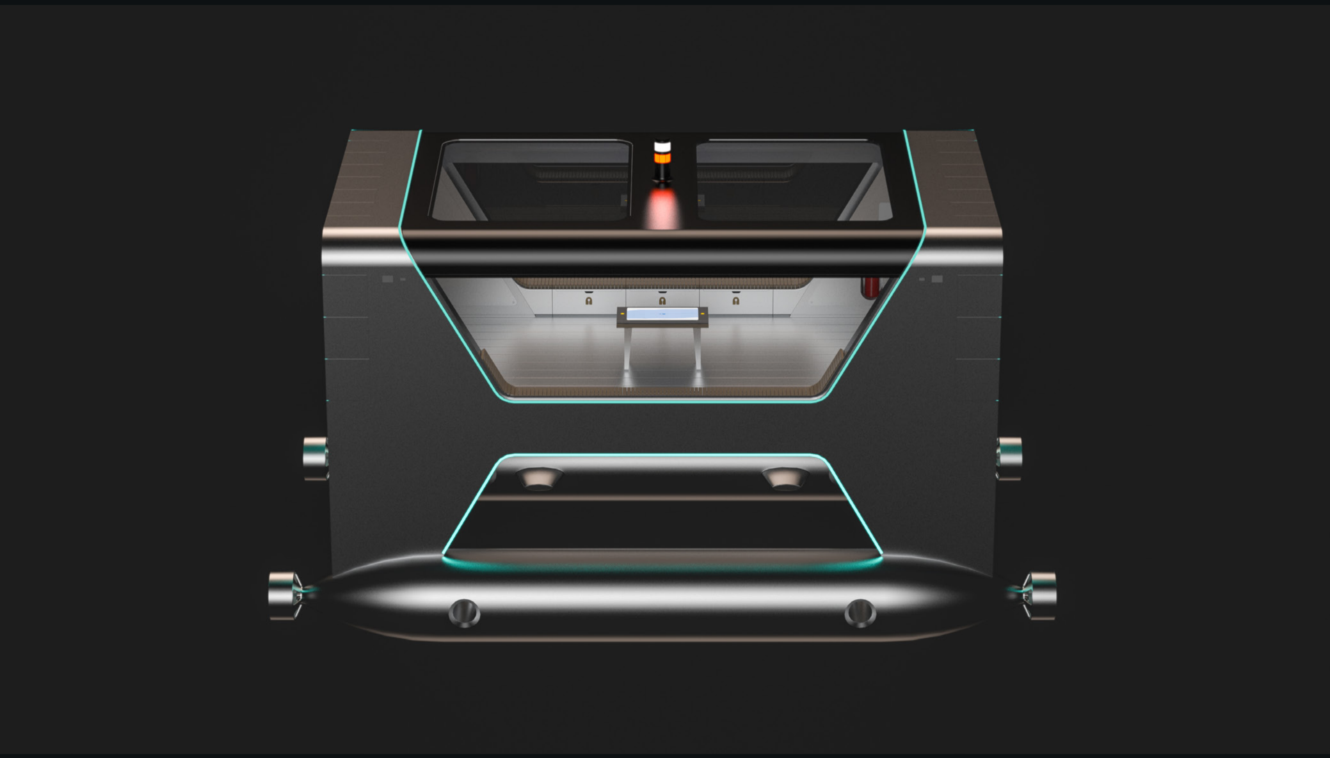
The screens, both the centre and top, are showing what we suggest should be presented on the screens, giving the passengers information about where the ferry is relative to shore and other vessels. It also presents its next place and estimated time of arrival. The external communication lighting is glowing turquoise, as this is the suggested standard colour for vessels driving autonomously.

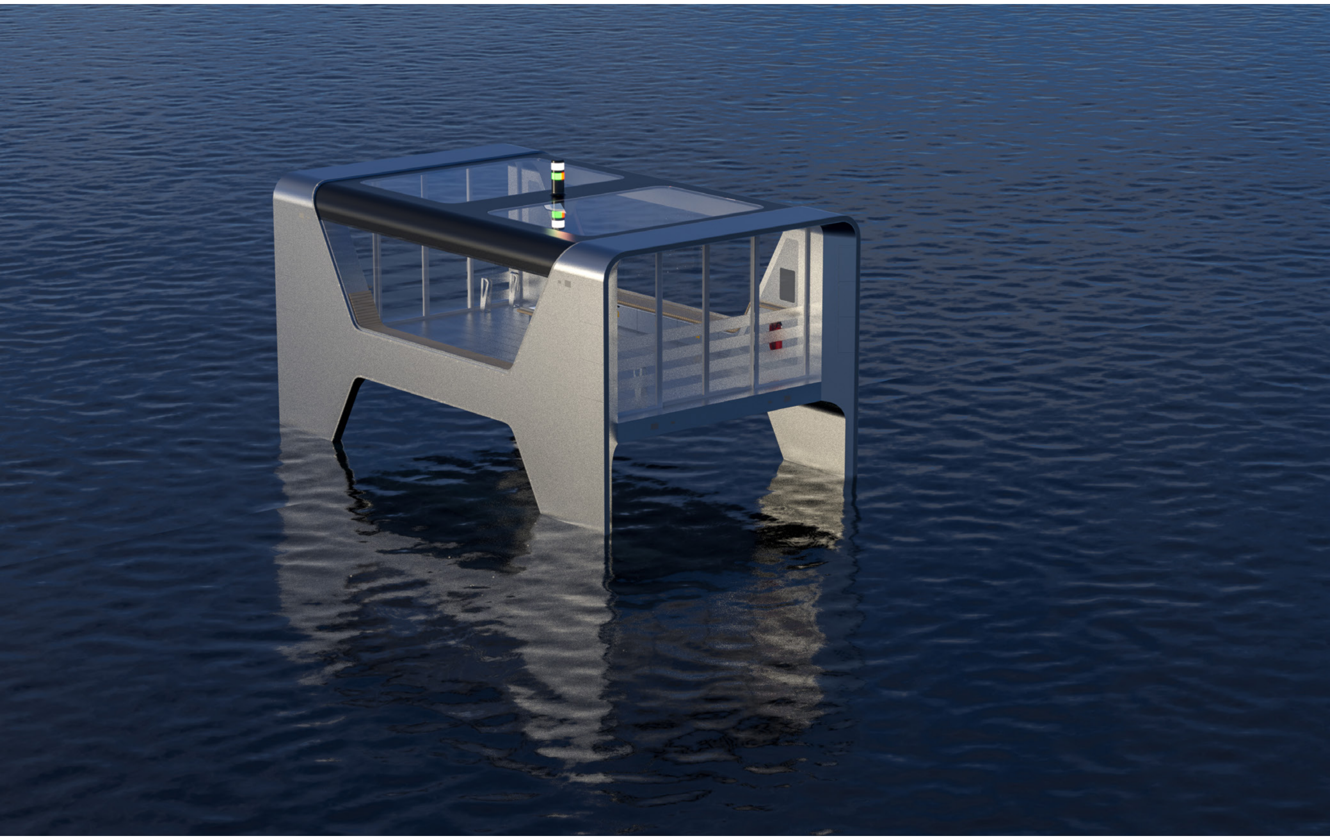
KEYSHOT

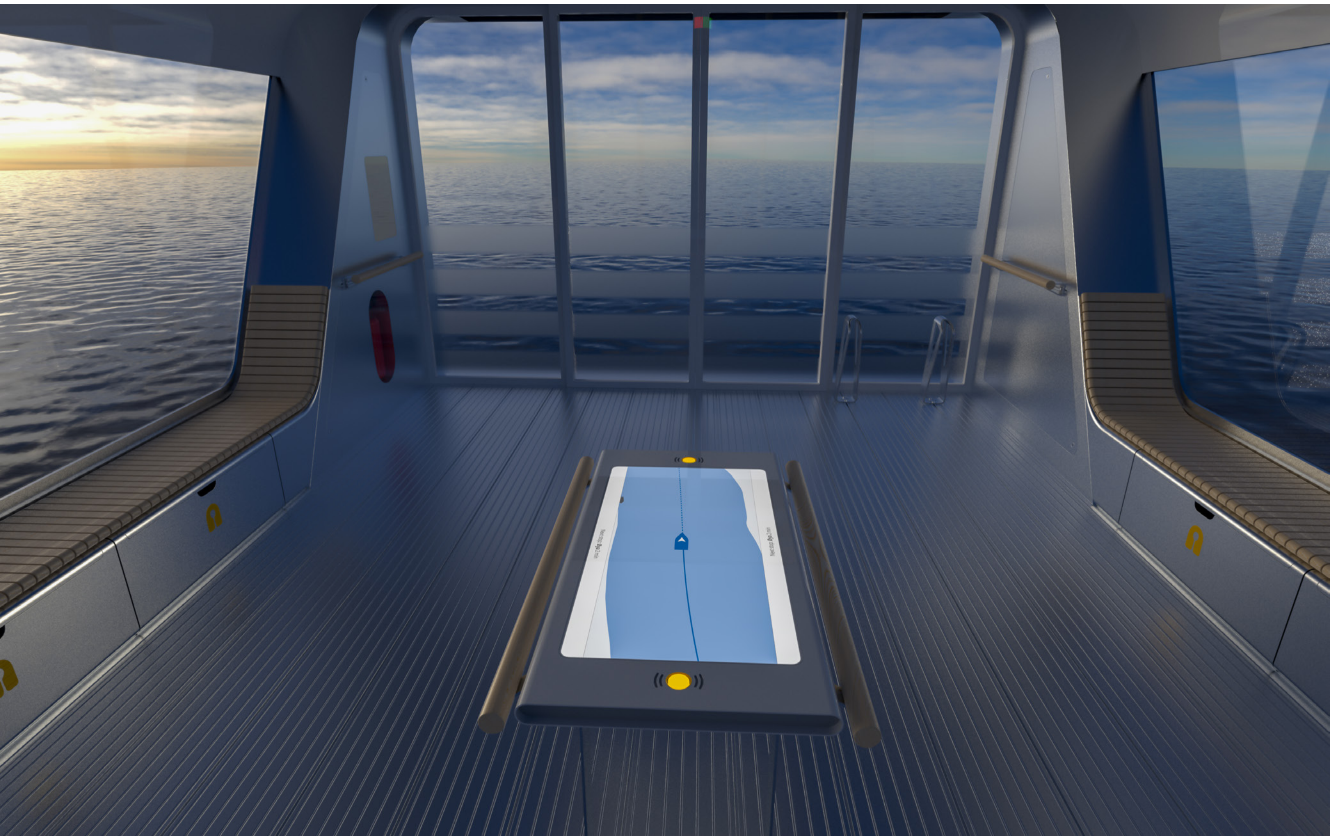


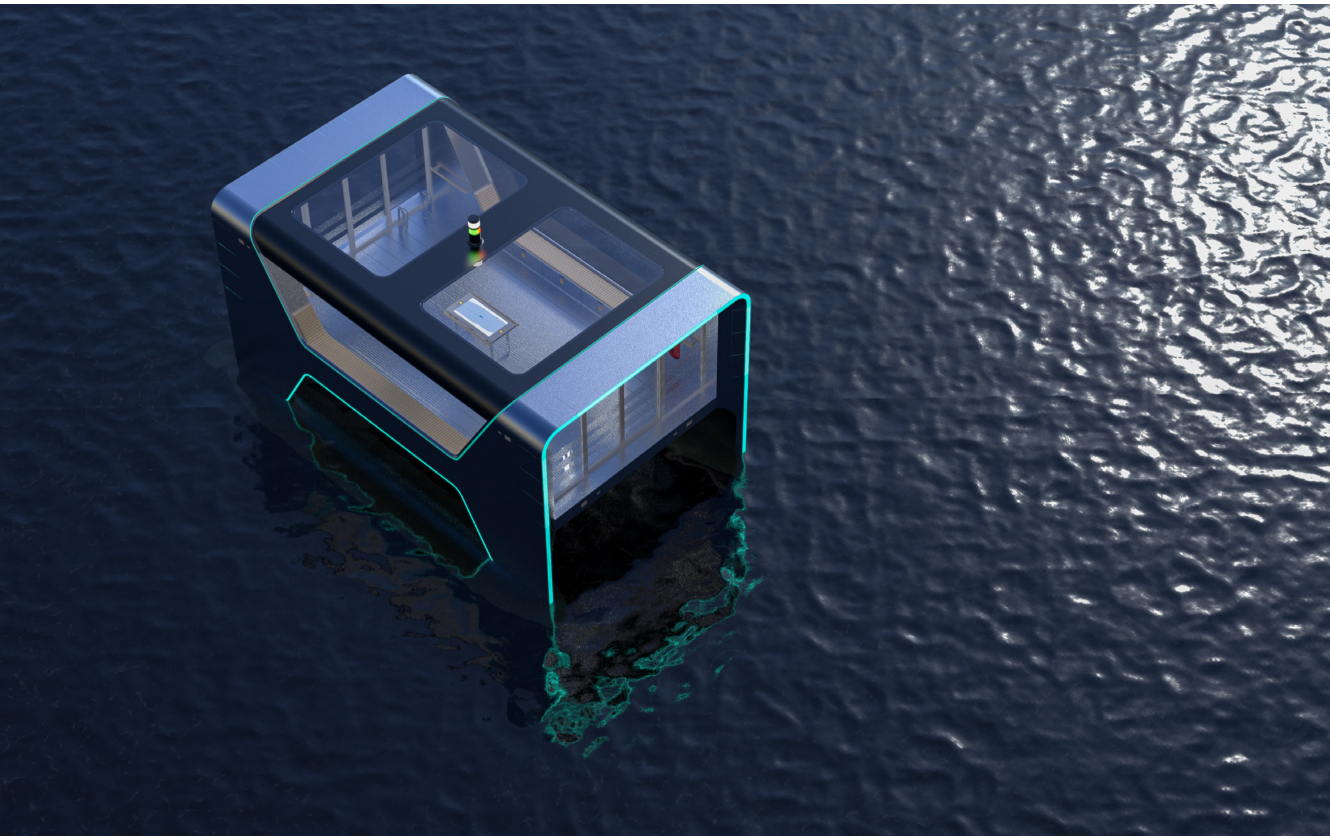


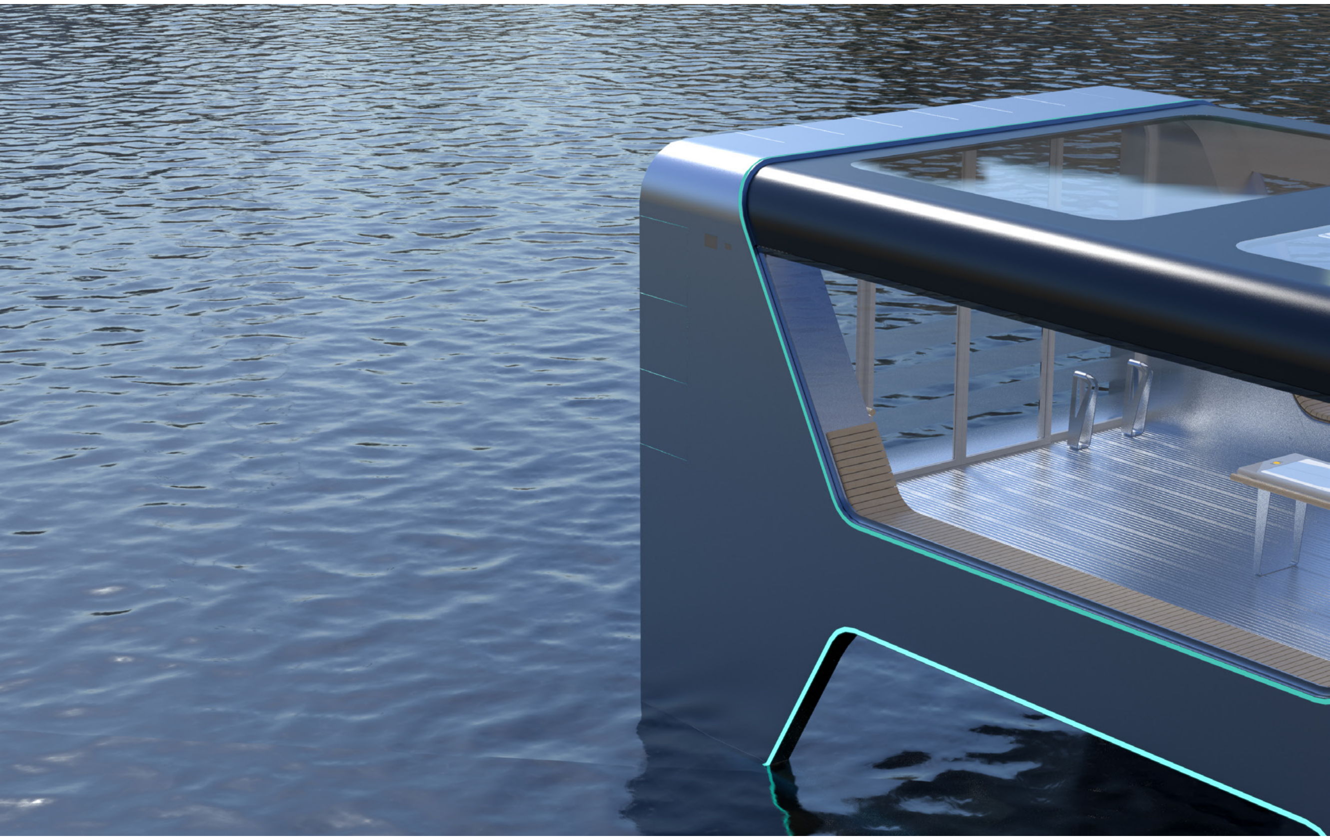


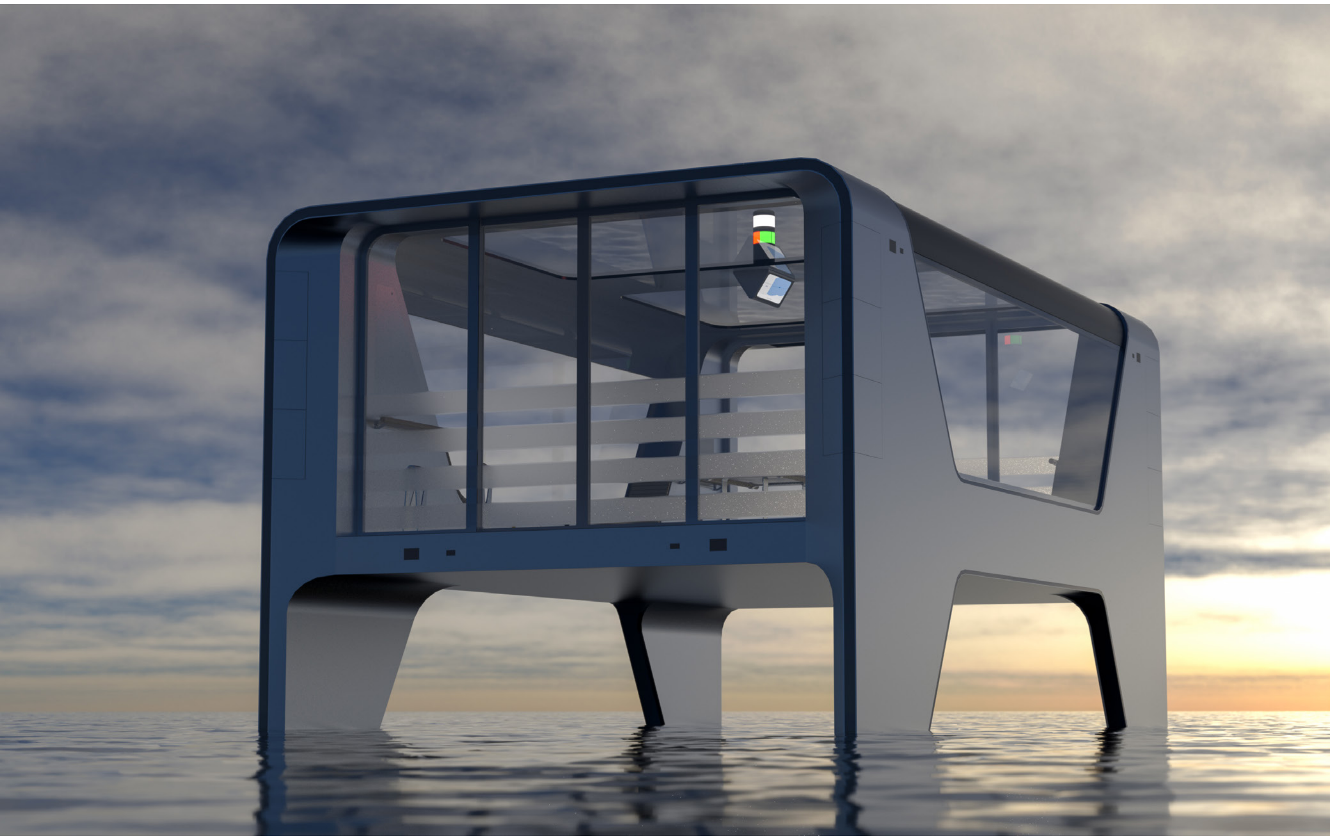


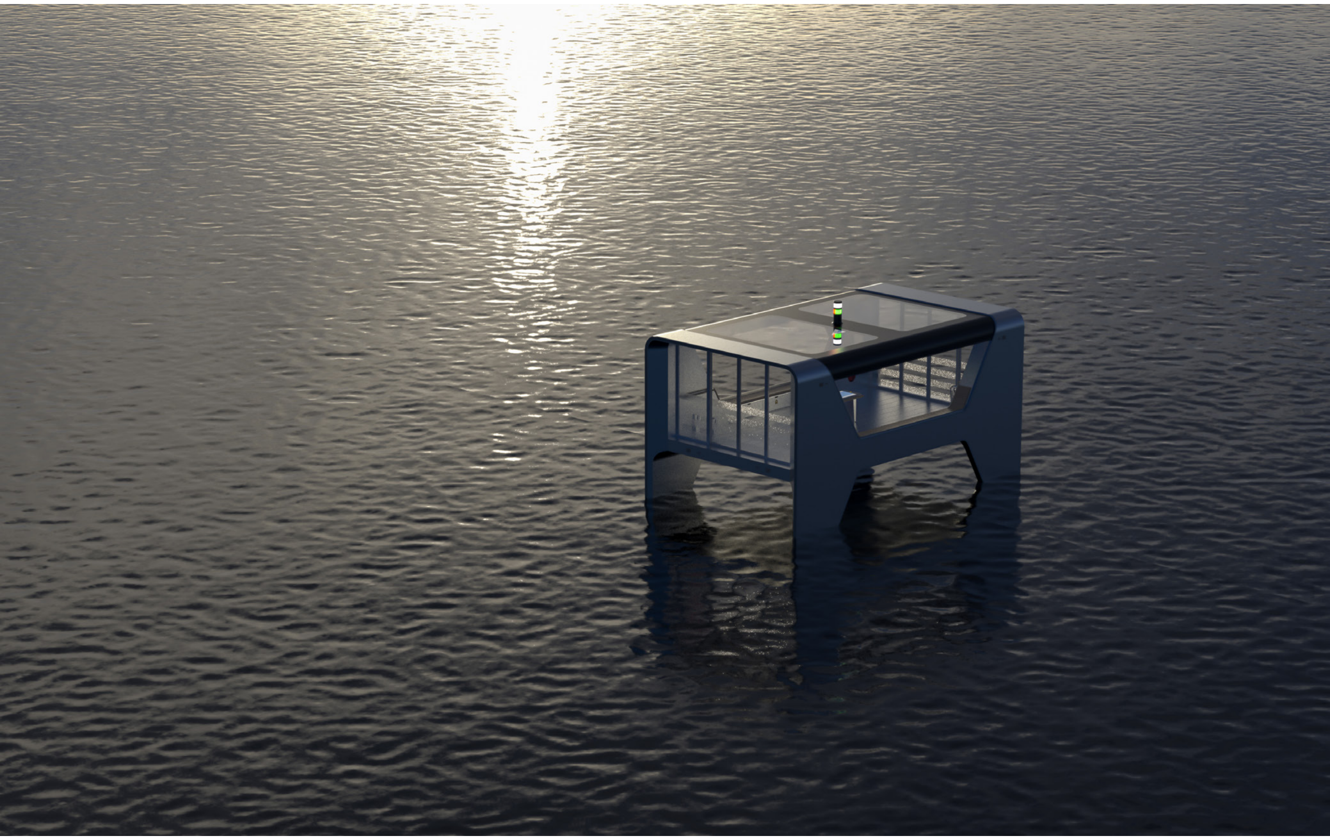


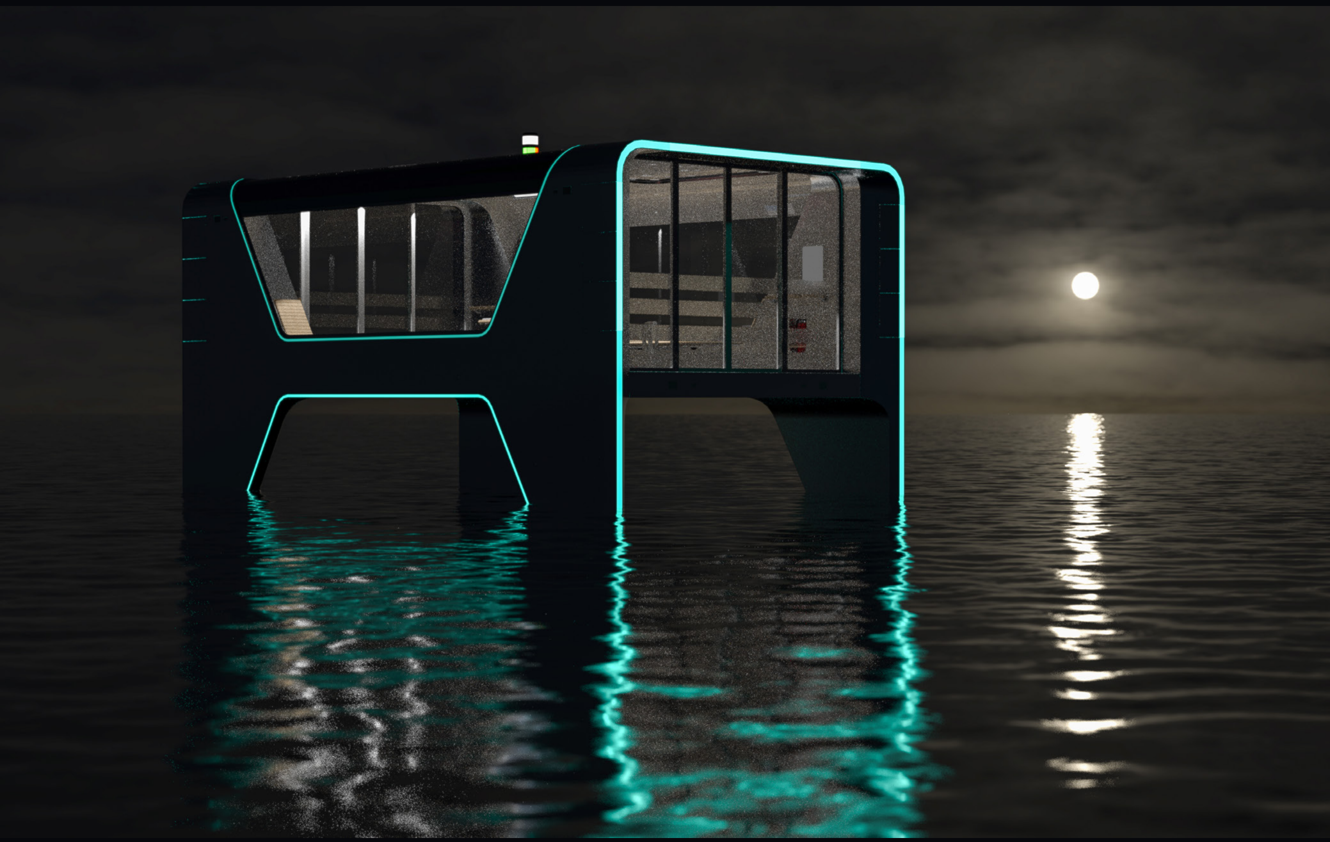


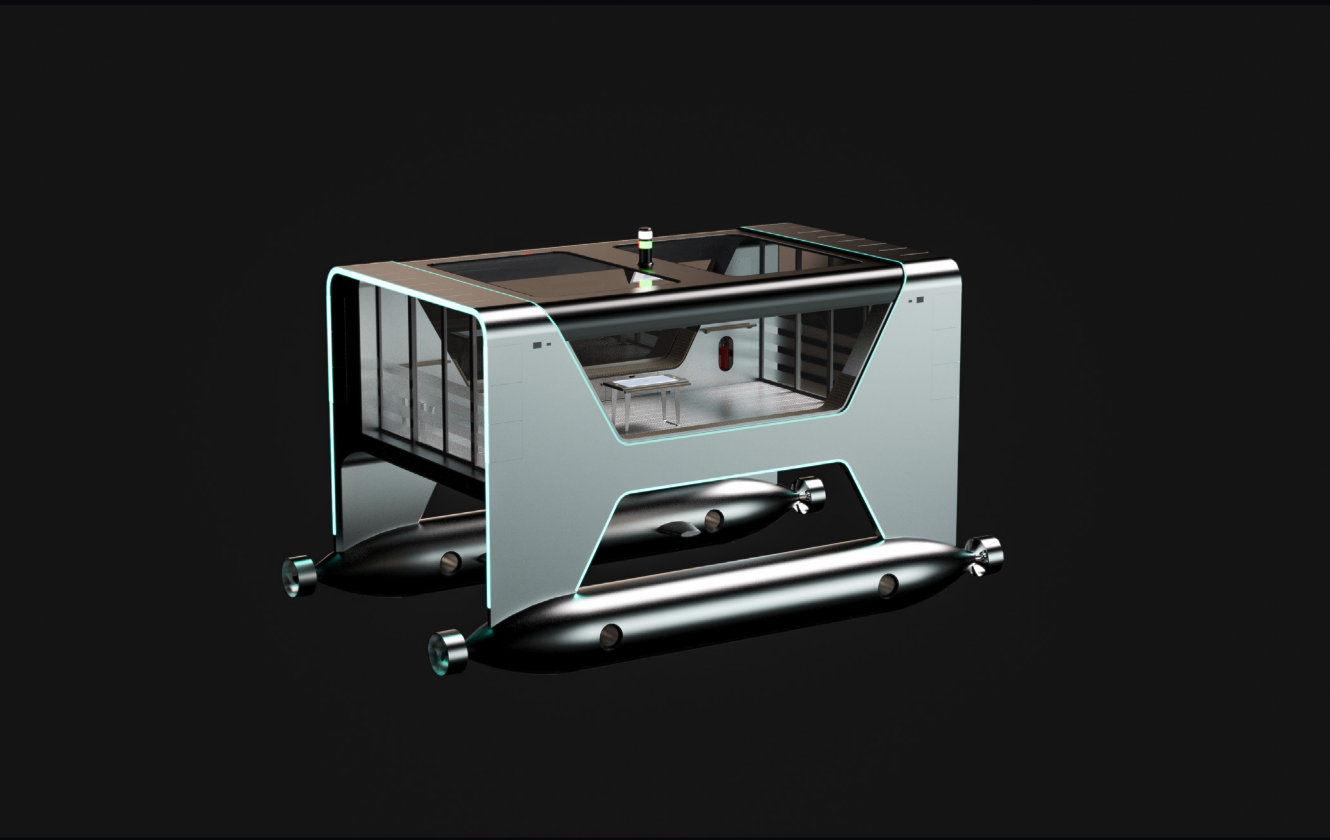


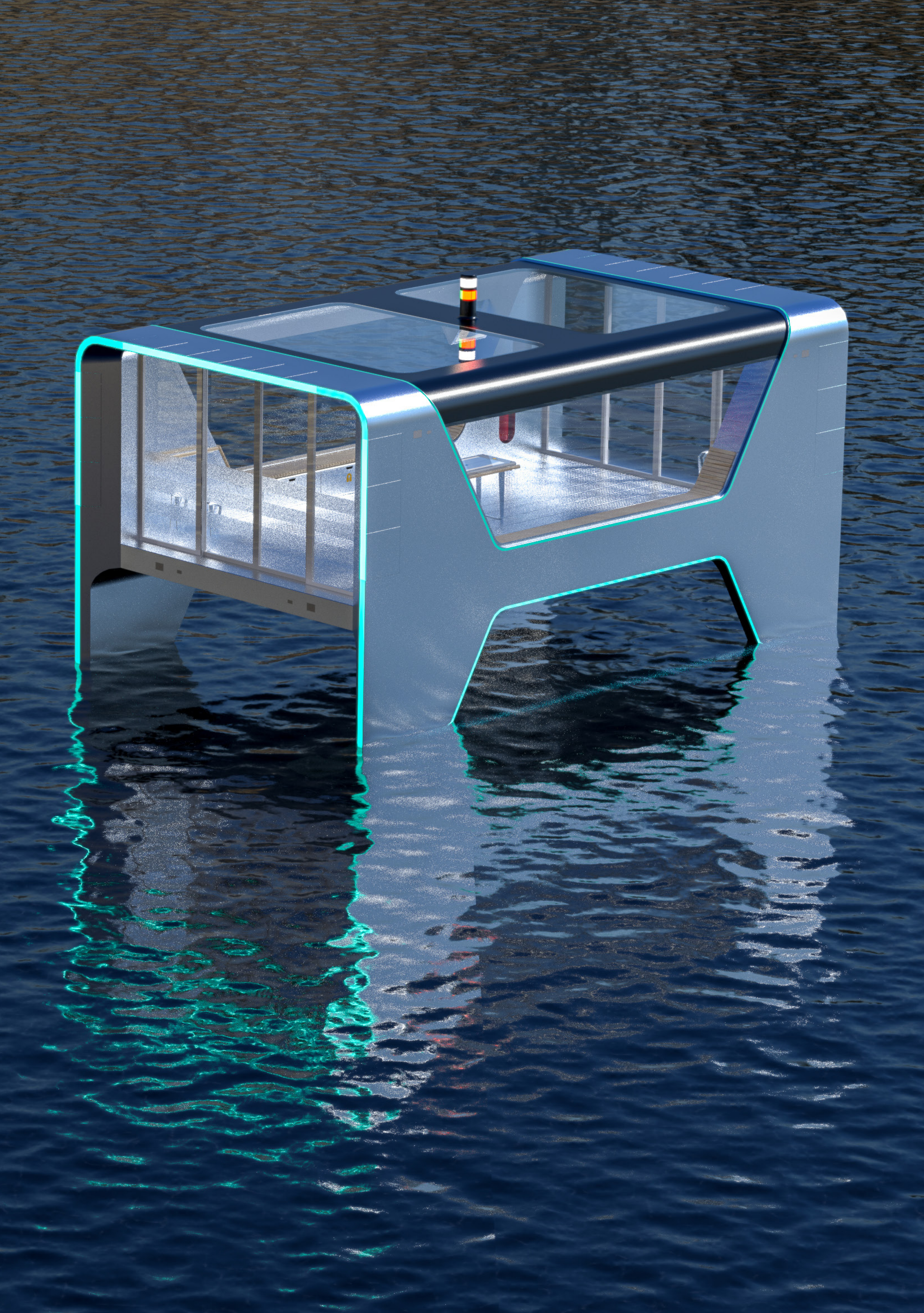






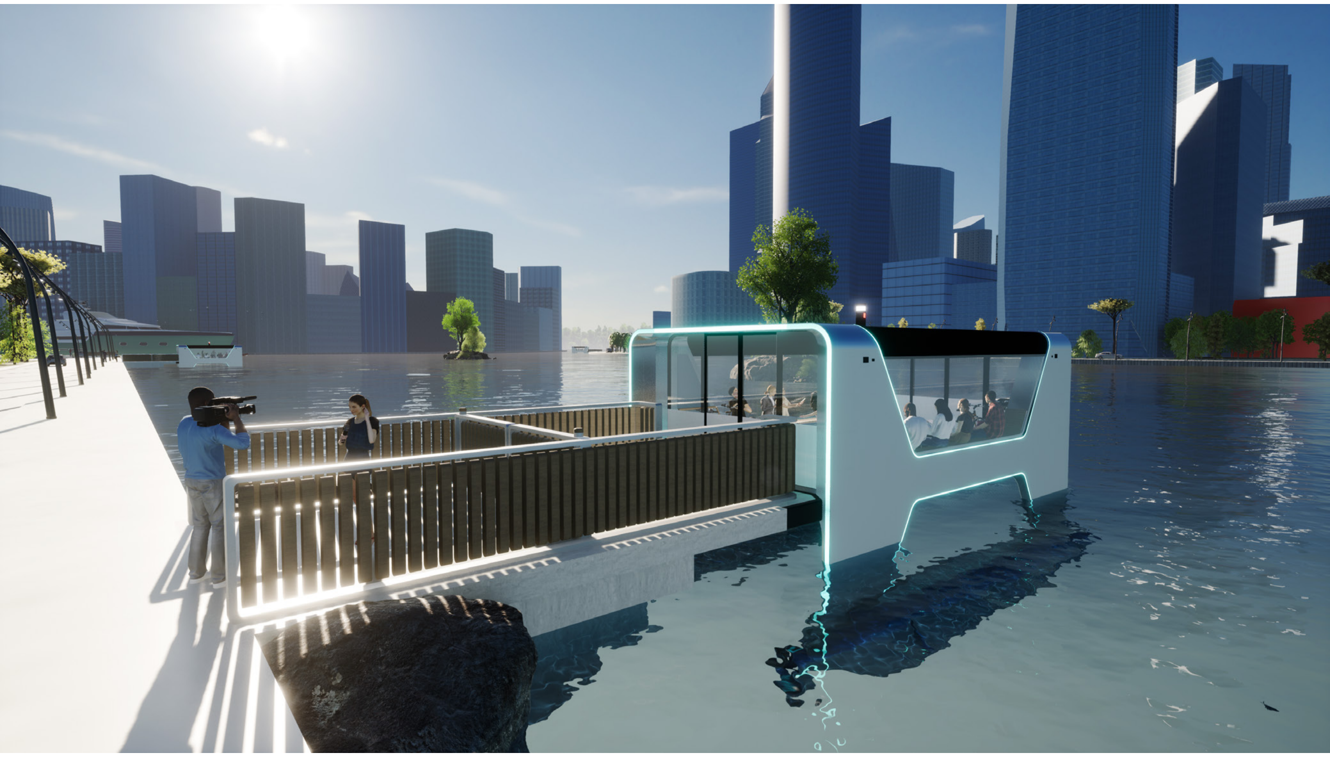






RESULTS
TWINMOTION

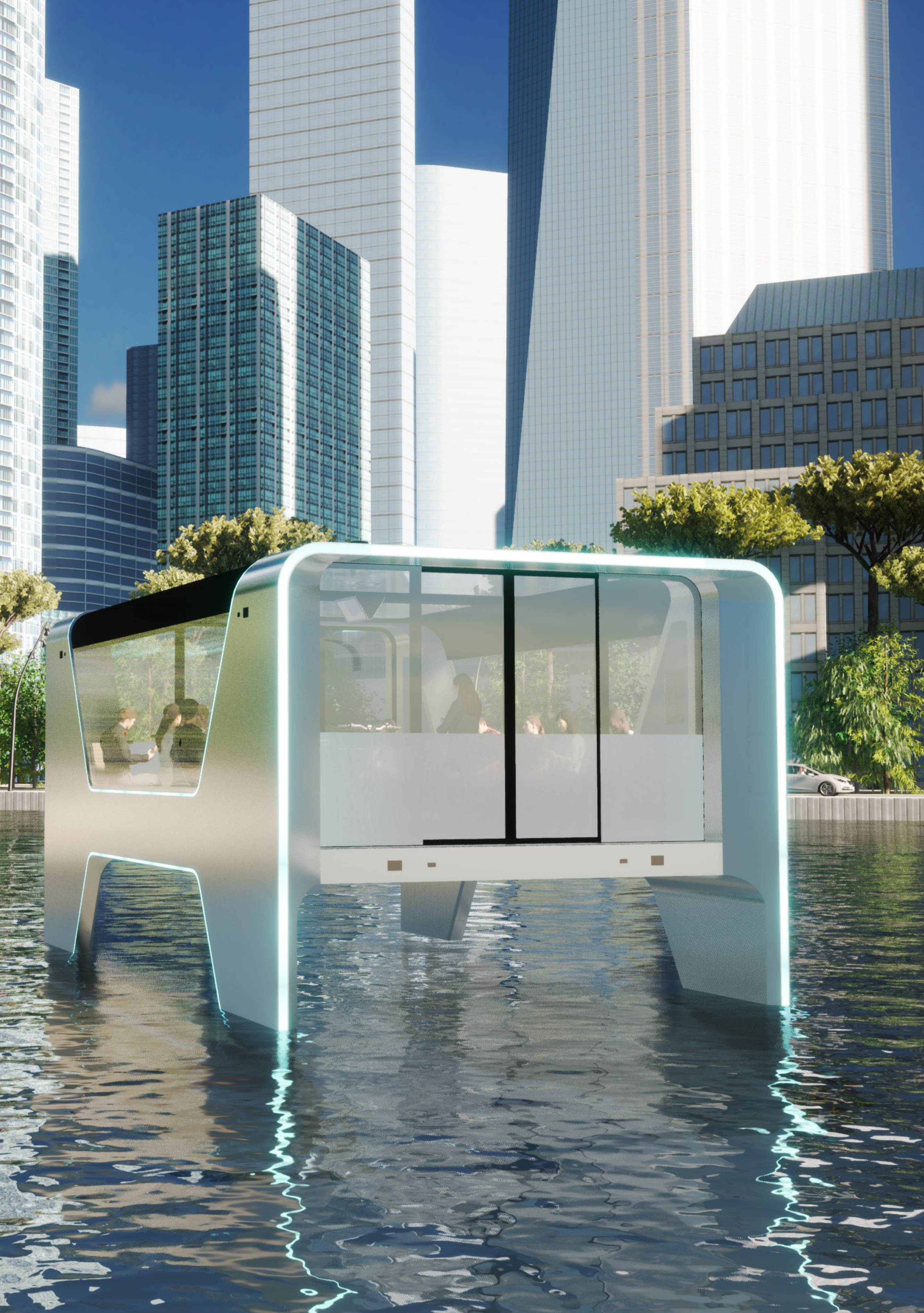
In the Twin Motion scene, a whole city has been built up around the ferry with moving people and cars populating the city. Multiple ferries are on the water, going in routes between different parts of the town. In addition, 12 passengers are placed inside the ferry, showing realistically how crowded a fully loaded ferry would look like. Here, we populated the ferry with people sitting on the benches, people looking at the centre screen, a person sitting in a wheelchair and four bikes, placed in the bike stands.

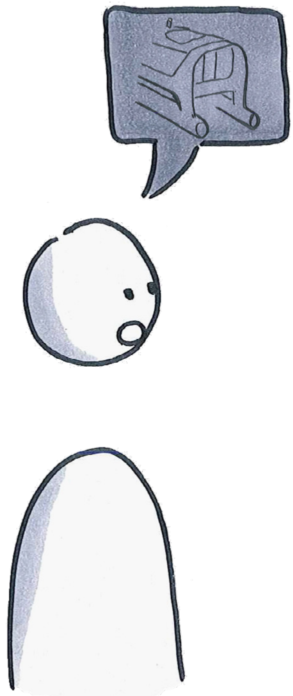


Link to the interactive cloud version of the TwinMotion scene

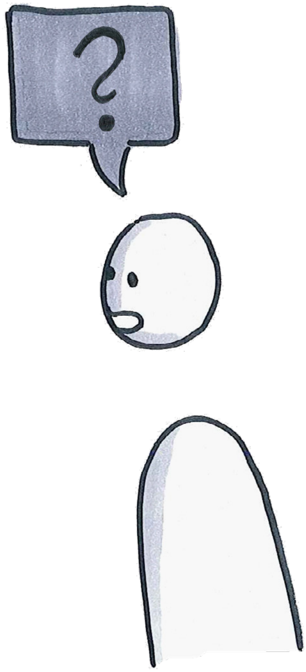
https://twinmotion.unrealengine.com/presentation/n1rGNBGSlREFDzg4

Password: NyrYxyY9





chapter 7



discussion

DISCUSSION

REFLECTING ON THE PROCESS

The process of designing the passenger ferry has gone beyond what we ever could imagine. At the beginning, we knew we wanted to make something that looked characteristic and cool. Despite our lack of knowledge within the field of hydrodynamics, we hoped we would be able to make a ferry that was at least floating. At the end of the project, we have a design that we can confidently say looks cool. Additionally, hydrodynamic experts have assured us that it will float. Where we are at now, we see that we have made a ferry design that challenges the existing traditions within ship design. We have applied design methods that are unknown within the field of naval architecture. Likewise the hull and superstructure are very innovative for a 8 metre long vessel. Furthermore, we have demonstrated how the design may take form without some of today's outdated maritime regulations. In addition, we have experimented with new ways for vessels to communicate with their environment. We have extracted a start-up company's values, knowledge in the field and the needs of the users, and translated them into a scalable ferry design. As a result, the design can be adjusted to be gradually introduced to the public into the new era of autonomous urban mobility.

The task of designing an autonomous ferry was set from the start. Still, we kept telling ourselves "it's not a ferry" throughout the process. This was to avoid to jump on the obvious idea, to focus on the users' needs and to keep our minds open for other solutions that may be better. Despite having this in our mind, we ended up with a ferry design. We think this is a sign that a boat is the best solution when the goal is to transport passengers across a body of water in a flexible way.

Throughout the process, we have discovered the power of switching up the tools you are using as a designer. The type of ideas you generate will differ from the tools you are choosing. In addition, when feeling uninspired, working in a different way may be exactly what you need to get hyped and excited for the project again. That is boosting creativity. For those reasons we have been switching between hand-sketches in 2D and 3D, 3D-modelling, VR-sketching, 3D-printing, building small scaled models, paper mockups and full scale mockups. We believe this has allowed us to stay creative and excited throughout the whole project.

DEALING WITH COMPLEXITY

Without a doubt, this is the most comprehensive design process we have ever encountered. We have main expertise within the field of product design. To solve the task, we had to use additional design tools within all industrial design disciplines - both service design, strategic design and interaction design. After conducting this project, we believe that it is not possible to set clear lines between the disciplines. Instead, we would argue they float together in a multidisciplinary project like this one. On one hand, we had to see the ferry design as a part of a service and as a part of Zeabuz' strategic plans to make a suitable ferry concept. On the other hand, we wanted to design the ferry to a level of detail that makes it realistic. For those reasons, it was hard to clearly set the scope of the project. The further we dived into the project, the more new research areas were discovered. To stay on track, we always went back to the values and the functional analysis that were defined.

DISCUSSION

WORKING IN A TEAM

Another interesting aspect of the project is how we have worked together as a team. The initial plan was to share some of our insights, and work individually on each part of one ferry design. Along the way we figured out that we were a group of designers that complemented each other's competences very well. Consequently, we chose to work closely together for most of the project. However, we believe another reason for our success as a team is how we worked together.

For instance, we started the project by telling each other about ourselves, what our strengths are as designers and discussing what we wanted to learn throughout the project. We set clear lines for meeting times, and how we should act if we would be too late or could not show up to a meeting. In addition, we were honest about the flexibility we needed, and planned for this. On an everyday basis, we started mornings with a check-in, where we updated each other on what had happened in our life since we saw each other the last time. This helped us get to know each other and to have empathy for each other. Every morning we set a list of tasks that we were supposed to get through that day. We set some time to work individually on each task, and some time to discuss the findings together. In addition we had many collaborative ideation sessions with brainstorming and sketching, to build on each other's ideas.

We are very happy with how we chose to do the information sharing and documenting as well. The whole design process was shared in a Miro board, where our supervisors got access as well. All insights, pictures and sketches were imported everyday in a chronological timeline. As a result it was easy to show our work and discuss during supervisions by opening the Miro board. Likewise, it was an effective way to capture all insights we needed for the report writing. We used Microsoft Teams for sharing documents, photos and to make presentations. That worked well for sorting files and to work in smaller files together.

FUTURE WORK

The ferry design in this thesis, can be adjusted to different use cases with small alterations. An operator station may be added to the design in the transition time between the present with regulations and in the future where an operator is no longer considered needed on board. In addition, the presented dock idea needs to be designed in detail. Furthermore, the information visualisation and the user experience on board requires more work.

Operator station

Because it is recommended to gradually introduce a new technology to gain trust, it may be necessary to include an operator station to our design in the transition time. We have sufficient space for an operator station in the thick corner walls. By adding windows, the operator would have the 225 degrees view that is required. Another solution would be to have a glass bridge on the centre roof, with a ladder in the centre of the passenger compartment. Having a moveable operator control panel could be another solution that may be accepted by the class authorities, due to the possibility for the operator to move around in the passenger compartment and similarly have a full overview of the outside surroundings.

Docking

The docking process of the ferry needs further design work. How the ferry charges, how it connects to the dock and how the dock should be designed to detail needs to be solved. The user journey map in this thesis may give inspiration for how to design the dock and belonging elements for keeping a good user experience when docking.

Information visualisation and UX

In the user journey, it was mapped that there is a need for information visualisation to ensure the users feeling of safety when travelling with the ferry. The same information must also be displayed for people with different disabilities. For example, light and sound may be up for experimentation to design for an optimal user experience.

THE FUTURE SERVICE

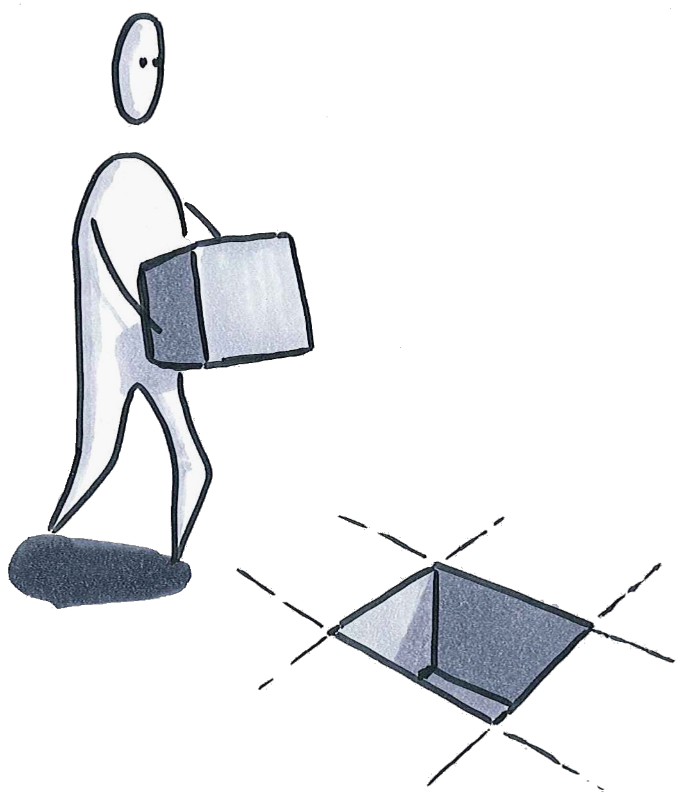
We have made assumptions on how the service should be designed through tools such as service blueprint, user journey map, vision in product design and business canvas model. This has given us an overview of how the service can take form. However, we believe there are many possibilities of how the future service may look like that should be investigated further.

On one hand, more user insights should be collected to better understand their needs of the service. On the other hand, what users think they need and what their impression is after trying the service may differ. In fact, this was the case for the research in the TRUSST-project. People's perception of the service changed after trying the MilliAMpere 2 in real life. We believe it will be important to include the users through well-designed user tests for gathering solid insights and to increase acceptance within the user group. Another challenge of the service design is the many maritime regulations that set limitations on what is possible to achieve. We think designers can serve an important role in making visualisation for convincing all parties. Furthermore, designers can facilitate co-designing activities for all stakeholders, to make an arena for discussions of the possibilities and the obstacles with introducing the new service. Indeed, it will increase their understanding of each other and possibly speed up the process of updating the maritime regulations.

DISCUSSION

WHAT IS THE FUTURE?

We have designed a ferry for 5-10 years from now based on today's technology and trends. In our expert interviews we figured out that today's sensor packages, computers and batteries may take up a whole lot less space. For instance, computers may not even be necessary to have on board the ferry with the evolution of information sharing and storing. This may lead to more light-weight and thus more sustainable ferries. Because we can only predict the future outcome, it was vital for us to make the design scalable to make it work for different future scenarios. The use of AI is increasing as well. This will open up new possibilities. For example, the ferry may be able to scan the shore for possible docking spots and adjust its height automatically. Car manufacturers such as Tesla rely more on cameras and less on sensors. For what we know, sensors may be removed from the future ferry.

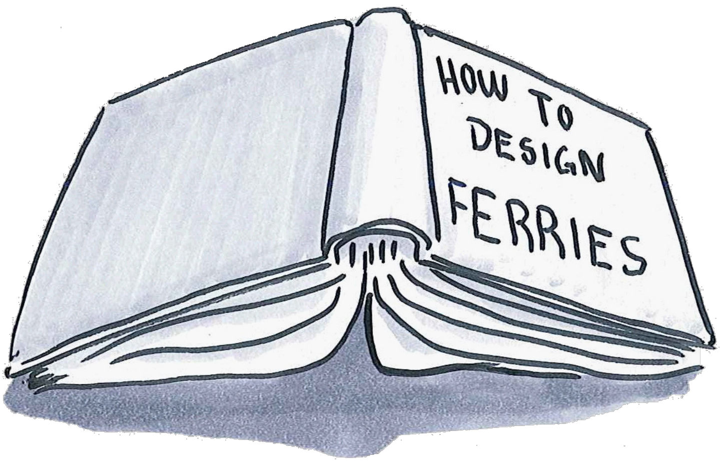


chapter 8

conclusion

An autonomous ferry for 12 passengers has been designed for the company Zeabuz. Through a creative process with a variety of design tools and methods, we have ended up with a scalable ferry design that is in line with the company's values and the discovered users' needs. In addition, we have designed a belonging modular furniture system and we have explored how the ferry may communicate with its surroundings. Within the field of naval architecture, we have demonstrated new approaches for designing a vessel. We cannot know for sure what the future will look like, but with a scalable design it is possible to keep the main characteristics and functions of the design with small adjustments. The further design work should consist of involvement of users to ensure their needs are covered. In addition, all stakeholders should come together to solve the obstacles that hinders the development of future waterborne mobility.

chapter 9



references

(NAD), N. A. o. D. (2009). Universell utforming på ferjer.

Agnihotri, A., Chan, A., Hedaoo, S., & Knight, H. (2020). Distinguishing Robot Personality from Motion Companion of the 2020 ACM/IEEE International Conference on Human-Robot Interaction, Cambridge, United Kingdom. https://doi.org/10.1145/3371382.3378389

Ahola, M., Murto, P., & Mallam, S. (2018). When people are the mission of a ship—design and user research in the marine industry. In Marine Design XIII (pp. 285-290). CRC Press.

Andressen, M. S. (2021). Passasjerers tillit til autonom ferje.

AS, B. A. (2022). Brødrene Aa.

AS, H. S. C. F. (2022). The Future of Urban Mobility. https://hydroliftsmartcityferries.com/

Bazilinskyy, P., Dodou, D., & de Winter, J. (2019). Survey on eHMI concepts: The effect of text, color, and perspective. Transportation Research Part F: Traffic Psychology and Behaviour, 67, 175-194. https://doi.org/https://doi.org/10.1016/j.trf.2019.10.013

Beck, A., & Cruxen, I. A. (2019). New uses for old rivers: Rediscovering urban waterways.

CAPTN. (2022). Vaiaro. https://captn.sh/en/vaiaro-englisch/

Carmona, J., Guindel, C., Garcia, F., & de la Escalera, A. (2021). eHMI: Review and Guidelines for Deployment on Autonomous Vehicles. Sensors, 21(9), 2912. https://www.mdpi.com/1424-8220/21/9/2912

Carmona, J., Guindel, C., Garcia, F., & de la Escalera, A. (2021). eHMI: Review and Guidelines for Deployment on Autonomous Vehicles. Sensors, 21(9), 2912. https://www.mdpi.com/1424-8220/21/9/2912

Cheemakurthy, H., Tanko, M., & Garme, K. (2018). Urban waterborne public transport systems: An overview of existing operations in world cities. https://doi.org/10.13140/RG.2.2.32606.69446

Chef, T. S. (2022). What Size Letter are Ideal for Your New Signage? Retrieved 1 June 2022 from https://www.thesignchef.com/letter-sizing-calculator

Deb, S., Strawderman, L. J., & Carruth, D. W. (2018). Investigating pedestrian suggestions for external features on fully autonomous vehicles: A virtual reality experiment. Transportation Research Part F: Traffic Psychology and Behaviour, 59, 135-149. https://doi.org/https://doi.org/10.1016/j.trf.2018.08.016

Dey, D., Habibovic, A., Pfleging, B., Martens, M., & Terken, J. (2020). Color and Animation Preferences for a Light Band eHMI in Interactions Between Automated Vehicles and Pedestrians. In Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems (pp. 1–13). Association for Computing Machinery. https://doi.org/10.1145/3313831.3376325

Dey, D., Matviienko, A., Berger, M., Pfleging, B., Martens, M., & Terken, J. (2021). Communicating the intention of an automated vehicle to pedestrians: The contributions of eHMI and vehicle behavior. it - Information

Technology, 63(2), 123-141. https://doi.org/doi:10.1515/itit-2020-0025
Dictionary, C. (2022). Ambiguity. Retrieved 1 June 2022 from https://dictionary.cambridge.org/dictionary/english/ambiguity
DOGA. (2022). Vision of The Fjords. https://doga.no/en/tools/inclusive-design/cases/vision-of-the-fjords/
Eide, E. (2022). Experiences from the MilliAmpere 2 project. In.
Equality, T. N. M. o. C. a. (2009). Norway universally designed by 2025.
Evegren, F., & Rahm, M. (2015). Preliminary analysis report – Eco-Island ferry. In.
Faas, S. M., Mathis, L.-A., & Baumann, M. (2020). External HMI for self-driving vehicles: Which information shall be displayed? Transportation Research Part F: Traffic Psychology and Behaviour, 68, 171-186. https://doi.org/https://doi.org/10.1016/j.trf.2019.12.009
Favi, C., Germani, M., Campi, F., Mandolini, M., Manieri, S., Marconi, M., & Vita, A. (2018). Life Cycle Model and Metrics in Shipbuilding: How to Use them in the Preliminary Design Phases. Procedia CIRP, 69, 523-528. https://doi.org/10.1016/j.procir.2017.11.071
Ferraris, S., & Volpone, L. (2005). Aluminium alloys in third millennium shipbuilding: materials, technologies, perspectives. The Fifth International Forum on Aluminium Ships, Tokyo, Japan,
Fet, A. M. (1998). ISO 14000 as a strategic tool for shipping and shipbuilding. Journal of ship production, 14(3), 155-163.
Fiskerstrand, T. (2022). Visit at Maritime Partner AS. In.
Følstad, A., & Kvale, K. (2018). Customer journeys: a systematic literature review. Journal of Service Theory and Practice.
Forskrift om fartøy under 24 m som fører 12 eller færre passasjerer, (2020). https://lovdata.no/forskrift/2020-01-14-63
Forskrift om tryggleik i passasjerområde, (2022). https://lovdata.no/forskrift/2021-12-17-3666
Glesaaen, P. K., & Ellingsen, H. M. (2020). Design av brukerreise og brygger til autonom passasjerferge NTNU].
Goerlandt, F., & Pulsifer, K. (2022). An exploratory investigation of public perceptions towards autonomous urban ferries. Safety Science, 145, 105496. https://doi.org/https://doi.org/10.1016/j.ssci.2021.105496
Goerlandt, F., & Pulsifer, K. (2022). An exploratory investigation of public perceptions towards autonomous urban ferries. Safety Science, 145, 105496. https://doi.org/https://doi.org/10.1016/j.ssci.2021.105496
gylkeskommune, T. (2019, 18 June 2019). Først i verden med høyspent ferjelading. Retrieved 1 June 2022 from https://www.trondelagfylke.no/nyhetsarkiv/forst-i-verden-med-hoyspent-ferjelading/
Habibovic, A., Lundgren, V. M., Andersson, J., Klingegård, M., Lagström, T., Sirkka, A., Fagerlönn, J., Edgren, C., Fredriksson, R., Krupenia, S., Saluäär, D., & Larsson, P. (2018). Communicating intent of automated vehicles to pedestrians. Front Psychol, 9, 1336-1336. https://doi.org/10.3389/fpsyg.2018.01336
Håkonsen, E., & Jensen, A. D. (2021). Design

for trust NTNU].
Henrik Midtvåge Ellingsen, P. K. G. (2020). Design av brukerreise og brygger til autonom passasjerferge https://ntnuopen.ntnu.no/ntnu-xmlui/handle/11250/2776801
Hoback, A. (2018). Pareidolia and Perception of Anger in Vehicle Styles: Survey Results.
Intel. (2016). A Matter Of Trust: How Smart Design Can Accelerate Automated Vehicle Adoption. https://www.intel.com/content/dam/www/public/us/en/documents/white-papers/trust-autonomous-white-paper-secure.pdf
International Maritime, O. (2003). COLREG : Convention on the International Regulations for Preventing Collisions at Sea, 1972. International Maritime Organization.
Källmar, K., Karlsson Sundqvist, T., & Sundin, E. (2013). Integration of Environmental Aspects in Product Development and Ship Design. In Re-engineering Manufacturing for Sustainability (pp. 41-46). Springer.
Kongsberg. (2022). Autonomy is Here - Powered by Kongsberg. https://www.kongsberg.com/no/maritime/about-us/news-and-media/our-stories/autonomy-is-here--powered-by-kongsberg/
Lee, Y. M., Madigan, R., Garcia, J., Tomlinson, A., Solernou, A., Romano, R., Markkula, G., Merat, N., & Uttley, J. (2019). Understanding the Messages Conveyed by Automated Vehicles Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications, Utrecht, Netherlands. https://doi.org/10.1145/3342197.3344546
Lin, A. Y., Kuehl, K., Schöning, J., & Hecht, B. (2017). Understanding "Death by GPS": A Systematic Study of Catastrophic Incidents Associated with Personal Navigation Technologies Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems, Denver, Colorado, USA. https://doi.org/10.1145/3025453.3025737
Löcken, A., Golling, C., & Riener, A. (2019). How Should Automated Vehicles Interact with Pedestrians? A Comparative Analysis of Interaction Concepts in Virtual Reality Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications, Utrecht, Netherlands. https://doi.org/10.1145/3342197.3344544
Mallam, S. C., Lundh, M., & MacKinnon, S. N. (2017). Integrating Participatory Practices in Ship Design and Construction. Ergonomics in design, 25(2), 4-11. https://doi.org/10.1177/1064804616684406
Mallam, S. C., Lundh, M., & MacKinnon, S. N. (2017). Integrating Participatory Practices in Ship Design and Construction. Ergonomics in design, 25(2), 4-11. https://doi.org/10.1177/1064804616684406
Mercedes-Benz. (2022). The VISION AVTR. Retrieved 1 June 2022 from https://www.mercedes-benz.com/en/vehicles/passenger-cars/mercedes-benz-concept-cars/vision-avtr/
Merriam-Webster. (n.d.). Pareidolia. In

Merriam-Webster.com dictionary. Retrieved June 1, from https://www.merriam-webster.com/dictionary/pareidolia.
Moore, D., Currano, R., Strack, G. E., & Sirkin, D. (2019). The Case for Implicit External Human-Machine Interfaces for Autonomous Vehicles Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications, Utrecht, Netherlands. https://doi.org/10.1145/3342197.3345320
Moore, D., Currano, R., Strack, G. E., & Sirkin, D. (2019). The Case for Implicit External Human-Machine Interfaces for Autonomous Vehicles Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications, Utrecht, Netherlands. https://doi.org/10.1145/3342197.3345320
Mustvedt, P. (2019). Autonom ferge designet for å frakte 12 passasjerer trygt over Nidelven https://ntnuopen.ntnu.no/ntnu-xmlui/handle/11250/2620987
Neufert, E., & Neufert, P. (2012). Architects' data. John Wiley & Sons.
Nordisk båtstandard for yrkesbåter under 15 meter,, (1990). https://www.sdir.no/veiledninger/nordisk-batstandard/
Norge, S. (2011). Universal design of developed outdoor areas - Requirements and recommendations (NS 11005:2011). In.
Ocejo, R. E., & Tonnelat, S. (2014). Subway diaries: How people experience and practice riding the train. Ethnography, 15(4), 493-515. https://doi.org/10.1177/1466138113491171
Österman, C., Berlin, C., & Bligård, L.-O. (2016). Involving users in a ship bridge re-design process using scenarios and mock-up models. International journal of industrial ergonomics, 53, 236-244. https://doi.org/10.1016/j.ergon.2016.02.008
Österman, C., Berlin, C., & Bligård, L.-O. (2016). Involving users in a ship bridge re-design process using scenarios and mock-up models. International journal of industrial ergonomics, 53, 236-244. https://doi.org/10.1016/j.ergon.2016.02.008
Oudshoorn, M., de Winter, J., Bazilinskyy, P., & Dodou, D. (2021). Bio-inspired intent communication for automated vehicles. Transportation research. Part F, Traffic psychology and behaviour, 80, 127-140. https://doi.org/10.1016/j.trf.2021.03.021
Pantelatos, L. (2022). Safety Information on MilliAmpere 2. In.
Pariafsai, F. (2016). A review of design considerations in glass buildings. Frontiers of Architectural Research, 5(2), 171-193. https://doi.org/https://doi.org/10.1016/j.foar.2016.01.006
Porathe, T. (2021). Human-Automation Interaction for a small Autonomous Urban Ferry: a concept sketch.
Preece, J., Sharp, H., & Rogers, Y. (2015). Interaction design : beyond human-computer interaction (4th ed.). Wiley.
Reddy, N. P., Zadeh, M. K., Thieme, C. A., Skjetne, R., Sorensen, A. J., Aanondsen, S. A., Breivik, M., & Eide, E. (2019). Zero-Emission Autonomous Ferries for Urban Water Transport: Cheaper, Cleaner

Alternative to Bridges and Manned Vessels. IEEE Electrification Magazine, 7(4), 32-45. https://doi.org/10.1109/MELE.2019.2943954
Roboat. (2022). Roboat. https://roboat.org/
Rouchitsas, A., & Alm, H. (2019). External Human–Machine Interfaces for Autonomous Vehicle-to-Pedestrian Communication: A Review of Empirical Work. Front Psychol, 10, 2757-2757. https://doi.org/10.3389/fpsyg.2019.02757
Rover, J. L. (2018, 28 August 2018). JAGUAR LAND ROVER'S VIRTUAL EYES LOOK AT TRUST IN SELF-DRIVING CARS. Retrieved 1 June 2022 from https://media.jaguarlandrover.com/news/2018/08/jaguar-land-rovers-virtual-eyes-look-trust-self-driving-cars
Ryan, M. (2020). The Future of Transportation: Ethical, Legal, Social and Economic Impacts of Self-driving Vehicles in the Year 2025. Science and Engineering Ethics, 26(3), 1185-1208. https://doi.org/10.1007/s11948-019-00130-2
Schank, J. F., Savitz, S. A., Munson, K. J., Perkinson, B., McGee, J., & Sollinger, J. M. (2016). Designing Adaptable Ships: Modularity and Flexibility in Future Ship Designs.
Schmidt, J. H., & Watson, J. (2014). Eco Island Ferry: Comparative LCA of island ferry with carbon fibre composite based and steel based structures.
Selvikvåg, J. (2021). D6 - Autoship. https://www.notion.so/D6-Autoship-0ff7a74490e74c33a751025d6547fd7c
Simmel, G. (1903). The metropolis and mental life. 47 p. Stimuli.
Forskrift om forebygging av sammenstøt på sjøen, (1977). https://lovdata.no/forskrift/1975-12-01-5
Lov om fritids- og småbåter, (1999). https://lovdata.no/dokument/NL/lov/1998-06-26-47
Smogeli, Ø. (2022). Client meetings. In.
Standardization, I. O. f. (2006). Environmental management — Life cycle assessment — Principles and framework. In.
Stensvold, T. (2015). Fjordbanen: – Båtene bør bygges i karbon, ikke aluminium. Teknisk Ukeblad.
Tabone, W., de Winter, J., Ackermann, C., Bärgman, J., Baumann, M., Deb, S., Emmenegger, C., Habibovic, A., Hagenzieker, M., Hancock, P. A., Happee, R., Krems, J., Lee, J. D., Martens, M., Merat, N., Norman, D., Sheridan, T. B., & Stanton, N. A. (2021). Vulnerable road users and the coming wave of automated vehicles: Expert perspectives. Transportation Research Interdisciplinary Perspectives, 9, 100293. https://doi.org/https://doi.org/10.1016/j.trip.2020.100293
Tanko, M., & Burke, M. I. (2017). Transport innovations and their effect on cities: the emergence of urban linear ferries worldwide. Transportation Research Procedia, 25, 3957-3970. https://doi.org/https://doi.org/10.1016/j.trpro.2017.05.483
Tanko, M., & Burke, M. I. (2017). Transport innovations and their effect on cities: the emergence of urban linear ferries worldwide. Transportation Research Procedia, 25, 3957-3970. https://doi.org/https://doi.org/10.1016/j.

trpro.2017.05.483
Tanko, M., Cheemakurthy, H., Hall Kihl, S., & Garme, K. (2019). Water transit passenger perceptions and planning factors: A Swedish perspective. Travel Behaviour and Society, 16, 23-30. https://doi.org/https://doi.org/10.1016/j.tbs.2019.02.002
Tannum, M. S., & Ulvensøen, J. H. (2019). Urban mobility at sea and on waterways in Norway. Journal of Physics: Conference Series,
Thompson, R., Burroughs, R., & Smythe, T. (2006). Exploring the connections between ferries and urban form: Some considerations before jumping on board. Journal of Urban Technology, 13, 25-52. https://doi.org/10.1080/10630730600872021
Thompson, R., Burroughs, R., & Smythe, T. (2006). Exploring the connections between ferries and urban form: Some considerations before jumping on board. Journal of Urban Technology, 13(2), 25-52. https://doi.org/10.1080/10630730600872021
utforming, U. (2020). Universal design in maritime passenger transport – passenger ships, ferries and speedboats. In.
utforming, U. (2022). Universal design in maritime passenger transport – passenger ships, ferries and speedboats. https://maritim.universellutforming.org/
Veitch, E., & Alsos, O. (2021). Human-Centered Explainable Artificial Intelligence for Marine Autonomous Surface Vehicles. Journal of Marine Science and Engineering, 9, 1227. https://doi.org/10.3390/jmse9111227
Wang, P., Motamedi, S., Qi, S., Zhou, X., Zhang, T., & Chan, C.-Y. (2021). Pedestrian interaction with automated vehicles at uncontrolled intersections. Transportation Research Part F: Traffic Psychology and Behaviour, 77, 10-25. https://doi.org/https://doi.org/10.1016/j.trf.2020.12.005
Weast, J., Yurdana, M., & Jordan, A. (2016). A matter of trust: How smart design can accelerate automated vehicle adoption.
Web, T. N. (2011, 2 March 2011). What's the most readable font for the screen? https://thenextweb.com/news/whats-the-most-readable-font-for-the-screen
Yavuz, A. (2010). An experimental study on vandalism: Trabzon Parks. Scientific Research and Essays, 5(17), 2463-2471.
Zhang, J., Chevali, V. S., Wang, H., & Wang, C.-H. (2020). Current status of carbon fibre and carbon fibre composites recycling. Composites. Part B, Engineering, 193, 108053. https://doi.org/10.1016/j.compositesb.2020.108053

appendix

SURVEY 1 - COMMUNICATION WITH THE ENVIRONMENT

20 responses

Accepting responses

Summary | Question | Individual

Do you have a design education background?

20 responses

Untitled Section

Do you have any type of visual disability? (Colourblindness, blindness, low vision, partially sighted...etc.)

20 responses

If you answered Yes in the previous question, which visual disability do you have?

0 responses

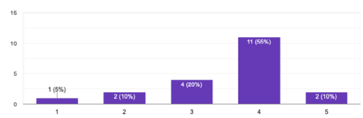
No responses yet for this question.

Question time!

Question 1.

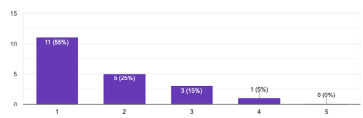
The boat is signaling that it is speeding up.

20 responses



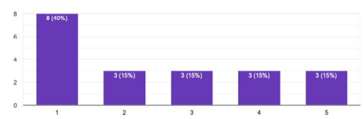
The boat is signaling that it is slowing down.

20 responses



The boat is signaling that it is turning towards you.

20 responses



If you think none of the statements above fit the picture, please write a short answer of what YOU understand the boat is signaling.

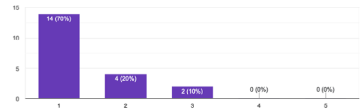
0 responses

No responses yet for this question.

Question 2.

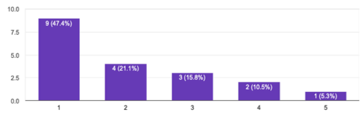
The boat is signaling that it is turning left.

20 responses



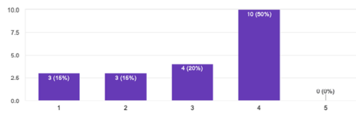
The boat is signaling that it is moving forward.

19 responses



The boat is signalling that it has seen you in the water.

20 responses



If you think none of the statements above fit the picture, please write a short answer of what YOU understand the boat is signaling.

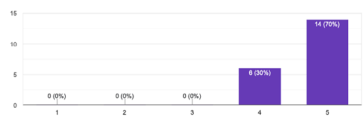
5 responses

- Just that is there, even though that's not the correct lights according to Norwegian law
- Looks like another variant of the red/green/White type lanterns that are used in boat navigation
- Emergency lights, full stop
- The boat is docked
- Unsure about the meaning of blinking lights...

Question 3

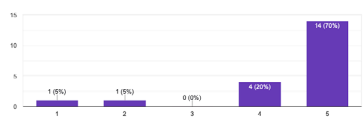
The boat is signaling that it is not waiting for you to pass.

20 responses



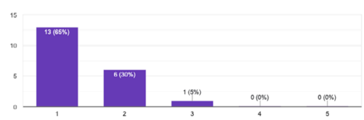
The boat is signaling that you should stop.

20 responses



The boat is unaware of you as a kayaker.

20 responses



If you think none of the statements above fit the picture, please write a short answer of what YOU understand the boat is signaling.

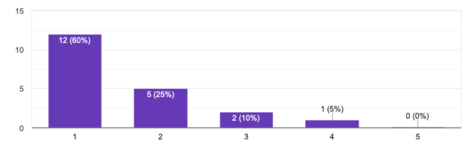
0 responses

No responses yet for this question.

Question 4

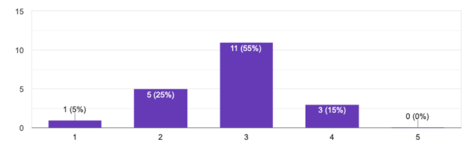
The boat is signaling that it is turning towards you.

20 responses



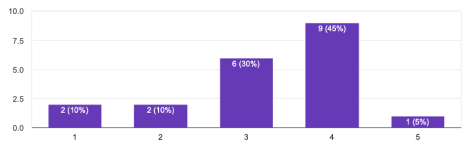
The boat is signaling that it is waiting for you to move first.

20 responses



The boat is signaling that it is slowing down.

20 responses



If you think none of the statements above fit the picture, please write a short answer of what YOU understand the boat is signaling.

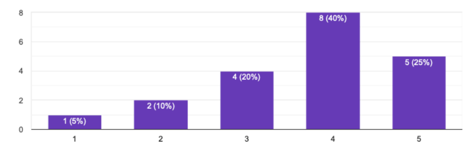
1 response

Unclear what the light is meaning

Question 5

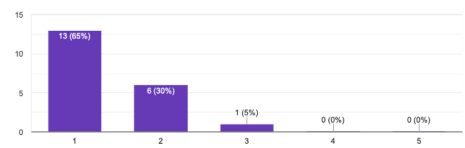
The boat is signaling that it is turning towards you

20 responses



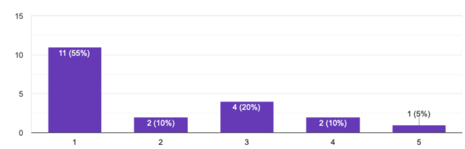
The boat is signaling that it is moving away from you.

20 responses



The boat is signaling that it is letting you pass first.

20 responses



If you think none of the statements above fit the picture, please write a short answer of what YOU understand the boat is signaling.

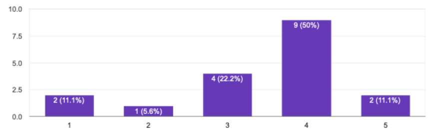
1 response

Maybe...

Question 6

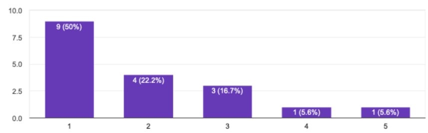
The boat is signaling that it is turning towards you.

18 responses



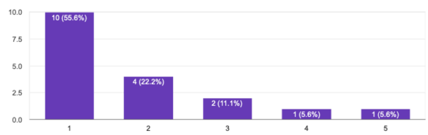
The boat is signaling that you should stop.

18 responses



The boat is signaling you to pass first.

18 responses



If you think none of the statements above fit the picture, please write a short answer of what YOU understand the boat is signaling.

2 responses

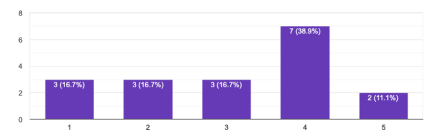
I do not know. As the kayaker, I would stop as I do not understand it.

Doesn't look like a signal at all. It looks like a part of the machinery, like a fan or something.

Question 7

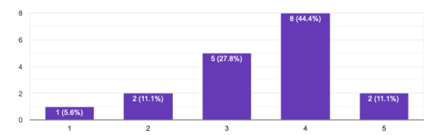
The boat is signaling that it is slowing down.

18 responses



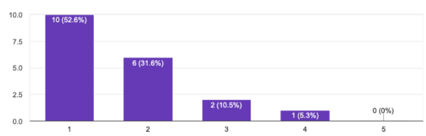
The boat is signalling that it has seen you in the water.

18 responses



The boat is signaling that it is speeding up.

19 responses



If you think none of the statements above fit the picture, please write a short answer of what YOU understand the boat is signaling.

3 responses

It seems like it is slowing stopping. Reminds me of aiplane flaps when landing.

Doesn't look like a signal at all.

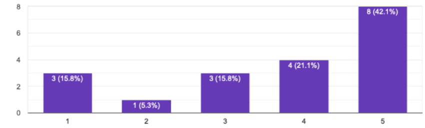
The boat is dancing

Question 8

The boat is signaling that it is letting you pass first.

Copy

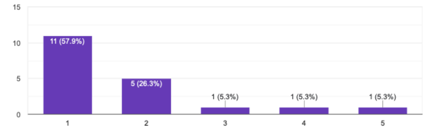
19 responses



The boat is signaling you to stop.

Copy

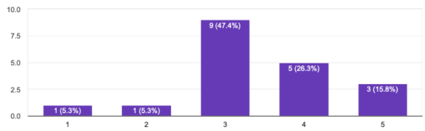
19 responses



The boat is greeting you.

Copy

19 responses



If you think none of the statements above fit the picture, please write a short answer of what YOU understand the boat is signaling.

2 responses

Seems like a way to point where it will go.

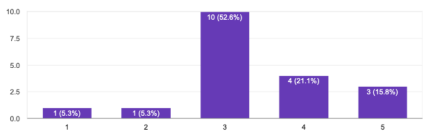
Doesn't look like a signal at all.

Question 9

The boat is signalling that it has seen you in the water.

Copy

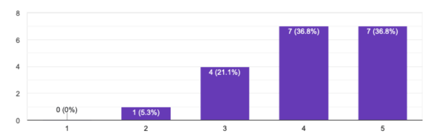
19 responses



The boat appears to be attracting attention.

Copy

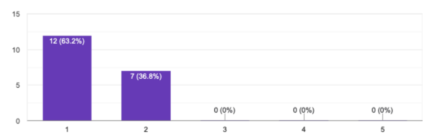
19 responses



The boat seems to not have seen you.

Copy

19 responses



If you think none of the statements above fit the picture, please write a short answer of what YOU understand the boat is signaling.

2 responses

Doesn't look like a signal at all.

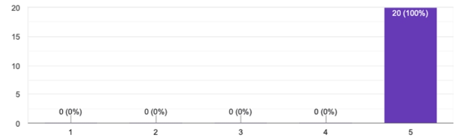
Can be confusing, not unlike question 8?

Question 10

The boat is letting you pass first.

Copy

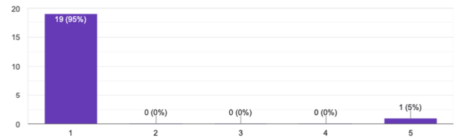
20 responses



The boat is signaling that it wants to pass first.

Copy

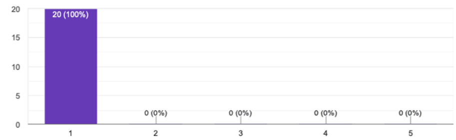
20 responses



The boat is signaling for you to stop.

Copy

20 responses



If you think none of the statements above fit the picture, please write a short answer of what YOU understand the boat is signaling.

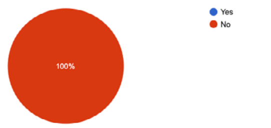
0 responses

No responses yet for this question.

SURVEY 2 - COMMUNICATION WITH THE ENVIRONMENT

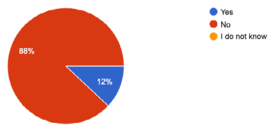
Do you have a design education background?

25 responses



Do you have any type of visual disability? (Colourblindness, blindness, low vision, partially sighted...etc.)

25 responses



If you answered Yes in the previous question, which visual disability do you have?

3 responses

Mild astigmatism

Partially sighted

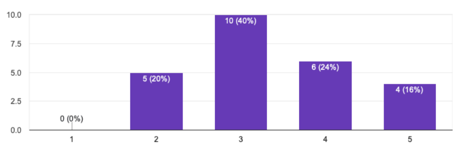
Low vision

Question time!

1

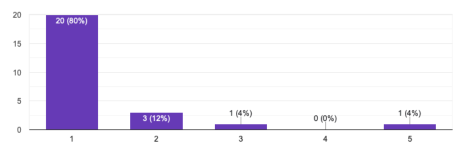
Statement: The boat is signaling that it is turning towards you.

25 responses



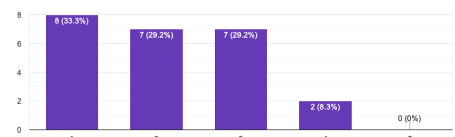
Statement: The boat is signaling that it is turning towards you.

25 responses



Statement: The boat is signaling that it is turning towards you.

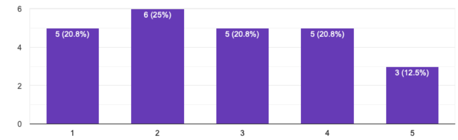
24 responses



2

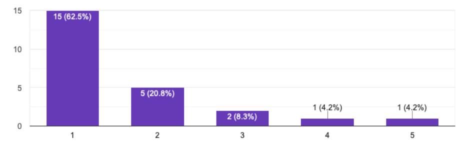
Statement: The boat is signaling that it is speeding up.

24 responses



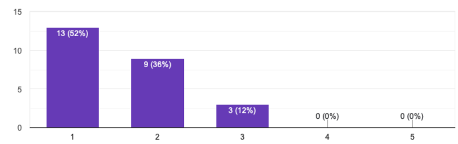
Statement: The boat is signaling that it is speeding up.

24 responses



Statement: The boat is signaling that it is speeding up.

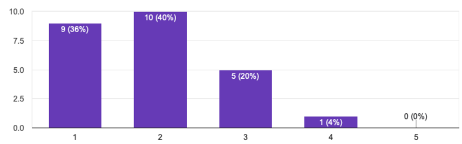
25 responses



3

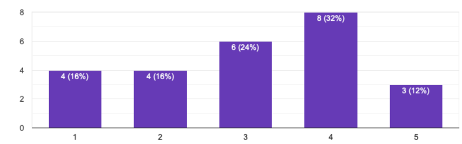
Statement: The boat is signaling that it is slowing down.

25 responses



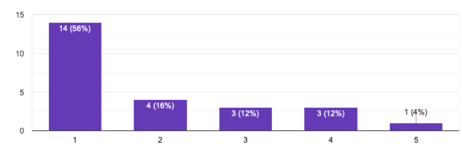
Statement: The boat is signaling that it is slowing down.

25 responses



Statement: The boat is signaling that it is slowing down.

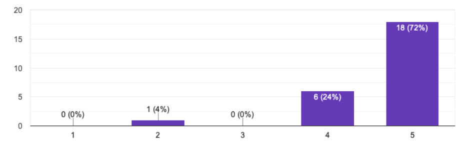
25 responses



4

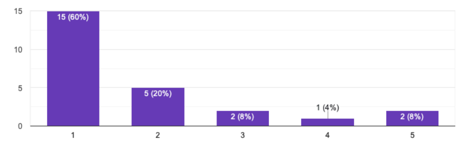
Statement: The boat is signaling that it waiting for you to move across.

25 responses



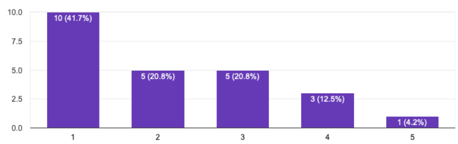
Statement: The boat is signaling that it waiting for you to move across.

25 responses



Statement: The boat is signaling that it waiting for you to move across.

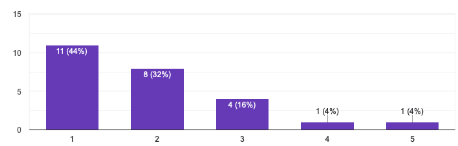
24 responses



5

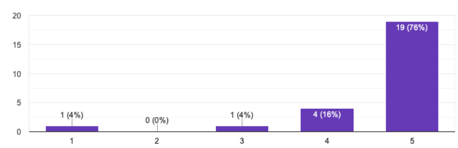
Statement: The boat seems to NOT give you the right of way.

25 responses



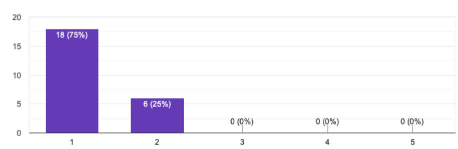
Statement: The boat seems to NOT give you the right of way.

25 responses



Statement: The boat seems to NOT give you the right of way.

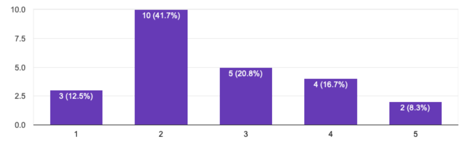
24 responses



6

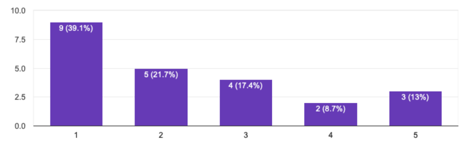
Statement:The boat is signaling that it has noticed you.

24 responses



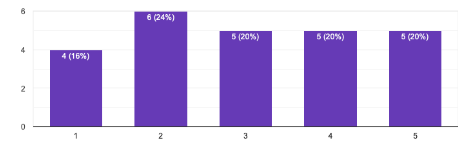
Statement:The boat is signaling that it has noticed you.

23 responses



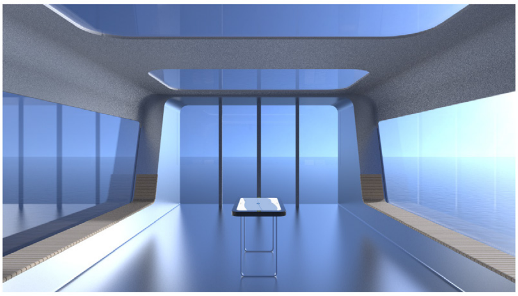
Statement:The boat is signaling that it has noticed you.

25 responses



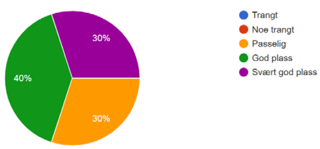
SURVEY 1 - PASSENGER JOURNEY

Oppsett 1



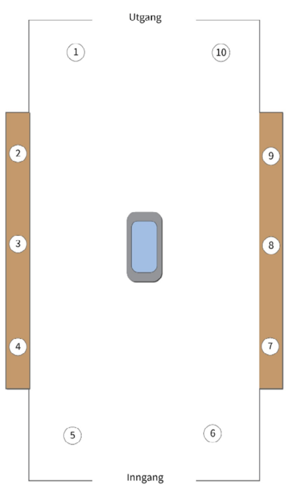
Hvordan opplevde du plassen ved inngangspartiet til fergen? Copy

10 responses



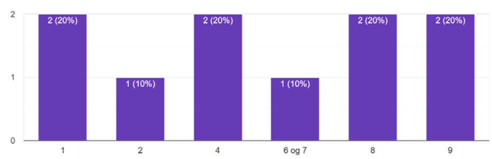
Hvor valgte du å oppholde deg på fergeturen? *

(Skriv det nummeret som er nærmest der du oppholdt deg. NB! Legg merke til hvor inngang/utgang er på tegningen)



Hvor valgte du å oppholde deg på fergeturen? Copy

10 responses



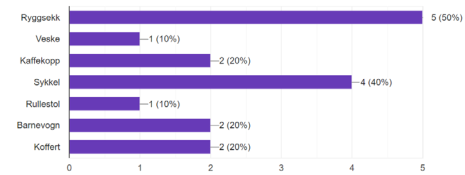
Hvorfor valgte du å oppholde deg der?

10 responses

- For å få sitteplass og god utsikt
- Mulighet til å sitte
- Grei sitteplass, satte meg ved siden av en jeg kjente
- Der det var ledig plass
- Hadde med sykkel som ble plassert på 6,satt selv på 7. Best i forhold til å ha sykkelen ute av veien
- Nærmest utgang med sykkel
- Ledig plass, vi kom sent inn på fergen og der var det ledig til hele familien
- Best plass der når vi gikk inn, og ikke for tett opptil andre passasjerer. Ville sitte ved vindu.
- Godt å lene ryggen mot kanten /vinduskarmen, og fint å sitte ved vindu
- For å se framover/komme meg tidlig av ved ankomst. Føles naturlig å gå fram i båten

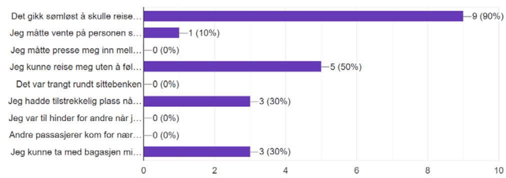
Hva hadde du med deg på fergen? Copy

10 responses



Hvordan opplevde du å gå av fergen? Copy

10 responses

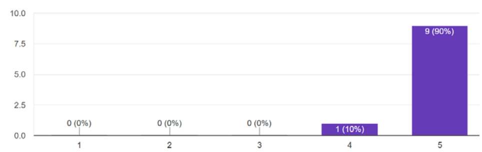


Hvor god plass hadde du der du oppholdt deg? *

1 2 3 4 5

Trangt ○ ○ ○ ○ ○ God plass

10 responses

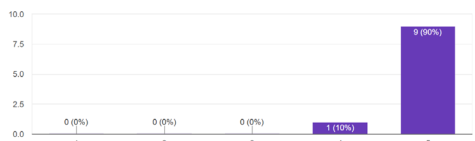


Hvor god oversikt hadde du over det som skjedde i fergen? *

1 2 3 4 5

Dårlig oversikt ○ ○ ○ ○ ○ God oversikt

10 responses



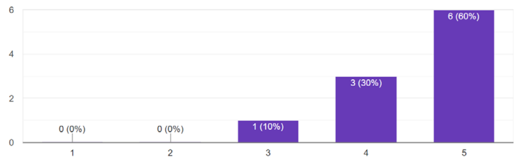
Hvor god utsikt hadde du fra plassen du oppholdt deg? *

Forestill deg at du har utsikt over elven i byen når du ser ut vinduene

1 2 3 4 5

Dårlig utsikt ○ ○ ○ ○ ○ God utsikt

10 responses

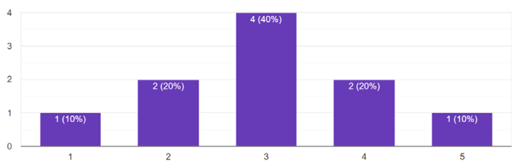


Hvor synlig var informasjonsskjermer og knapper fra der du oppholdt deg? *

1 2 3 4 5

Lite synlig ○ ○ ○ ○ ○ Veldig synlig

10 responses

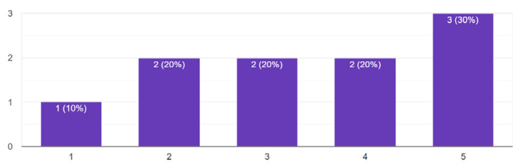


Hvordan ville du beskrevet plasseringen av sitteplasser? *

1 2 3 4 5

Privat ○ ○ ○ ○ ○ Sosial

10 responses

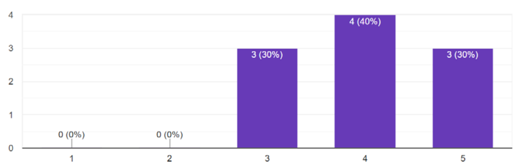


Hvordan ville du beskrevet dette oppsettet av møbler og skjermer i en ferge? *

1 2 3 4 5

Tradisjonell ○ ○ ○ ○ ○ Nytenkende

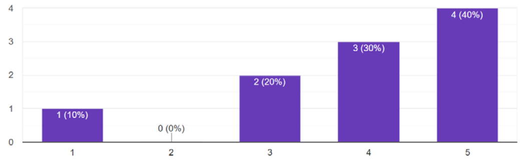
10 responses



Hvordan ville du beskrevet dette oppsettet av møbler og skjermer i en ferge? *

1 2 3 4 5

Upraktisk ○ ○ ○ ○ ○ Funksjonell



Hva kunne du tenkt deg å gjøre annerledes med møbler, skjermer eller knapper?

10 responses

- Kunne hatt stropper for å holde seg i fra taket
- Skjermen var noe vanskelig å se når man satt på benkene, kunne kanskje vært plassert over benkene nå hver side. Men veldig kreativt å ha den i midten slik som den var.
- Kunne kanskje tenkt meg at skjermen var i taket, en på hver side sånn at de som satt på benken kunne se opp og få informasjonen de trengte. Møblering var god, gir mye plass til på/av stigning og evt. bagasje/sykkler
- Muligheten til å kun sitte med de man kjenner
- Satte meg rett ned på første plass, så oppdaget ikke knappene før jeg av båten.
- skjermen burde hengt på en av veggene
- Syns det funket veldig bra. Kan ikke komme på noe som kunne vært bedre 😊
- Muligens kunne se skjermen tydeligere mens man sitter, men det er god nok plass til å reise seg, så ikke noe problem i utgangspunktet.
- Skjønte ikke helt hvor skjermene var utover den store i midten og om de skulle brukes til noe annet enn informasjon. Synes det var litt lite variasjon i møblene kanskje. Når man reiser alene er det OK, men reiser man en gruppe ønsker man kanskje en mer sosial sittegruppe. Så ville kanskje hatt litt ulike alternativer og markert/tilrettelagt plass for folk med sykkel /rullestol o.l.
- Det opplevdes romslig og behagelig

Hvor oppbevarte du det du tok med deg på fergeturen, og hvorfor?

10 responses

- Ved siden av meg. Det pleier jeg på offentlig transport
- Ved punkt 5, fordi det var god plass til å sette fra seg sykkelen der
- Koffert foran meg ettersom jeg har god oversikt over den, sekken tok jeg ikke av på denne korte turen
- Hadde sekken på ryggen, mens sykkelen sto igjen ved inngangen. Var ikke plass til sykkel ved sittebenken, ikke noe problem det
- Ryggsekken på fanget, sykkelen ute av hinder for andre
- Sekk pp ryggel, holdt sykkelen med hendene stående
- Rett foran meg
- Ved siden av, trygt å ha barn og ting i vogna nært
- Ved siden av benken jeg satt på, fordi det ikke var plass noe annet sted. Føltes litt knotete at det ikke var
- Hadde ikke med noe

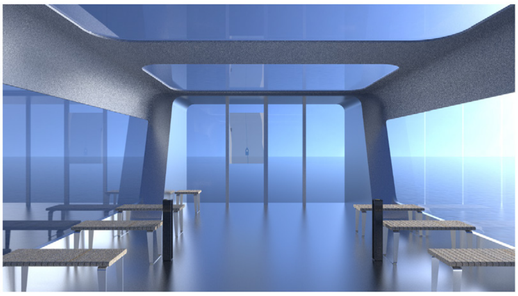
Fikk du en bra plass sammenlignet med de andre passasjerene? Hvorfor/hvorfor ikke?

10 responses

- Ja, fordi jeg kom raskt ombord
- Like god som andre. God plass i mellom passasjerene.
- Jeg hadde en god plass, det var mer enn nok plass til andre passasjerer
- Alle hadde like bra eller like dårlig plass, ettersom hvordan man ser på det
- Tror alle hadde god plass. Hadde ikke vært problemer med flere.
- bra plass med sykkel
- Ja og nei. Alle fikk se ut av vinduet og det var bra. Alle hadde god plass. Jeg likte at vi fikk sitte til en kant, så vi bare hadde andre folk på den ene siden, og dermed lettere og holde oss samlet.
- Bra plass. Fikk god sitteplass med ingen utenfor familien tett ved siden av.
- Bra plass, gikk tidlig på og kunne velge langt fram i ferga.
- Synes det var romslig plass for alle

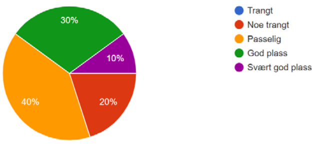
SURVEY 2 - PASSENGER JOURNEY

Oppsett 2



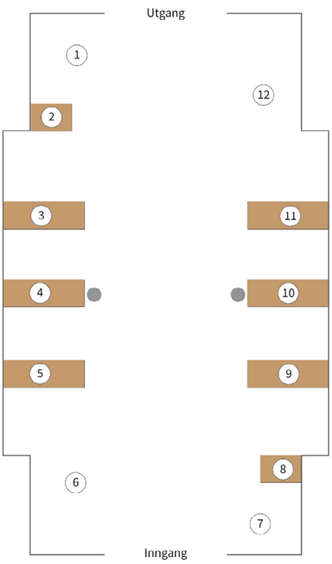
Hvordan opplevde du plassen ved inngangspartiet til fergen? Copy

10 responses



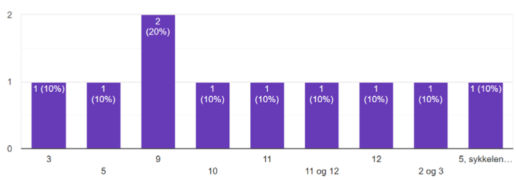
Hvor valgte du å oppholde deg på fergeturen? *

(Skriv det nummeret som er nærmest der du oppholdt deg. NB! Legg merke til hvor inngang/utgang er på tegningen)



Hvor valgte du å oppholde deg på fergeturen? Copy

10 responses



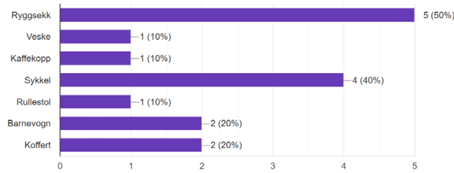
Hvorfor valgte du å oppholde deg der?

10 responses

- Ekstra plass for kofferten jeg hadde med meg
- For å ha utsikt framover i båten samt på siden
- Ledig benk, nærme sykkelen
- Der det var ledig plass i nærheten av sykkelen
- Gikk først inn og guttungen på 3 vill se foran i båten
- Hadde med sykkel
- Det var ledig plass ved vinduet. Måtte gå litt inn of så ut igjen fordi jeg ikke fant plass
- Tenkte det var der man kunne stå hvis man ikke skulle være i veien (hadde rullestol)
- Perfekt plass til en liten familie. En benk hadde vært for trangt.
- Plassene fremst i ferga var tatt av andre passasjerer. Hadde sykkel og det var den beste plassen som var ledig med sykkel. Plassen foran hadde en søyle som var i veien for sykkelen.

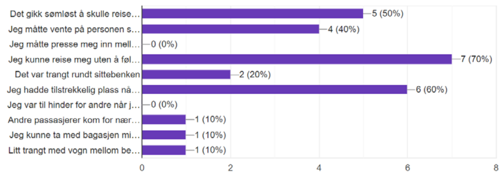
Hva hadde du med deg på fergen? Copy

10 responses



Hvordan opplevde du å gå av fergen? Copy

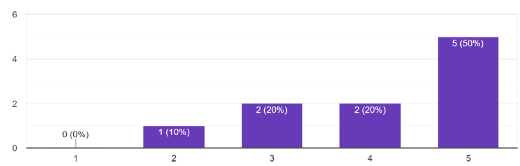
10 responses



Hvor god plass hadde du der du oppholdt deg? *

	1	2	3	4	5	
Trangt	○	○	○	○	○	God plass

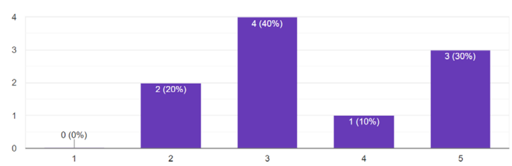
10 responses



Hvor god oversikt hadde du over det som skjedde i fergen? *

	1	2	3	4	5	
Dårlig oversikt	○	○	○	○	○	God oversikt

10 responses

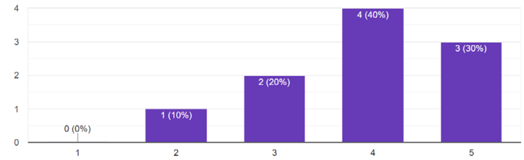


Hvor god utsikt hadde du fra plassen du oppholdt deg? *

Forestill deg at du har utsikt over elven i byen når du ser ut vinduene

	1	2	3	4	5	
Dårlig utsikt	○	○	○	○	○	God utsikt

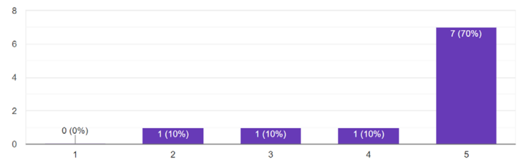
10 responses



Hvor synlig var informasjonsskjermer og knapper fra der du oppholdt deg? *

	1	2	3	4	5	
Lite synlig	○	○	○	○	○	Veldig synlig

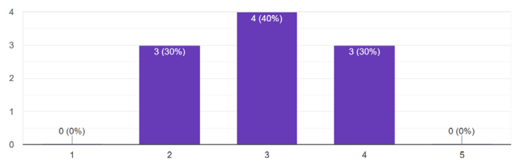
10 responses



Hvordan ville du beskrevet plasseringen av sitteplasser? *

	1	2	3	4	5	
Privat	○	○	○	○	○	Sosial

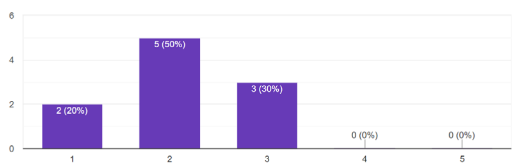
10 responses



Hvordan ville du beskrevet dette oppsettet av møbler og skjermer i en ferge? *

	1	2	3	4	5	
Tradisjonell	○	○	○	○	○	Nytenkende

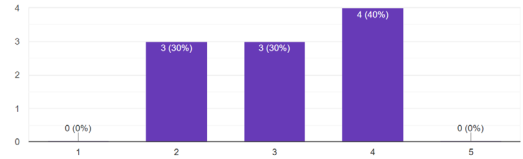
10 responses



Hvordan ville du beskrevet dette oppsettet av møbler og skjermer i en ferge? *

	1	2	3	4	5	
Upraktisk	○	○	○	○	○	Funksjonell

10 responses



Hva kunne du tenkt deg å gjøre annerledes med møbler, skjermer eller knapper?

10 responses

Skjermer stenger kanskje litt for utsikten? Mindre oversikt over hva som skjer i fergen med slik sitteplassering

Ikke noe.oppsettet fungerte bra

Godt plassert. Benkene kan fort bli som på buss, at man ikke setter seg med fremmede og at den fortere vil bli full enn den forrige. Sollys kan være til hinder for å se skjermene.

Vet ikke om sollyset hemmer hvor godt man ser hva som står på skjermene?

Kanskje knappene ved siden av dørene?

Grei løsning. Kanskje noe kunne vært bedre i forhold til sykkel om det skulle bli dårligere vær

Savnet rygglene på benken, føltes litt rotete og at man måtte gå inn og ut. Her kunne det også vært litt ulike alternativer. Kanskje noen "toerbenker", noen grupper hvor to og to sitter mot hverandre. Synes det var rart at knappene var på midten. Ville ha spredt de mer ut i ferga. F.eks en ved inngangen, en i midten og en ved utgangen.

Kanskje skjermen fremst blokkerer for utsikten fremover hvis den dekker store deler av frontvinduet

Ikke noe så lenge man får ta to benkerader til gruppen. Ellers kjedelig å ikke sitte sammen. Også litt trangt mellom hvis man har med seg mye.

Fjernet søylene, og de to minste bordene. Det ville gitt bedre plass for sykkel

Hvor oppbevarte du det du tok med deg på fergeturen, og hvorfor?

10 responses

Forran meg for oversikt

Ved siden av meg på setet. Det satt ingen sammen med meg så jeg hadde god plass

Punkt 6, plass til å sette fra meg sykkelen

Sekken på ryggen, sykkelen bak i fergen

Foran meg, fordi jeg vil ha barnet (som satt i barnevognen) i nærheten av meg

Hadde ryggsekken på. Kaffekopp i hånda

Foran meg inntil veggen. Det var god nok plass der.

Hadde ikke med noe

Mellom radene. Så man kan snakke med både barn og baby samtidig.

Ryggsekk på ryggen, holdt i sykkelen mens jeg satt.

Fikk du en bra plass sammenlignet med de andre passasjerene? Hvorfor/hvorfor ikke?

10 responses

Den var grei

Ja, jeg fikk sitte ca slik jeg ville ønsket om jeg fikk velge fritt

God plass ved beina, bedre utsikt, dog mindre plass til å sette fra seg utstyr som sykkel. Bedre plass i midtgangen

Like bra plass alle sammen

Bra plass. Hadde god utsikt både til siden og forran

Veldig god plass. Verken bedre eller dårligere enn andre

Helt greit, likere plasser enn i første alternativ.

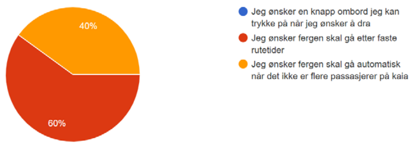
Føltes litt trangt/litt lite rom for bevegelse uten å være i veien

Bra plass. Kunne se skjermene godt forran, og brukte to rader mot hverandre til å se hverandre bedre

Plassen var bra. Fungerte godt, men søylen var i veien for sykkelen

Dersom du skulle tatt denne autonome passasjerfergen, hva skal avgjøre når den skal starte reisen?

10 responses



Claes, Liavaag, Simic

Design an autonomous passenger ferry for urban areas

NTNU

Kunnskap for en bedre verden