

# Boat for All: Interior Overhaul

Designing a Versatile Interior for Marine Public Transit

Master's Thesis in Industrial Design Engineering

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Cover: Top-down view of the proposed passenger compartment.

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## Abstract

This project concerns the development of the interior passenger compartment of the Cstrider waterborne vessel currently being developed, intended for marine public transit. With an emphasis on comfort and accessibility, research has been conducted in the form of a literature review, public observations, and an explorative user study. This resulted in a multitude of suggestions for the interior layout, and a few were methodologically selected for further development. In the evaluation phase of the project, a complete 1:1 scale mock-up of the boat interior was constructed to conduct additional high-fidelity user experience studies. These studies were conducted to evaluate different concepts with consideration to different user groups. The results laid the foundation for the proposal of a layout design for an accessible, comfortable and versatile passenger compartment.

**Keywords:** User experience, accessibility, public transit, marine vessels, interior, layout

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Wilhelm Svanlund

# Thesis Outline and Table of Contents

The report structure follows the project's progress chronologically. Chapters 2, 3, 4 and 5 detail the research, ideation, evaluation and final concept phases, respectively. Chapter 6 is the discussion section, followed by a conclusion answering the research questions and objectives. Lastly, an unnumbered chapter containing the authors' recommendations for future work is included, deemed interesting enough to include, yet not part of the process leading up to the conclusion.

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# 1. Introduction

Chapter 1 introduces the reader to the context in which this thesis project has been conducted, and presents the objectives that the project aimed to solve. Additionally, a brief overview of the methodology throughout the project is also presented here.

## 1.1 Background

Waterways have been used to efficiently transport goods and passengers since the dawn of civilisation (McGrail, 2009). This naturally created a large amount of traffic, which is one of the reasons why, historically, the most significant cities and trade hubs have always been concentrated near coastlines and rivers (Bergkamp, Diphorn & Trommsdorff, 2013). Water transportation is still relevant today, but with many other equally or more efficient alternatives for passenger travel, the waterways in and around cities are primarily used for cargo traffic (MMR, 2023), while bridges and tunnels have become common ways of transportation across water for land-based vehicles. In today's waterfront cities, with an increasing population concentrated in metropolitan areas and a shifting focus towards green urban development, the need for environmentally friendly transportation solutions is an important problem to solve. Public transit is utilised by almost half of the global population (Statista, 2023), making it an essential system in every major city. Highly developed metro and bus networks are expected across most urban areas, but public transport on water is largely underused. In Sydney, for example, ferry transport only accounts for 3% of all public transit journeys, despite evidence that commuters are often more satisfied with journeys on water because of the premium value often associated with ferry travel and the additional services it can provide, such as the ability to bring a bike on board (Cheemakurthy, Tanko & Garne, 2017). This, however, is reasonable as water transportation solutions are limited in that they are only able to reach destinations along the waterfront. Another critical factor to consider for the successful integration of waterborne public transit is the connection to other modes of transport so that passengers can interchange effortlessly between services (Cheemakurthy, Tanko & Garne, 2017). An example of this can be found at Stenpiren in Gothenburg, Sweden, a waterfront public transit hub where passengers can change from bus or tram to ferry, all operated by the same public transport company.



*Figure 1. Cstrider concept from their website (Cstrider, 2023)*

This thesis project was conducted in collaboration with Cstrider, a tech start-up founded in 2023 and operating from Lindholmen, Gothenburg. They are currently developing an electric boat for public transit that aims to become semi- or fully autonomous in the future (Figure 1). Cstrider aims to introduce a sustainable, accessible and desirable solution for water transportation that can compete with and reduce the load on other modes of public transportation. The vessel will be relatively small and carry a maximum load of 12 passengers. This makes the boarding and disembarking processes quick, highlighting the potential agility of the Cstrider solution compared to other ferry options. This also means that it is easier to scale the capacity up or down depending on demand. The idea is that the Cstrider transport solution should not be seen as singular vessels but as a system of boats. For rush hour scenarios, vessels on stand-by can be added to the fleet, and during low capacity hours, the Cstrider vessel is more economically and environmentally sustainable than running a large, almost empty ferry. The smaller size also allows access to many points not currently reachable by larger vessels. This solution can be utilised in any city where there is a need to commute across or along bodies of water, like Gothenburg, Stockholm, Hong Kong or Venice, to name a few. This implies a good opportunity for growth but also the need for a solution that fits into vastly different contexts and caters to a vast range of different user needs. This thesis will focus on researching and developing the passenger compartment of the Cstrider vessel to meet user expectations and maintain a high standard of comfort and utility.

## 1.2 Aim & Purpose

This project aimed to design a commercially viable interior for a small autonomous waterborne vessel that will be used in public transit.

## 1.3 Research Questions

- How should the interior of a self-steering boat for public transport be designed?
- Which aspects of the experience do users perceive as important?
- How can a design problem about a non-existent concept be solved in a startup setting with resource efficiency?

## 1.4 Objectives

The main objective was to deliver a feasible layout design concept, and emphasis was put on designing so that it can be realised in a near-future scenario with current technologies and production methods. This project aimed to create something that did not exist. Still, the authors believed there were more or less innovative solutions to the problem. For example, an already existing layout of elements from some other means of transportation could just be put into the vessel, in contrast to developing an entirely new layout, possibly introducing never-before-seen elements. The marker was set on not striving for innovation at all costs but a rigorous design process where, on several occasions, there was room for the creation, introduction and evaluation of innovative elements.

The client expressed the need for the interior solution to be functional, efficient and available to all passengers. Since many commuters use combinations of different transport means, i.e. bicycles or similar combined with ferries, storage space suited for these needs had to be taken into consideration. Attention also had to be paid to passengers with special needs, such as those depending on wheelchairs and parents with strollers. At the same time, the objective was to also have a passenger compartment that felt welcoming and safe for all passengers.

At the end of the project, one goal was to produce a physical 1:1 scale model of the vessel interior that reflects the concept's functionality and spatial dimensions so that it could be utilised for evaluation and user testing. From this, a UX and usability evaluation and its outcomes were other important deliverables. The last deliverable, a proposal for a layout design, showed the suggested interior layout in a CAD model as a visualisation of the future vision of the finished product. A complementary guide for future implementation was also produced, but it did not contain specific technical details.

## 1.5 Ethical Considerations

Throughout this thesis, several studies have been conducted using voluntary test participants. The participants have not been subjected to any task that may endanger them in any way, and they always had the option to terminate the test at any point and for any reason. The participants all gave their consent to having their test activities documented in writing and with pictures. They were also told that if any image of them would be used in this report, their permission would be required again. Hence, any person appearing in images from the studies in this report is aware of their appearance and has consented. The names or any other personal information of any test participant has not been documented for the sake of integrity, with the only means of identification being the aforementioned images captured during the tests.

One test conducted during the thesis involved young children. The children were involved intending to diversify the user tests and provide insights into the concepts' ability to accommodate children's needs. On behalf of their teachers, extra care has been taken to preserve the integrity of these children, and their faces have, therefore, been blurred in any image used in this report.

The authors have tried to represent the diversity of public transit passengers (age, cultural background, special needs) throughout these tests but, due to a lack of resources, have been unable to accomplish this to the desired extent. The authors are aware of this and discuss the topic in chapter 6.

## 1.6 Sustainability Aspects

### 1.6.1 Environmental Sustainability

As mentioned in section 1.1, Cstrider's mission is to introduce an agile and adaptable electricity-driven ferry solution for public transit. They are doing so with a focus on sustainability, arguing that their solution fixes the issue of large ferries running mostly empty outside of peak rush hour and in the off-season, thus saving energy resources.

Because of this, the project to design the interior layout was also undertaken with environmental sustainability in mind. Repurposed wooden planks and plywood sheets were used throughout the construction of the mockup used in the final study and evaluation. Cstrider has also expressed a desire to keep the mockup after this project has concluded for further testing, meaning that a new test environment will not have to be built. Additionally, the seats used in the mockup will be refurbished and installed in the final version of the Cstrider vessel, further emphasising the commitment to reusing components.

## 1.6.2 Social Sustainability

This project aimed to create a solution that was inclusive and accessible for all. Designing an accessible space for passengers with impaired mobility has been a top priority, and their special needs have been considered at every step of the process. Contact was made with an association for parents with children with non-normative functionality, and an invitation was extended to participate in the study where the concepts were evaluated. One family responded to the invitation, and a test was conducted with an 8-year-old child utilising an electric wheelchair. His parents were also included in the test, acting as spokespersons to provide valuable opinions on the concepts' abilities to accommodate electric wheelchairs and personal assistants during transit.

Moreover, it was discussed how the solution could offer utilities for transporting bicycles and strollers, which heavily influenced the final result. A separate test was also conducted with a large group of around 60 preschool children to ensure their perspective was considered and determine if the concepts were well adapted to child passengers.

## 1.7 Overview of Methodology

This project aimed to design one or several different boat interior layouts with an emphasis on creating solutions that satisfied explicitly defined user needs, offered accessibility for all and provided sufficient safety, utility and comfort on par with- or exceeding existing marine public transit. A user-centred design approach has been applied throughout the project, with an emphasis on user experience (UX). The user-centred design process is iterative (Interaction Design Foundation, n.d). It consists of different sequential stages, with each stage being based on the results of the former and with each subsequent phase increasing in level of detail, generating both results and potentially new questions, hence the need for iteration.

To specify, this project consisted of four main phases: research, ideation, evaluation and final concept. The **research phase** consisted of a substantial literature review of credible academic sources to get familiar with the topic and gather initial insights for the following stages of the project. The literature review was followed by an observational field study intended to analyse layouts of existing public transit solutions in the local context (Gothenburg, Sweden) and dissect how passengers interacted with the environment and each other. Next, an interactive user study was constructed following the CARE model (Pettersson, 2018), where participants generated interior layouts for the Cstrider vessel in a 1:1 scale environment based on their previous experiences and assumptions about public transport. The CARE user study is explained further in section 2.4.

In the following **ideation phase**, the insights from the different research studies were organised and used as references for formulating user needs. The defined user needs served as guidelines in a series of brainstorming sessions, during which an interactive mediating representation was utilised to generate a large number of different possible solutions. These were subsequently evaluated through a Pugh matrix, and three were selected for real-life testing in the next phase.

The third phase, titled the **evaluation phase**, mainly concerned the construction of a 1:1 scale mock-up of the Cstrider waterborne vessel interior. The mock-up was constructed to represent the user experience in the finished product accurately. Hence, the focus was on constructing the correct dimensions and presence of barriers, such as walls, a roof, a door frame and windows. The purpose of the mock-up was to be used in a user study where the selected concepts from the previous phase were tested in a series of scenarios and subsequently evaluated based on feedback. Three tests were conducted during the evaluation. One max capacity test with 12 participants to simulate trips with a fully loaded boat, one test with a disabled child and his parents to learn about travelling on public transport with an electric wheelchair, and one test with about 50 preschool children divided into four groups.

A refined version of the finished layout is presented in the fourth phase, the **final concept phase**. This phase includes the basis for decisions about the placement of all interior elements and dimensions, as well as visualisations of the finished concept. The chapter also touches briefly on further expansions of the concept and recommendations for implementation.

## 2. Research

This chapter details the theoretical foundation of the thesis on which the future phases are built. The research phase consists of three studies: a literature review, an observational field study, and an explorative user study, with the latter being the major activity of the research phase.

### 2.1 Theoretical Framework

#### 2.1.1 UX Definition

UX is an acronym for the term User Experience, which relates to a User's experience, encompassing all aspects of a user's interaction with some product or service (Nielsen & Norman, 1998). What specific definition is ascribed to the concept of UX can vary between the different contexts where it is used. In this work, the word and concept of UX have been central to every part of the process and, naturally, likewise in this report. Thus it is important to define here what it has meant throughout the process and what it means in this report. This section is based on definitions encountered by the authors in prior studies as well as in the literature relevant to this report.

A prerequisite for understanding UX in this project is presented by Petterson (2018) in her PhD thesis. The perspective held throughout this thesis comes from Crotty (1998), as cited by Petterson (2018). The adopted understanding is *"...that the world is influenced by subjective constructions, in other words, that humans construct individual meanings as they engage with the world [...], where one cannot expect complete predictability and verifiability of a topic such as eliciting user experience data"*. This results in a perspective on experience as inherently unique and subjective in its nature. A natural question following this view is, if every experience is inherently unique, what then is the value of studying UX if it cannot be properly predicted or even verified? An answer to this is given later in the same text: *"...research has a place in attempting to understand as much as possible of other people's experiences, making sense of them and suggesting an actionable way forward in a design process based on an understanding of the world instead of assumptions based on one's own horizon"*.

#### 2.1.2 Atomic Experiences

An important concept in this project, not based on any bodies of academic literature but nonetheless used, is that of experience as a set of smaller, almost atomic experiences (atomic as in the Greek word *"atomos"*, meaning indivisible). This term emerged during discussions in the project and was therefore not previously familiar to the authors or referenced from any previous work. It involves basic aspects of set theory, taught in introductory mathematics. In some ways it can be seen as conflicting the

notion that UX is inherently subjective, but should instead be looked at as a compromise when designing for UX as you cannot design to cater for each user individually. For example, everyone travelling by boat will experience maritime travel in some way. Some aspects of this will be experienced by all, such as waves and weather. However, what is noticed and the reaction to this will be based on an individual frame of reference, forming subjective experiences. Such an individual experience could, for example, be of the sunny weather to be experienced as nice, as the person in question always likes sunny weather. Another individual's experience of the same sunny weather can be that it is too bright and causes a headache, which leads to a negative experience. When studying these different individuals, it is possible to map their different atomic experiences, in this case, the good/bad response to the weather. This can then be considered a **set** of experiences collected from a group of individuals, derived from the boat travel experience. In this set, the opposing experiences of the weather provide a representative idea of what possible atomic experiences can be had within the **superset** boat travel and, given a large sample size of users, provide an idea of ratio. The use of this perspective is in generalising a way which enables an understanding of the possible experiences that can be had in a specific context, which can be used as a basis for design decisions or indications of the need for further inquiry into some specific unexplored part of some superset of experience (Figure 2).

This perspective can provide additional benefits to that of contemporary experience research. From past experience of design work done by the authors, having this perspective does not change much of the process. In fact, the idea of atomic experience came as a result of discussion from user studies in this project. During prior work the authors have been involved in, user studies have been used to research experience. When the data collected is analysed, the way it is divided in order to enable analysis has not been expressed. A concept or framework for how experience can be divided has proven useful when discussing and being aware of the limits to the divided experience. A discussion about working with atomic experience can be read in chapter 6.

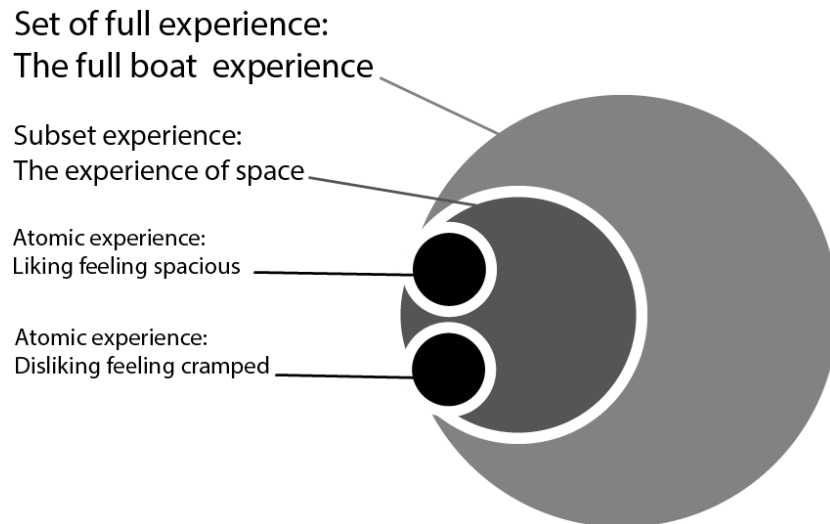


Figure 2. Graphic illustrating sets and subsets of an experience.

### 2.1.3 Availability and Design for All

Another word and concept heavily used throughout the process, and this report is availability. Worth noting, as most work and appurtenant discussion besides this report was carried out in Swedish, the Swedish word that has been used is *“Tillgänglighet”*. Accessibility, the translation to English used in this project, clashes very slightly in definition. *“Tillgänglighet”* carries the meaning that something should not only be accessible but also effectively available, as in relative ease of utilisation. This is important, as the combined meaning of accessibility but also availability has been central to all discussions throughout the process. If the word accessibility is used, presume also that availability is factored into the definition. This section was based on definitions encountered in prior studies and in the literature relevant to this report.

According to DO (2018), the Swedish National Board of Discrimination and Inequality, an accessible society allows everyone *“...to participate on equal terms, regardless of their functional ability”*. With regards to limitations affecting the extent to which this can be realised, the ambition is to allow everyone some level of use at least and, as far as possible, make the experience for everyone, not only differently abled, easily available. The limitations mentioned regard first the limited perspective of the authors of this work, following the idea of the inherent subjectivity of experience mentioned above.

## 2.2 Method

### 2.2.1 Literature Review

A general comprehensive literature review was performed as a first step to familiarise with the topics of public transport, boats, autonomous vehicles, and any combination of the three. The articles reviewed were found through Google Scholar using the following list of search terms:

- UX + public transport
- Public transport + Sweden
- Autonomous + public transport
- Boat + interior design
- Public transport + interior design
- Interior design + boat + public transport
- Commuter + tourist

The search was somewhat sporadic and explorative, with no specific goal other than learning more about the context in which the project was to be performed. No articles were found that described precisely the same scenario as the one in this project, but it was assumed that public transport across water was comparable to other means of public transit and thus shared many of the same design philosophies and possible problems, such as how to layout the interior to provide comfort and accessibility. The same assumption was made for the user experience in different types of autonomous vehicles, hypothesising that the general population's somewhat suspicious approach to autonomous vehicles is the same whether the vehicle is on land or in the water, even though people are more used to land-based travel and the idea of autonomous cars, compared to the equivalent in boats. By reading, summarising and discussing the articles, insights were gathered that highlighted a few interesting aspects of the user experience in public transport that were directly applicable to the project's context and acted as pointers for further research in the subsequent studies. Specifically, this study resulted in a series of questions that needed to be answered by other means of research.

### 2.2.2 Observational Field Study

During this study, the project authors travelled around Gothenburg, Sweden, using different public transit means (bus, tram, boat) to observe passengers' behavioural patterns and interactions. The purpose was to build a frame of reference around public transit travel and gather impressions in the local context. The study's points of interest were to conclude which seats were the most popular and by whom they were utilised, social behaviour, interior layout, the behaviour of elderly and movement-impaired people, and how cargo was stored (large bags, strollers, walking aids, bicycles, etc.). The study was documented through notes and quick sketches and took place over two

days. Measurements of seating dimensions were also made using a yardstick. On the first day, the authors observed passengers on buses and trams from noon to late afternoon, and on the second day, the observation took place on several public transit boats for a duration of a few hours. Throughout the study, the types of passengers varied greatly, allowing insights into the public transit habits of passengers of different age groups and how behaviour varied based on passenger density. The template used for the observation is attached in Appendix A.

### 2.2.3 Explorative User Study

A user could not have had a contemporary experience related to a waterborne public transport vessel of the variety concerned in this project, as no such transport solution was available. Because of this, there was also no way of creating or putting users in such an environment to observe them. The technological elements existed but had not yet been combined into a functioning package or been honed into a viable service. However, to design interior elements and the composition of the boat for a great user experience on board, a solid basis of knowledge about the user's experience is needed to guide development. This basis needs to consist of a set of relevant individual user experiences in order to identify needs and specify a list of requirements.

Such a method was suggested by PhD Fredrick Ekman during a meeting discussing experiences of public transport on water. The method is called CARE and was developed at Chalmers University as part of PhD Ingrid Pettersson's doctoral thesis *Eliciting User Experience Information in Early Design Phases* (2018). As the title suggests, it was created to elicit user experience data to guide the early phases of a design process. The method and its expected output were deemed well-suited for this project, and it was decided that after reading through the relevant sections, a study based on our understanding of the method and its source material should be devised. The text was read through by both authors of this report with notes taken, then discussed and understood roundabout as follows.

The approach's name, CARE, is an acronym for its four components: **Contextualise, Act, Reflection** and **Express**.

**Contextualising** means conveying the intended use situation and preparing the participant in a way that opens them up to respond in a more context-specific way to the provided stimuli. In this case, this was done by crafting a scene and setting which aimed to provoke associations with the participants' prior experiences with similar waterborne travel and public transport. This was done by including an ambient soundscape of seagulls, crashing waves and similar harbour sounds, accompanied by a video collage of scenes recorded on a local passenger ferry. A scenario of boat travel over the same body of water was provided, along with an explanation and depiction of the Cstrider vessel. This all provided a solid foundation, enabling the user to:

**Act.** This means enabling interaction even through low-fidelity means. In the case of this project, to fully enable the user to immerse and trigger experience, material for interaction was provided. First, the vessel's effective floor space was marked out on the floor. Close by, 12 chairs were placed with the intention of allowing the participants to experiment with their ideal layouts using chairs as placeholders for the refurbished bus seats, which would be used in the actual boat. A bike and a wheelchair were also placed in proximity, allowing the participants to evaluate the interaction between these elements and the layout (Figure 3). The next step of a care test is:

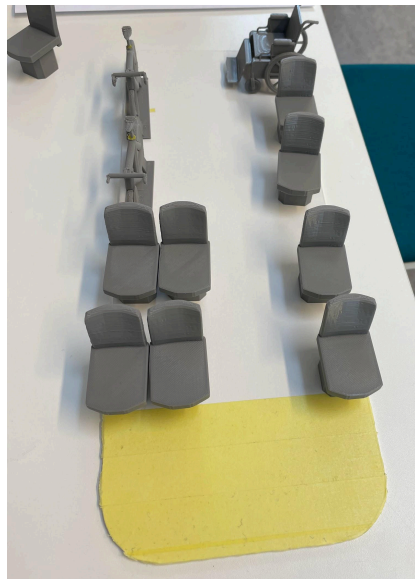


*Figure 3. Photographs of test space setup*

**Reflection.** It is important to trigger reflection and further thoughts on what is being acted out during the session. A triangulation of methods is encouraged to provide different angles of approach for the future experience. In the case of this study, the elements for building an interior were provided gradually during the test to provide spaces to focus and reframe as new elements were introduced. In the last stage, a small-scale model of the interior with loose interior elements was provided, as seen in Figure 3, which generated further interaction and a new perspective, observing the floor surface from above. During all parts of the test, the participants were encouraged to

think out loud and ask questions. In the end, the reflection should help prepare the participant to:

**Express** their experiences. Here, multiple ways of communication provide different bridges to convey ideas, such as combining interview questions with sketches and photos. In this case, it was achieved using interview questions and the same small-scale model used in the reflection (Figure 4). Both answers and constellations were recorded and provided useful data to understand user experiences in such a setting. For the complete test document, see Appendix B.



*Figure 4. Photograph of small-scale model*

Together, these four components of the CARE approach aim to create a user study that yields rich and in-depth UX data in the early design phases. In total, 16 participants took part in the study across 10 test instances. The test participants were a convenience sample consisting of a mix of master's students enrolled in the Industrial Design Engineering and Interaction Design and Technologies master programmes at Chalmers.

After conducting the CARE-based study in this project, an analysis phase was initiated. First, notes of dialogue and pictures were structured into groups sorted by test participants. The notes were read through, and quotes that were regarded as related to experience were extracted and written on Post-it notes. These notes were then sorted into categories based on the themes of the quotes. From the themes and numbers of similar quotes, interpretations of the importance of elements of the different users' experiences were made. In addition, singular quotes of experiences deemed valuable in some way were also noted.

Interiors were documented with a camera when some form of satisfaction or finality in arranging was expressed by the participants. From the documented interior variations, vector graphic representations were made with elements and dimensions made to be

representative of the vessel's planned geometry at the time. Common features in the different layouts were grouped and sorted into categories. The number of layout variations in each group and the number of participants that reached similar conclusions were discussed. In addition, singular layouts with interesting features were noted.

## 2.3 Results

This section presents the results from each research method. Note that some of the results are similar across the different studies. This is intentional and meant to highlight important findings through method triangulation.

### 2.3.1 Literature Review

The relevant insights and questions generated from each article reviewed during the literature study were written down and subsequently categorised under the following topics, as seen in Table 1 below.

- Technical aspects
- Social aspects
- Individual aspects
- User Acceptance
- Safety
- Elderly/disabled

<b>Technical aspects</b>	<b>Social aspects</b>	<b>Individual aspects</b>	<b>User Acceptance</b>	<b>Safety</b>	<b>Elderly &amp; disabled</b>
Consider weight distribution.	How to appeal to all socio-economic classes?	Coherent design language improves ambience.	Increasing trust & transparency increases user acceptance.	A small vessel increases passengers' sense of vulnerability.	Longitudinal seats in combination with rails are preferred by the elderly and disabled
Modularity increases the efficiency of manufacturing .	Remember the image of public transit. Can it be improved?	Accommodation of activities during transit may increase satisfaction	How to make a small isolated vessel feel inviting?	How can the sense of personal safety be improved through interior planning?	Forward-facing seats lead to narrow aisle that causes problems for people with walking aid
Foyer width greatly impacts boarding efficiency.	Personal space is highly valued.	People enjoy observing their surroundings.	Water transit is considered 'premium'. How to enhance this?	A pleasurable ride requires some sense of control.	Elderly & disabled prefer seating close to entrance/exit
	The seating arrangement is an important influence on atmosphere.	Cultural background and context influence passenger priorities.	How to increase appeal to people with no prior boating experience?		
		Being productive during transit is important for some.			

*Table 1. Results from the literature study*

These insights sparked discussions that led to the realisation of the importance of a general solution that was able to satisfy diverse user needs to as great of an extent as possible. Since public transit passengers are not a homogenous group but rather have vastly different expectations of an optimal public transport journey, it was considered unethical to exclude one group for improved comfort for the others. Some insights also led to concrete guidelines for the continued development of the product, such as elderly passengers being more anxious about space for movement and preferring a seat near an exit and the general level of discomfort that most people feel about strangers possibly invading their personal space, cementing the importance of space optimisation and the required amount of space to feel adequately separated from strangers. It was also concluded that people prefer facing the direction of travel and find enjoyment in being able to look at the outside environment as they pass by. Moreover, these insights sparked discussion about what to find out through the consecutively performed studies.

### 2.3.2 Observational Field Study

The results gained from the observation were important in understanding people's behaviour and social interactions on existing public transit solutions since they could be applied to the user scenario of the Cstrider vessel to an extent.

The bus and tram observations concluded that the elderly preferred to sit near an exit. If they were using a walker, crutches or carried luggage, such as a shopping bag on wheels, commonly known as “dra-maten”, they chose side-facing seats or priority seats with extra space in all instances. The most common form of pastime during transit was to look at one's mobile phone, but a surprisingly large percentage of passengers resorted to looking out the windows or observing their fellow passengers, suggesting that accommodation for these activities is also important to consider when designing a public transit interior space. It was also noted that strangers tended to try to keep their distance from each other. This is typical behaviour in Swedish public transit and something to keep in mind when designing an interior space for 12 people that is intended to run at max capacity for the most part since this requires strangers to sit next to each other or choose a standing spot. Another point of interest was that groups of friends who had to split up and sit on opposite sides of the aisle tended to rotate towards the aisle to converse, leading to a partial blocking of the aisle, which may cause accessibility issues. It was also observed that people tended to stand up and queue near the exits ahead of their disembarkation, which suggested that there may be a need for an increased area of space around the doors. When moving through the interior, most people relied on rails for stability, to some extent. This behaviour was especially prevalent in elderly passengers, who required more support when entering and exiting the vehicle.

The layouts of the buses and trams were also analysed, mostly to conclude which interior elements and different types of seating options were used, as well as the overall

layout to gain inspiration. It was noticed that 4-seat configurations (two forward-facing seats and two backwards-facing) were not used to the same extent as regular two-seat modules. The same could be observed for 2-seat modules facing backwards. The latter also aligns with the findings from the other studies. The distance between seats measured from backrest to backrest was found to be circa 71 cm on the *Älvsnabbare* ferry and approximately 74 cm on the local trams.

When observing the public transit ferries, slightly different behaviours were noted. A larger share of passengers were observed looking out the window when travelling across water. Because of the more spacious interior of the ferries, people were also less mindful about taking up as little space as possible and making way for each other, as that was not necessary. A clear distinction was also noted in behaviour between passenger ferries on longer routes with multiple stops and ferries acting as a ‘virtual bridge’, running between 2 points on opposite sides of a river. On the virtual bridge ferries, the crossing was short, and a large portion of travellers chose to stand, especially those with bicycles.

### 2.3.3 Explorative User Study

The analysis of the data collected from the CARE study resulted in insights and conclusions in the following forms:

- Experiences the specific context gave rise to and an overview of how prevalent they were among the different participants
- Which variations of constellations participants might construct, and provide an overview of their prevalence among the participants.



*Figure 5. Pictures from instances of the CARE study*

### **Analysis of experience**

214 excerpts were made from the notes. Some quotes had content relating to two categories, but instead of duplicating and placing them under both, it was deemed enough to place them in the most fitting category, as long as the quote was represented somewhere. When sorting through the quotes from the notes, 10 different themes were identified:

1. Social aspects
2. Seating preferences
3. Standing passengers
4. Positive surprises
5. Negative aspects/concerns
6. Wheelchair users
7. The boat experience
8. Size
9. Bikes & Cycling
10. Miscellaneous

During sorting, discussions about the categories provided insight and deepened the authors' connection with the material. This resulted in an overall understanding and appraisal of the experience taking place in the test. From the category-specific discussions, the following conclusions were drawn based on the number of related quotes and judgments based on memories of the occasions from which they stem:

### 1. Social Aspects

Eleven quotes were sorted into one group, sharing the theme of social aspects of the interior. Several participants expressed the desire to socialise with friends on board. From this came the idea of social zones or areas, which enable larger groups of people to socialise more easily. But when travelling alone, more than one participant stressed the preference for isolation.

### 2. Seating preferences

Most quotes were sorted into the seating preferences category (47). Within this category, groups of similar quotes resulted in subcategories concerning foldable seats, view from seats and motion sickness. The mentions of foldable seats were often made when contemplating the uncertainty of there being bikes or wheelchairs on board, and that if there were not any it would be good to utilise the space for sitting passengers. Overall, it was observed and hypothesised that the participants liked the idea of a combined solution just because it could do both. The idea was appealing, but worth noting is that they did not know if it could do both to a satisfying degree. Regarding seating and view, a preference for seats near windows and facing forward was expressed. It was also noted that the idea of such a seating position was met with not only preference but positive excitement. In contrast, quotes concerning orientation and motion sickness expressed the apprehension of taking a backwards facing seat, even more so than in other public transport alternatives, as this was also a boat, where many additional factors promote sea sickness.

From the other quotes, that were more difficult to sort into more specific categories, there were many mentions which hinted towards some interesting experiences and impressions the study environment could give rise to. There were mentions of not wanting to sit next to, or even preferably face, strangers. There were also several mentions of desiring the option to sit in the back if the user was in a rush or just stressed. Interestingly, many contrasting preferences for the optimal seating location were expressed. Most quotes expressed a desire for a good view close to windows, but others said the seats along the aisle were the best, with the explanation that it felt easier to exit without any passenger barring your way out. Appreciative mentions were made of being able to choose between isolated seating and group seating. Interesting mentions were made of feeling exposed, for example, when sitting alone or close to the aisle.

### 3. Standing passengers

In the group of quotes concerning standing passengers, many mentioned that they lacked rails and poles to hold onto in the test setup. Several quotes stressed the perceived importance of support for standing passengers. This was stressed several times when some of the participants contemplated the possibility of having fewer seats than max capacity. The preference for solid material rails over straps was also expressed. Several participants expressed that they preferred standing during ferry trips for the duration posed in the test scenario.

### 4. Positive surprises

In the category named positive surprises, the content is exactly what could be expected from such a title. Several participants expressed a positive feeling of surprise regarding the size of the boat interior represented in the test. Many expressed that it felt larger and more spacious than at first expected. Others expressed that they were positively surprised by the boat's small size because it resulted in a sense of premium associated with more exclusive and smaller-scale transport options such as taxis. The front-facing window and realisation of the expected view also resulted in several remarks of positive surprise. One user expressed the feeling that the boat was cool, and another mentioned the comfort of side-facing seats.

### 5. Negative aspects/concerns

Interestingly, the category of concerns grew larger than the category above. Some users expressed concerns about it being cramped. Another participant expressed that there was space but that it felt like a waste to limit the space to 12 passengers. Many expressed concerns about whether there would be enough room for bikes and potential luggage aboard. Several of the users expressed the desire to go outside and the disappointment of not being able to do so. Some also expressed concerns about being exposed to too much light or heat. Other interesting concerns were the fear of not having anywhere convenient to throw up if seasick and the fear of focusing on placing the majority of seats in the front, resulting in a bad overview of luggage if that has to be stowed in the back.

### 6. Wheelchair users

The next category came from quotes regarding the participants' interactions with the wheelchair and thoughts regarding strollers on board. A subcategory of quotes relating to inclusivity could be established, with several quotes mentioning the impression of the wheelchair as being "banished" to the back (note none of the test participants had experience with wheelchairs or impaired movement). Many seemed to weigh the benefit of being situated with convenient proximity to the door against the sensation of not having access to the front part, perceived as more exclusive and desirable. Overall, many quotes relate to how the space should be used in different edge cases with many bikes, wheelchairs, or strollers and what these scenarios would be rational to account for in the layout of the interior. No real conclusions here, but the realisation that it is seemingly impossible to accommodate all these edge cases when they align

simultaneously. Other notes provided the subcategory obstruction, relating to how the placement of wheelchairs or bikes might in some way inconvenience or be inconvenienced in their position. Other interesting quotes related to how the seating arrangement should incorporate the possibility for friends or other people affiliated with someone in need of wheelchair space.

#### 7. The boat experience

The next category, The boat experience, stands out as it is separate from seating and almost purely just feelings related to the experience of an atmosphere, as in the word used for the mood of a place or situation, almost fully excluding anything relating to usability. The majority of quotes actually relate to the general appreciation and positive attitude towards boat travel. Many people speak of it as feeling like a luxury. The proximity to water and a great view of the riverside city (from the projector setup) also caused the participants to express appreciation.

#### 8. Size

Overall, reactions regarding size were mixed. Many experienced it as big, though most, judging from quotes, actually ended up expressing that they felt like it was small. Not surprisingly, an observation made during tests was that realisations about size limitations occurred as the participants interacted with the chairs and tested out ways in which to fit both bike and wheelchair inside.

#### 9. Bikes & Cycling

The category of bikes and cyclists also grew large. This is not surprising, as participants were presented with a bike to play around with. They also related a lot to their experience travelling with the ferry line *Älvsnabbare*, where many travel with bikes on board. Three distinct subcategories were found. Quotes about the location of bikes seemingly agree on the bike belonging in the back, which participants explained with not having to move the bike past any cramped space. Ideas of hanging bikes from the roof were expressed, along with some thoughts about putting them in the front to possibly utilise the dead space beneath the tilted window. Another category contained quotes regarding bike racks or rails where bikes could be locked or secured. An idea about combining rails for standing with locking bikes was proposed, and another participant expressed wanting built-in rubber straps to secure the bikes properly. The last subsection consists of quotes where participants worry about when many want to travel with their bikes at the same time. Several participants pose that it is not unlikely that sometimes the majority of travellers might want to bring a bike. Solutions of foldable wall seats all the way around the sides, effectively allowing for an empty and open floor, along with the notion that cyclists should maybe not expect a seat, were proposed.

#### 10. Miscellaneous

Any quote that might not be able to fit with enough similar ones to warrant their own category was put under Misc. Here, interesting thoughts like how to incorporate dogs or

children can be found. One participant spoke of benches instead of seats, and another of having access to drinking water and even a toilet.

### Analysis of Layouts

A second category of results came from the documented layouts built by participants during the tests, as seen in Figure 5. Representations in the form of vector images (Figure 6) were made from each constellation and then analysed alongside each other. These layouts varied greatly, but some recurring elements were noted. Many of the generated layouts were not feasible to build in a real scenario, but they all acted as inspiration and a starting point for the ideation in the next phase.

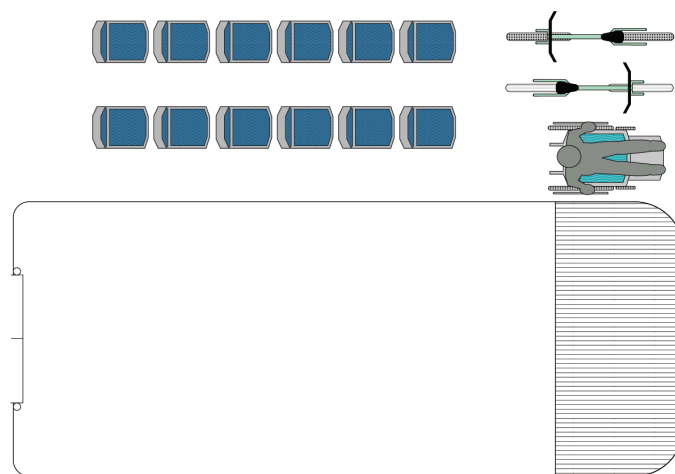


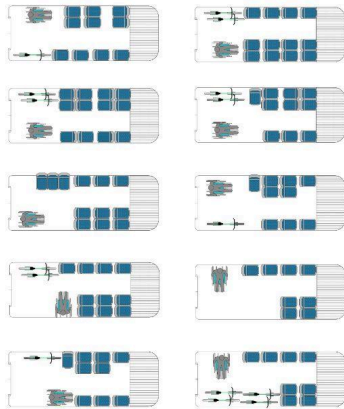
Figure 6. *Img of vector template*

During analysis and discussion, two ways of sorting the layouts emerged: by symmetry and by direction of sightlines in the majority of seats.

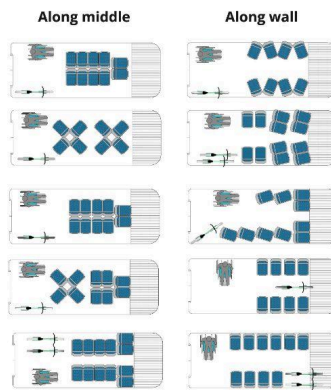
When sorting based on symmetry, first of all, it became evident that one of the most common layout trends was what became known as the “*Älvsnabbare*” layout. It consisted of a two-seat row along one side of the wall and a one-seat row along the opposite wall, creating a wide aisle between. Layouts were almost exclusively symmetrical, parallel to the aisle. Those not belonging to the “*Älvsnabbare*” category were sorted into groups based on symmetry emanating from the middle of the vessel and outwards or symmetry emanating from the wall and inwards. Few were asymmetrical.

The majority of layouts favoured arranging most of the seats facing a direction parallel to the aisle, see Figure 7. A few had the majority of seats facing orthogonal (90°) to the walls (also Figure 7). Fewer than the parallel but more than the orthogonal layouts were an almost equal mix of the directions the seats faced.

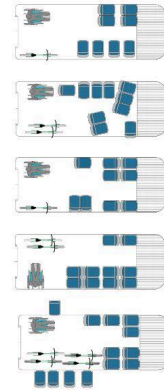
**Wide aisle + "Älvsnabben" layout**



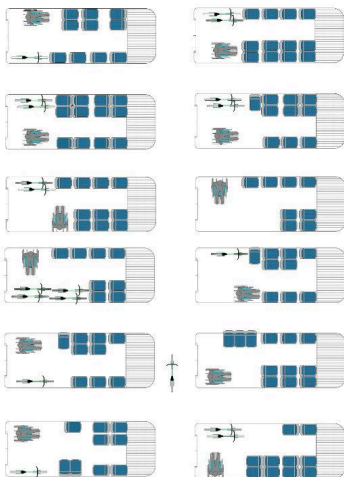
**Symmetric**



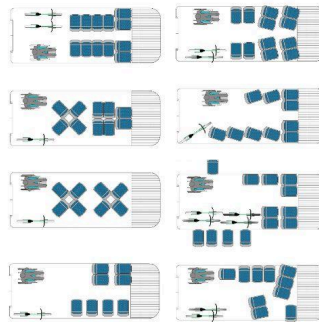
**Misc**



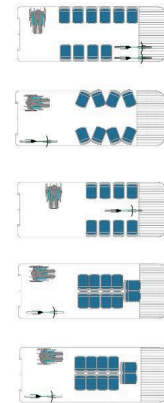
**Horizontal sightlines (majority)**



**Mix**



**Vertical sightlines**



*Figure 7. Board with sorted constellations*

## 3. Ideation

This chapter describes how the research results were analysed to formulate requirements, which acted as the basis for the generation of ideas. It also describes how the ideas were generated and evaluated and which were selected for further development.

### 3.1 Methodological Framework

#### 3.1.1 KJ Analysis

KJ analysis is a tool to structure insights gained from unstructured data gathering, such as observations or comments made during user tests. Comments or thoughts related to the main problem are written down on Post-it notes or similar, with one comment or thought per note. The notes are subsequently moved around based on the similarity of the topic, and categories emerge (Scupin, 1997). The categorisation helps to identify different important aspects of the problem and aids in defining requirements for the solution.

#### 3.1.2 Mediating Tool

Mediating tools in the design process refer to instruments, methods, or resources that facilitate communication, collaboration, and the overall workflow among design team members and/or other project stakeholders. These tools help bridge gaps in understanding, ensure alignment on objectives, and enhance the efficiency and effectiveness of the design process (Hahn & Gregory, 2007). In this project, the mediating tool used took the form of an interactive 2D map of the boat interior with loose interior elements that could be moved around to form different interior layouts and thus acted as a visual aid during discussions throughout the ideation.

#### 3.1.3 Pugh Matrix

The Pugh matrix is a concept evaluation tool in which requirements for a new product are weighed on importance from 1 to 5. All concepts are then compared against a benchmarking example to determine whether or not they fulfil the requirement better than the generic solution. This way, the concepts are evaluated as a whole against all requirements, and the score acquired clearly indicates which concepts are most suitable for further development (Pannell, 2023).

## 3.2 Method

### 3.2.1 Requirements

The insights gathered from the three studies in the research phase were amassed and subsequently translated to user needs through a KJ analysis, which was used to formulate requirements for the final concept. The requirements were categorised into three different topics: Basic requirements, comfort and environment. The basic requirements category covers all needs associated with general vehicular safety, boat safety, and accommodation of basic services, such as allowing space for the storage of bicycles and strollers and offering priority seating for the elderly and movement impaired. The comfort category encompasses the passengers' physical comfort, emphasising sufficient space for unhindered movement and adequate support for sitting and standing passengers alike. The third category, environment, collects the requirements related to the atmosphere and adds value to the experience on a more holistic level. These requirements were, therefore, not as clearly defined, such as making the trip feel more personal or making the experience seem more luxurious than other means of public transit. All requirements are listed in full below:

#### **Basic needs**

- Offer most seats in the front half of the vessel.
- Offer complete access to all emergency systems, such as life vests, life rafts and window-breakers.
- Offer safe parking of several bicycles and space for smooth loading and unloading of bikes.
- Offer priority seats and space for elderly, disabled and people with strollers for children, and make sure these designated spaces are clearly marked.

#### **Comfort**

- Offer sufficient space for mobility and comfort.
  - Offer support for standing passengers.
  - Make sure that the interior feels spacious.
  - Offer accessibility for all, regardless of physical capabilities.
- Offer space for and the possibility of keeping an eye on luggage.
- Offer protection from the sun.
- The solution must at least be able to accommodate the most common pastimes of public transit.
  - Look out the window.
  - Observe fellow passengers.
  - Looking at one's phone.
- The majority of seats must face the direction of travel.

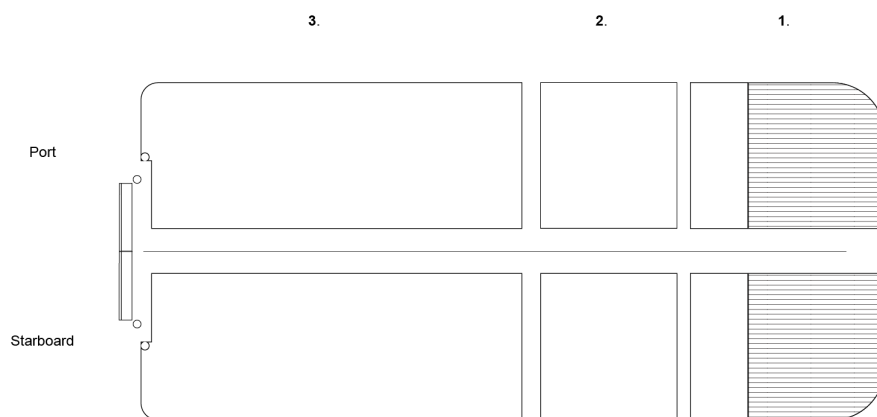
#### **Environment**

- The experience shall appear as a more premium alternative to transit by bus or tram.

- Fortify the boat experience.
- Make the journey feel more personal.
- The solution has “*Feng Shui*” (Madeddu & Zhang, 2017), meaning that the layout is well-structured, coherent in its design language and does not contain unnecessary visual clutter.
- Offer social space.
- Offer good views of the outside.
- Offer modesty barriers, physical or cognitive. These barriers allow passengers to feel somewhat shielded from others by physical barriers or other means, such as distance or angle of seats, to make the presence of strangers less tangible.

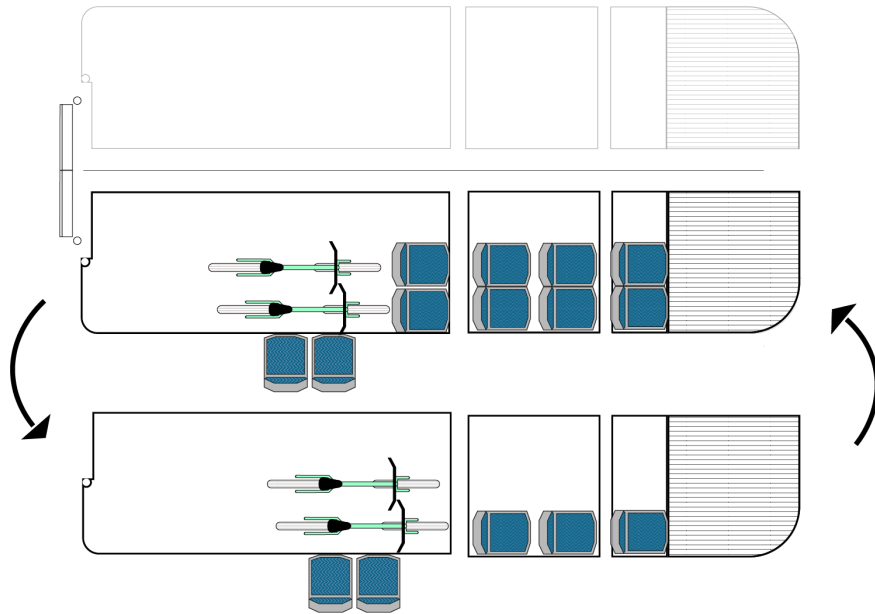
### 3.2.2 Representation of Layouts

From the layouts generated during the CARE study, vector graphic representations were made based on and inspired by insights from all parts of the research phase. Part of the method was to separate the interior floor area into six sections: dividing first along the aisle into a starboard and port side, then splitting each of these sections into a bow, mid and stern section (Figure 8).



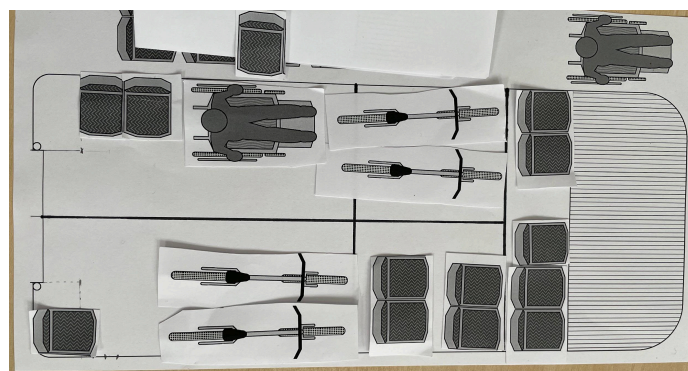
*Figure 8. The separation of the interior*

For each of these six sections, different variations of seat placement seen in the CARE test were proposed. Then, the variations were shuffled about, like tiles, and combined into different mosaics (Figure 9). The combinatorics make the number of all different tile combinations too large to evaluate. After experimentation and discussion, certain trends started to emerge. For example, it was realised that certain combinations of tiles were incompatible when put together as they did not result in coherent and functional layouts. Beneficial combinations of elements were also found through this method and proved to be a solid starting point for the continued ideation.



*Figure 9. Example of combining different tiles*

With the list of requirements in mind, a series of short, unstructured creative sessions took place over the course of a week, where ideas for potential layout solutions were generated. The precondition for the brainstorming was that a session would start as soon as an idea emerged during the day, leading to discussions, refinement, and more ideas. To provoke discussion and facilitate clear communication of ideas, a floor plan of the boat interior was printed out together with icons representing chairs, bicycles and wheelchairs that could be arranged freely (Figure 10). This floor plan acted as a mediating object when explaining and developing emerging ideas and allowed for easy documentation of the process and results.



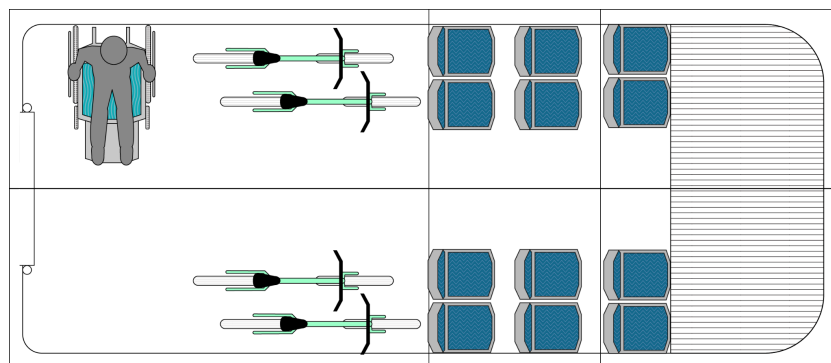
*Figure 10. Paper representation for ideation sessions*

The different concepts were then compared in a Pugh matrix (see Appendix C) against each other and a generic placeholder layout, previously produced by Cstrider, to see how the new layout ideas fared with regard to the requirements. If a concept performed better than the stock layout, it was given a '+'; if worse, it was given a '-'; and if it was equal, it was given a '0'. If given a '+' or a '-' on a requirement, it was then multiplied

by the weight of the requirement (1-5), which had been determined prior to performing the matrix. The most important requirements received higher weighting than requirements deemed less important. The performance on each requirement was then summed up to conclude a final score for every concept. It was discovered during the execution of the Pugh matrix that some of the requirements were not possible to evaluate based on the 2D sketches of the concepts, such as “ability to provide sun cover”. Therefore, These requirements were removed from the Pugh matrix evaluation and reintroduced at a later stage of development.

### 3.3 Results

The brainstorming and tile shuffling sessions resulted in 7 different layouts, some of which were close variations of one another. Other ideas also emerged during the brainstorming sessions that were discarded for various reasons, mainly that they were space-inefficient or too difficult to implement. The ideas were developed with aid from the results of the CARE study, and several of the resulting layouts from the brainstorming sessions shared similarities or were further developments of layouts generated in the study.



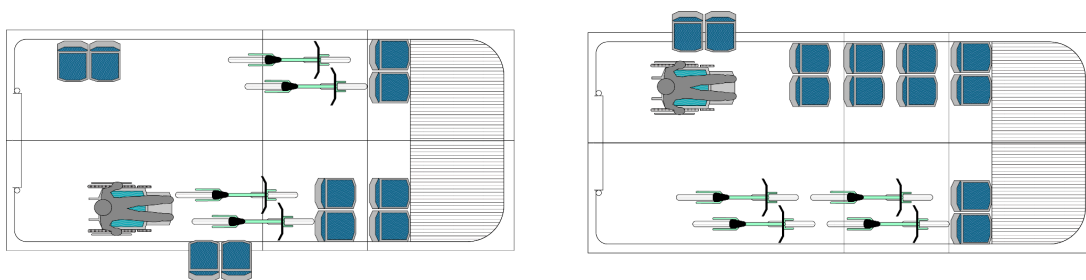
*Figure 11. Benchmarking reference concept C0*

The concepts, labelled C1 through C7 (with the stock layout labelled C0, see Figure 11), were all evaluated equally on whether they fulfilled the requirements better than C0 using the Pugh matrix. After concluding the Pugh matrix, all seven concepts received a final score, as shown in Table 2.

Concept	Score
C0	0
C1	1
C2	-10
C3	-6
C4	7
C5	14
C6	11
C7	3

*Table 2. Pugh-matrix score*

It became evident that the best-performing concepts (in descending order) were C5 and C6 (Figure 12). The initial idea was that these three best-performing concepts would be evaluated in the final user study, but it was deemed useful to also evaluate the benchmarking concept (C0) in a real-life scenario. Hence, C5, C6 and C0 were the definitive picks for the evaluation. Several insights emerged while evaluating the concepts that shed light on why these concepts scored considerably higher than the others. Having the bikes focused on one side and seats on the other seemingly improved accessibility to priority seating for the elderly and disabled, allowing them to stay close to a wall and utilise support rails to a greater extent. Another reason for dividing the interior as such is that the presence of bikes limits access to the window emergency routes, so keeping the majority of seats on the opposite side decreases the risk of blockage. Another reason these layouts performed better is that they lack the three-seat configuration in the front, which, for one, introduces an undesirable middle seat but also makes the aisle narrow. Another surprising result was that all layouts using the three-seat configuration scored negatively in the Feng Shui category because they looked uneven and unstructured.



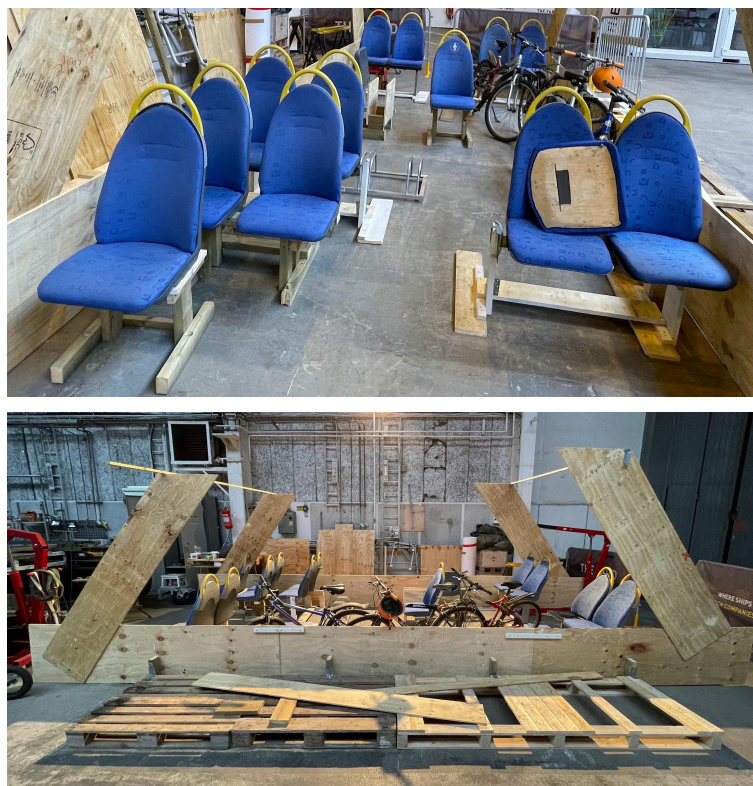
*Figure 12. Top scoring concepts C5 (left) & C6 (right)*

## 4. Evaluation

This chapter covers the user study conducted on-site at Lindholmen. The study used a 1:1 scale mock-up built to reflect the experience of the finished boat interior. Three tests were performed during the study to cover a broad range of future scenarios and users.

### 4.1 Construction of Test Environment

The evaluation phase aimed to test the selected concepts in an environment that convincingly reflected the finished product to accurately evaluate the user experience in a controlled study. To accomplish this, a 1:1 scale mock-up of the interior space of the Cstrider vessel was built. A mock-up is “a full-sized structural model built to scale chiefly for study, testing, or display” (Merriam-Webster, n.d.). Visually, the mock-up was a simplification of the finished product, utilising available material, but what was more important was that the model allowed users to experience the space itself accurately. Hence, much work was put into representing physical boundaries, such as walls, windows, and the roof, with correct shape and measurements.



*Figure 13. Pictures from construction seats (above) and chassis (below)*

The construction began by creating moveable seating modules (Figure 13, top) using seats from old demolished public transit buses. This was because multiple interior layouts could be evaluated using the same assets, and corrections and changes during the tests could be made instantly. Next, the walls were constructed using plywood panels that were tilted 4 degrees inwards to reflect the tilt of the walls in the digital model. The A- and B-pillars (structural elements to hold the roof) were then bolted to the walls, gaining the same inward tilt. The A- and B-pillars were also slanted backwards and forwards, respectively (Figure 13, bottom), which was especially important for the A-pillars since they would determine the slant of the front windshield. Various support elements were also incorporated to provide sufficient stability to the entire construction, after which the roof, made out of a tarp, was added. A door frame was built at the rear, and lastly, the windows were covered with transparent plastic sheets to complete the model of the boat interior (Figure 14).



*Figure 14. Outside (top) and indoor (bottom) view of the finished mockup*

Building the test environment provided many seemingly trivial but valuable insights which otherwise would not have been possible. For example, the 5 chairs in the front

row solutions were discarded as soon as it was tested in a 1:1 3D environment. On 2D blueprints, it had seemed perfectly fine and in line with the results from the care study of letting as many as possible access the desirable front-row seats. Well inside the test space, it was deemed so evidently cramped and undesirable that all concept layouts where it was included were immediately discarded.

## 4.2 Method

Design of the study, interview, and form built upon the work done prior. Results from the literature and the CARE study constituted the foundation for decisions on which aspects to evaluate. The layouts to be used during the evaluation were based on material from the ideation and then matrix evaluation.

While developing the test for evaluating the chosen concepts, it was quickly determined that the test was risking expanding into a size too big for its own good. The process of evaluating three layouts (Figure 15), with four different passenger groups and studying multiple aspects from each group's perspective in each layout was deemed cumbersome and complex to execute. To mitigate this, it was decided that the test should be divided into three clear segments: testing of the layouts, questionnaire and group interview. This structure was preferred to repeating the cycle of testing layout, followed by a questionnaire and group interview, for each layout at a time. It was expected to make the activity, along with the following interview and forms, more approachable for participants, thus leading to better engagement and results.

The study conducted using the vessel mockup was done in parts, as it was important to gain insights from all types of future passengers, in contrast to the CARE study conducted earlier in the project, where only design students participated. The study aimed to evaluate the three concepts selected from the Pugh matrix in a scenario representing real-life use as closely as possible. The study also included assets such as bicycles, a stroller and a wheelchair to determine whether the concepts could offer a comfortable journey for everyone on board.



*Figure 15. In order from the top left, Layouts 1, 2 and 3.*

#### 4.2.1 Max Capacity Test

The first test of the study was conducted with the help of 12 participants. This was seen as the max capacity test and a structured qualitative test. Due to factors such as the location and rules of the site where the mockup was built, a convenience selection of 12 contacts to the authors made up the test population. Care was made to ensure an equal male-to-female ratio and not to include only design or engineering students. A senior was also included with the intention of representation.

The duration of the test was about one hour and structured into a brief introduction to our project, followed by a realistic travel scenario where participants were encouraged to act as they would in public transport. The scenario started with participants boarding, then travelling, followed by a call to get ready to disembark, and finally disembarking.

Roles such as cyclist, wheelchair user and stroller user were distributed among the participants. Fixed roles were chosen over rotating to simplify the data collection types from each participant. The scenario was repeated for each of the three layout alternatives indicated by the prior stage as strong candidates.

Next, a form with the dual intention of promoting reflection as well as collecting data from the participants was distributed among participants. The forms were split into sections focused on different user experiences. There was one general section, another for seated passengers, yet another for standing passengers and finally one for cyclists. Semantic differential scales were used to compare the users' experiences of the different layouts. Semantic differential scales allow test participants to grade something on a non-incremental scale between two bipolar opposites on each end, for example, agree/disagree (APA, 2023). See section 4.3.1 for a visual representation. Complementary yes/no questions were used with the intention of providing a binary answer to whether some aspect of the interior influenced it negatively. Underneath yes/no questions, a space was provided for the participant to provide short explanations. The idea behind giving time for forms after all variations had been tested was to allow comparisons between them, which was worth risking a test structure more vulnerable to a peak-end effect.

After everyone had finished their forms, a group discussion was carried out. This was chosen over individual interviews because of the limited time available to all participants. The participants were asked to reflect on their experiences with the different layouts and compare them to other modes of public transit with which they had previous experience. They were asked to give their opinions on comfort, personal safety, accessibility and other value-adding factors, such as the view of the outside and the aesthetics of the different constellations. Measures were taken to counteract the risk that some participants stayed quiet while others occupied too much of the discussion by moderating the discussion. In addition, written notes, photographs and video were used to document the whole scenario in real-time.

The time required for entry and exit was measured for each layout. The entry duration was counted from when the first passenger entered until the last stopped moving about the interior, either standing or sitting, as long as they had found a place. The exit was measured from the first passenger exiting the doors until none remained inside. Time was measured with a cellphone stopwatch and video.

#### 4.2.2 Wheelchair and Motorised Wheelchair Accessibility Test

The second test conducted was created with the intention of evaluating the layout with regard to mobility aids. A participant with experience of daily use of a wheelchair and motorised wheelchair had been found, and a semi-structured qualitative test was prepared for the occasion. As communication with the participant proved difficult due to also having intellectual disabilities, the dialogue was instead between the authors and

the user's parents. Instead of following a structure with a scenario like the max capacity test, this test became an evaluative group interview, with the mockup as a mediating object. Boarding and disembarking were still tested for each layout, but discussion was held in parallel. In addition, written notes, photographs and video were used to document the whole scenario in real-time. Immediately afterwards, a short reflective discussion was held between the authors about the test, and additional notes were made.

### 4.2.3 Preschool Test

A test was conducted with around 50 children from a preschool close to the site, ages 3-6 years. It was deemed important to study the children's perspective during the process, and coincidentally, the school was currently working on the topics of technology and water.

To work with children required some adjustments to prior test structures. Questions were simplified, and greater focus was put on observing and interpreting behaviour. In the end, the test would best be described as a qualitative, unstructured and explorative group interview. Four groups with ten to twelve children in each were rotated into the mockup one group at a time. Due to the limited attention span of the children, strategic breaks where they were given fruit were implemented.

Some of the prepared questions were asked to initiate a group discussion, but the children responded better to dynamic discussion after that point. Notes of interesting points coming up during the discussion were written down in breaks between sessions with each group. Preschool teachers were present the whole time, creating a safe and focused environment and also helping through interpreting for some of the children. The preschool teachers also supplied valuable insights from their perspective as caretakers for large groups of children when they used public transport.

## 4.3 Results

The evaluation study's results are divided into three parts, each presenting the results from one of the tests.

### 4.3.1 Max Capacity Test



*Figure 16. Photo taken during boarding in Max capacity test*

Quotes and observations were noted during the interactive part of the test, where boarding, transit and disembarking were simulated (Figure 16). All three layouts gained positive remarks, such as being spacious for sitting passengers and offering good views of the outside. It was also noted that, in all three layouts, people began to stand up prior to disembarking, which led to crowding of the aisle. This behaviour was previously predicted and fortified the hypothesis that a wide aisle and increased space in the rear of the vessel would increase overall comfort and lead to faster disembarking times. Some participants expressed that being far from the exit prior to disembarking was a stressing factor, causing them to choose seats in the rear or standing in favour of choosing the front seats with the panoramic view. Other passengers did the opposite, marking a clear distinction in personal values of efficiency versus enjoying the ride, and all three layouts seemed to satisfy both. The participant with the wheelchair role positively remarked that the second and third layouts offered much more social inclusion as the proximity to other passengers in those constellations was shorter.

Each participant's entries in the semantic differential scales were meant to reflect their satisfaction with the three evaluated layouts. The line in the word scale was exactly 100

mm in width, and the placement on the scale directly corresponded to a score between 0 and 100 for each layout. From the first semantic word scale concerning overall satisfaction (Figure 17), a preference for Layout 2 could be seen, with an average score of 76, compared to 66 for Layout 1 and 64 for Layout 3. All participants filled out this scale regardless of their roles (sitting, standing, travelling with bicycle) during the test.

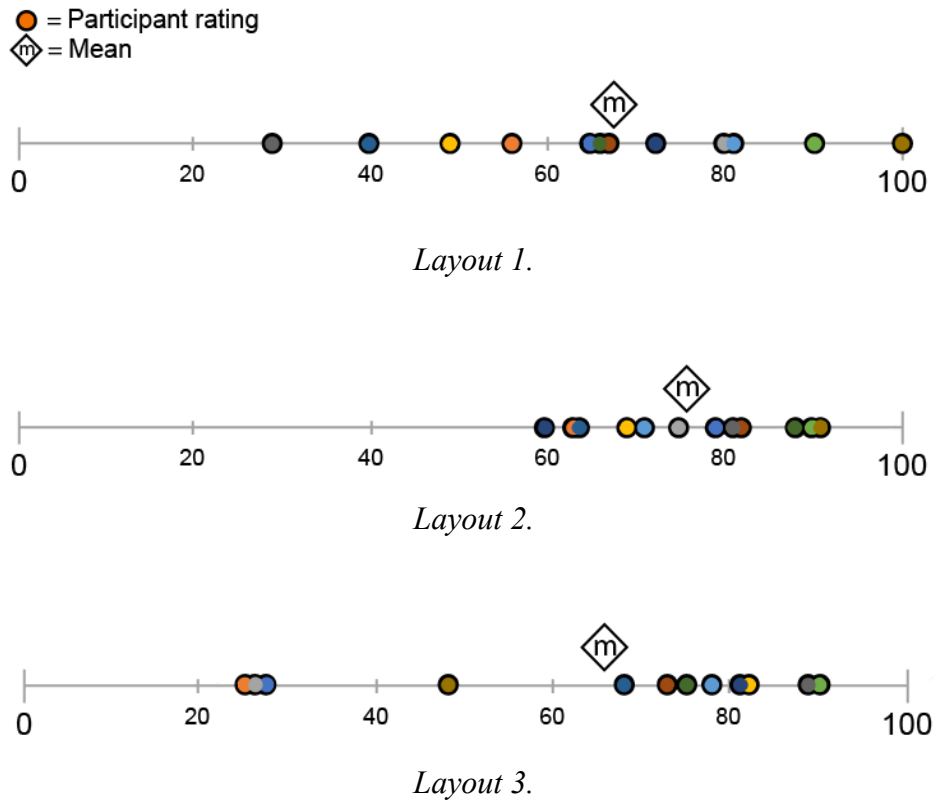


Figure 17. Semantic word scales outcomes on “Overall satisfaction”

A distinction was made between passengers who sat or stood during the tests, as it was believed that this might influence their comfort-related satisfaction with their journey. Participants who were given the role of cyclists were asked to fill out an additional form. The results from the sitting passengers (Figure 18) showed a preference for Layout 3, with an average score of 75, closely followed by Layout 2 at 73, while Layout 1 fell behind with an average score of 57.

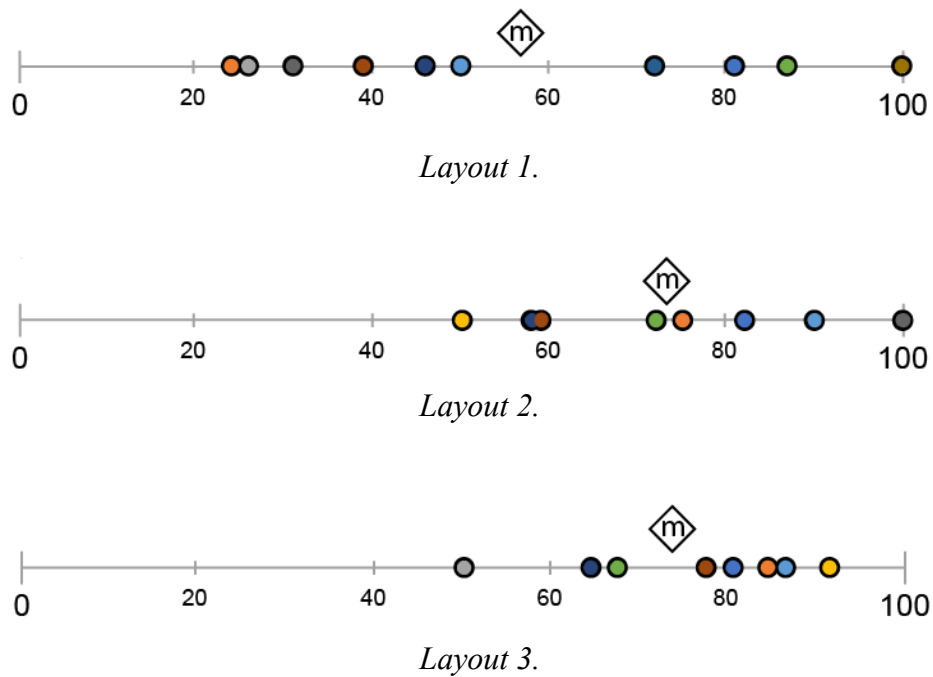


Figure 18. Semantic word scales outcomes on “Sitting passenger satisfaction”

The results from the standing passengers (Figure 19) showed that Layout 2 got the highest average score of 40, although there was only one single data point for this layout as only one passenger was standing. Layout 3 got an average score of 37 from four data points, and Layout 1 received, from its two data points, an average score of 33. Although there were too few data points to draw any real conclusions as to which layout performed the best for standing passengers, these results suggest that sitting passengers were more satisfied with their journeys.

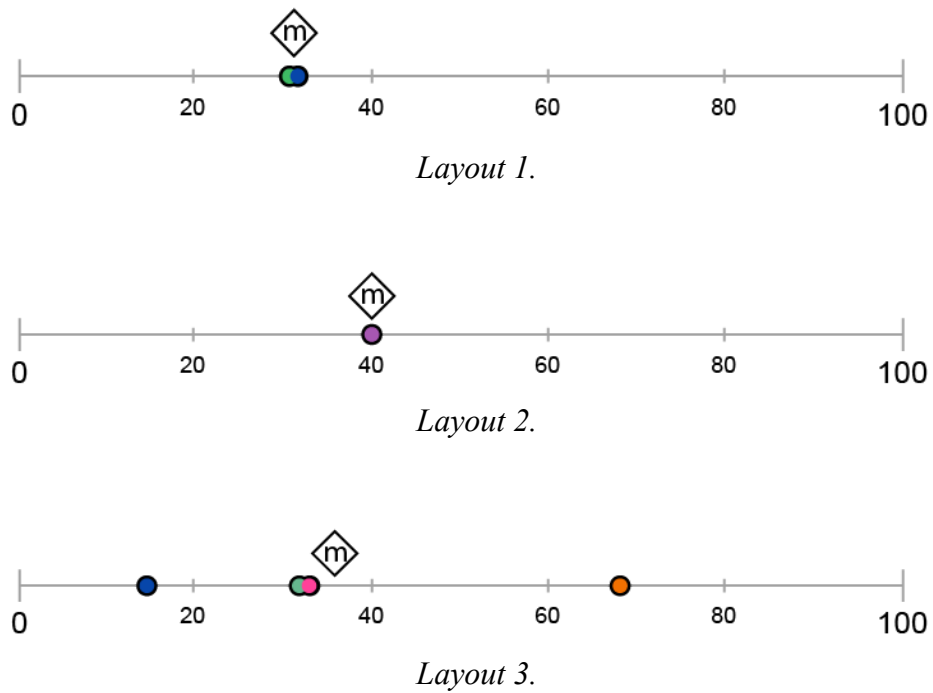
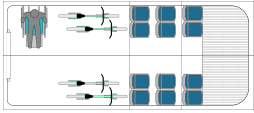
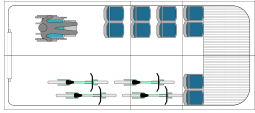
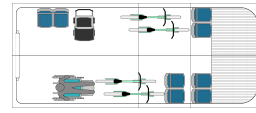


Figure 19. Semantic word scales outcomes on “Standing passenger satisfaction”

When examining the results from the cyclists’ evaluation, it was important to keep in mind that Layouts 1 and 3 had similar bike rack constellations (two bikes on each side of the aisle) compared to Layout 2, which had all four bikes on the same side (two rows of two bikes). The cyclists were asked to evaluate each layout on three different topics. The first concerned overall satisfaction with the available space in the vessel. Layout 1 got the best score at 65, while Layout 3 received a score of 55 and Layout 2 got 43. The next point concerned the ease of parking the bicycle in the vessel. Here, Layout 3 received the highest score at 71, Layout 1 was next at 66, and Layout 2 got a score of 61. The third point evaluated how each of the layouts fared when exiting the boat with a bicycle. Layout 1 was favoured with a score of 70, and Layout 3 was close behind at 63. Layout 2 performed significantly worse, with a score of 37. These results show that cyclists preferred the bike rack constellation in Layouts 1 and 3, especially when disembarking with their bicycles.

Table 3 below provides an overview of all the average scores and a total average.

	<b>Layout 1</b> 	<b>Layout 2</b> 	<b>Layout 3</b> 
Overall satisfaction	66	76	64
Sitting passenger satisfaction	57	73	75
Standing passengers satisfaction	33	40	38
Cyclist overall satisfaction	66	43	55
Boarding with bicycles	66	61	71
Disembarking with bicycles	70	38	63
<b>Total average</b>	60	55	61

*Table 3. Combined scores from semantic word scales.*

The overview of the scores in Table 3 shows a preference for Layouts 2 and 3 among non-cyclist passengers, but Layout 2 falls behind in that regard, giving Layout 3 the most favourable score overall.

The outcomes of the measured entry and exit times can be seen in Table 4 below.

	<b>Layout 1</b>	<b>Layout 2</b>	<b>Layout 3</b>
Entry	1 min 5 seconds	43 seconds	54 seconds
Exit	40 seconds	25 seconds	28 seconds

*Table 4. Entry and exit times of the layouts.*

Note that the measured time required for entry also included the time to get seated or find a spot. The exit time in the table does not account for the time many inside the vessel used to prepare to disembark when they, as part of the scenario, heard that they would soon arrive at their location. On the other hand, the time for entry did not account for the time passengers spent preparing a queue to enter the vessel.

Considering all this, it is still safe to say that entering the vehicle took longer than exiting the vessel. The ratio between exit and entry stayed about the same as well, with the duration of the exit being circa 60% of the duration of entry for Layouts 1 and 2 and the duration of the exit for Layout 3 leaning closer to 50% of the duration of its entry.

The test was finished with a group interview. On the topic of personal safety, comfort and accessibility, the participants expressed that the first layout felt the most intuitive since it was a familiar constellation that can be seen in existing public transport. Layouts 2 and 3 felt more spacious because they contained fewer seats and were also deemed more social for the person in a wheelchair because the designated space for it was closer to the seats. The seats by the front window were appreciated during transit, but participants who sat there expressed a bit of stress when disembarking because they were the furthest from the exit. Explicit requests were also raised to implement support elements for standing passengers and cyclists who chose to stand next to their bikes, such as perch seats, to allow leaning or rails on the ceiling and walls. Many participants mentioned that they would not mind standing for the duration of the transit if the trip was short but that the layouts evaluated in the test did not accommodate standing passengers to the desired extent. This opinion was especially true for Layout 1, which offered seats for all passengers so that no one would have to stand, meaning that passengers who would have preferred to stand during transit did not have the option to do so. Continuing on the discussion about standing and short trips, one participant asked if a layout empty of seats had been considered. This having been the case, a quick discussion followed, concluding that it may be beneficial to have many different layouts depending on the requirements of the route. The view of the outside was deemed satisfactory for all layouts, but cyclists expressed that their view suffered slightly when standing next to their bikes during transit if they faced inwards. Lastly, when asked to give their opinions on the aesthetic aspect of the layouts, Layout 1 stood out for its symmetrical properties. Layout 2 was also endorsed for being spacious and orderly, while Layout 3 received the most criticism for being unbalanced and unintuitive.

#### 4.3.2 Wheelchair and motorised wheelchair accessibility test



*Figure 20. Photograph from accessibility test*

The interview questions regarding prior use of public transport indicated that the parents, in the role of personal assistants, preferred to avoid it in most cases. They had travelled several times by train and found the experience convenient and overall good. On the other hand, they had travelled by bus and tram and told an anecdote of the tram ride, disclosing it as a great stress and that they felt very much like they were in the way. They said boarding and exiting were the most problematic parts of any travelling experience since, according to them, many vehicles lack proper consideration for accessibility. The feelings which arose when the boy could not access a space were discussed. The family talked about it in a way that implied that it was not only the boy but also them as a unit that was affected by exclusion.

As soon as the participant who was using a wheelchair boarded, he rolled straight down the centre towards the front of the vessel. His parents told us he had expressed excitement for the view in the front. When asked where they would like to sit, they said the boy would like to sit in the front. As the designated wheelchair spot was placed in the back close to the exit for ease of access (Figure 20), it was asked what they thought of this intention in contrast to the wheelchair user's preference. They agreed and said they believed the easy access to wheelchair spaces in the rear would appeal to many. With this dual revelation, the possibility of allowing for a place to sit in the front was discussed. The idea of foldable seats in the front was proposed by the parents.

The role of a steward aboard was discussed. It was expressed that it was much appreciated and that it might enable many solutions that would make travelling with a

disability or along with someone with a disability more accessible. An example was the possibility of guiding/conducting any boarding or disembarking procedures to help the wheelchair exit without being in the way. The parents said they often preferred waiting until after people had exited so they could do so in peace.

It can be concluded that the desires and needs relating to design for accessibility and a designated wheelchair space are diverse. Where possible, access to options was expressed to be appreciated.

### 4.3.3 Preschool test



*Figure 21. Photograph from the preschool test*

From the unstructured preschool test (Figure 21), several things were observed. From the notes recorded, the imagination of preschoolers provided a plethora of creative ideas. Here are some examples of ideas to paint a picture of what the answers could look like: small windows on the ceiling, the possibility of bringing toys, the importance of fitting motorcycles and the possibility of buying food when hungry. Some answers that sparked discussion were some places to have sick bags for seasickness and the possibility of sitting on the window ledge and sticking out a hand somewhere to feel the breeze.

While not measured, it was observed that both entry and exit times were considerably quicker than those measured for adults. During boarding and disembarking, children did not care about upholding personal space or accidentally butting into each other, causing someone to slip. The children had a different strategy for getting up in the

seats, climbing face forward like over a ledge instead of squatting down. But seemingly, everyone was able to get into the seats quickly, and none complained. The children seemed to enjoy the interior, based on answers to questions relating to interior elements and their playful and eager interaction with it. Among other things, they particularly seemed to like the windows and the view. Many children were observed sitting on the seat in many ways, sometimes standing on their knees, facing the rest, and looking backwards and around.

During the discussions, teachers suggested that somewhere to throw away waste easily was important. They also stressed that boarding and disembarking were critical moments for the teachers as all children were in movement, and dangerous things could happen. Standard practice for them was to have one teacher in the front of the group and one in the back to maintain an overview of the children at all times. When all are aboard, they can relax. They also mentioned that space for larger strollers is important.

## 5. Final Concept

This chapter presents detailed descriptions and images of the final concept and the reasoning behind the executive decisions that led to the proposed layout. It also covers complementary suggestions on a larger system scale and some practical aspects for implementation.

### 5.1 Layout suggestion

Depending on which user group's perspective is prioritised, the evaluative user studies favoured either Layout 2 or Layout 3 in the study. Non-cyclists favoured Layout 2, while cyclists liked it least, expressing the 2 pairs of bikes put together tightly, one in front of the other, making placing and retrieving the bikes from the racks tedious. On the other hand, the cyclists favoured either layout 1 or 3, where bike racks were placed on each side. However, adding all points together for all user groups gave layout number 3 the edge, prevailing as the preferred option as suggested from the max capacity test. Results from the availability test also favoured layout 3 and disfavoured layout 1. It was expressed that Layout 3 made it easy for passengers in wheelchairs to maintain social contact while travelling in a group or with an assistant. The preschool test provided no evidence against Layout 3 besides the fact that the children liked sitting down, which might be in conflict with fewer seats. This could be counteracted by introducing foldable seats, which the children were observed to like. Considering all the above, our process suggests Layout 3 (Figure 22).

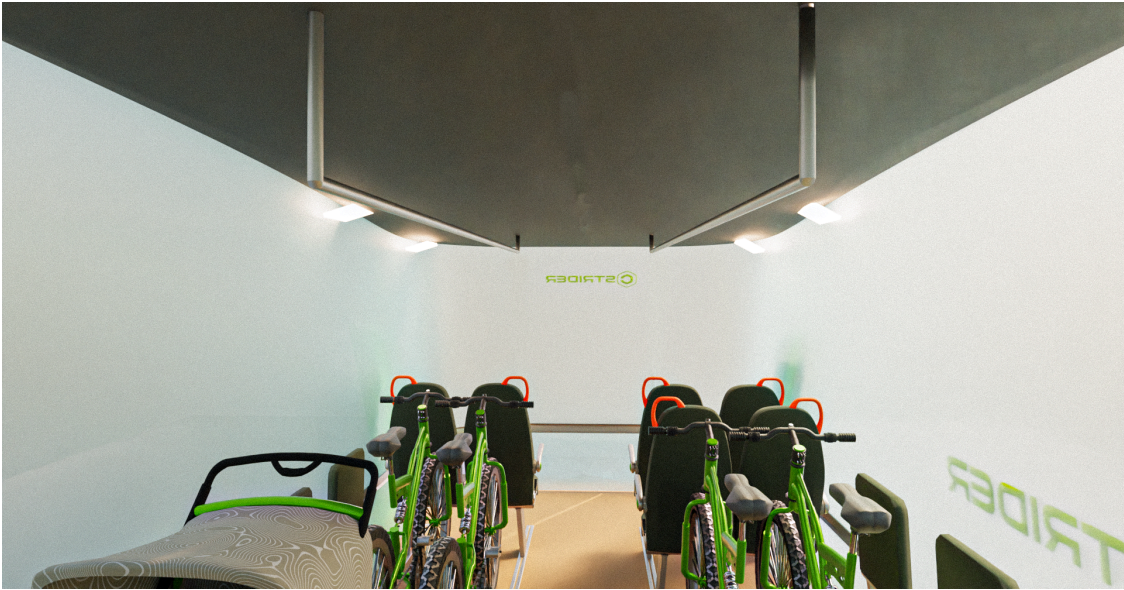


*Figure 22. 3D render of the proposed layout*

This layout features six ordinary seats in the front half of the vehicle, making use of the view provided by the large front window and the legroom resulting from the slant of the window. The bike racks are just behind the seats so as not to pose a stumbling hazard, and two bike spots are located on each side of the aisle. This constellation proved advantageous, as it provided easier access to the innermost bike, which became especially evident in the user study when observing the disembarking with the bicycles. On the walls, next to the bicycle racks on both sides, foldable seats have been placed so that the areas designated for bicycles can be utilised as seating when no bikes are on the vessel. The same areas can also be used by standing passengers, who are able to use the overhead rails for support. Two priority seats have been placed in the rear section of the interior for ease of access and close proximity to the exit. Next to the priority seats is an empty area that can either be used by standing passengers or as a parking area for a stroller or wheelchair. A similar empty area on the opposite starboard side can also be used for the same purpose.

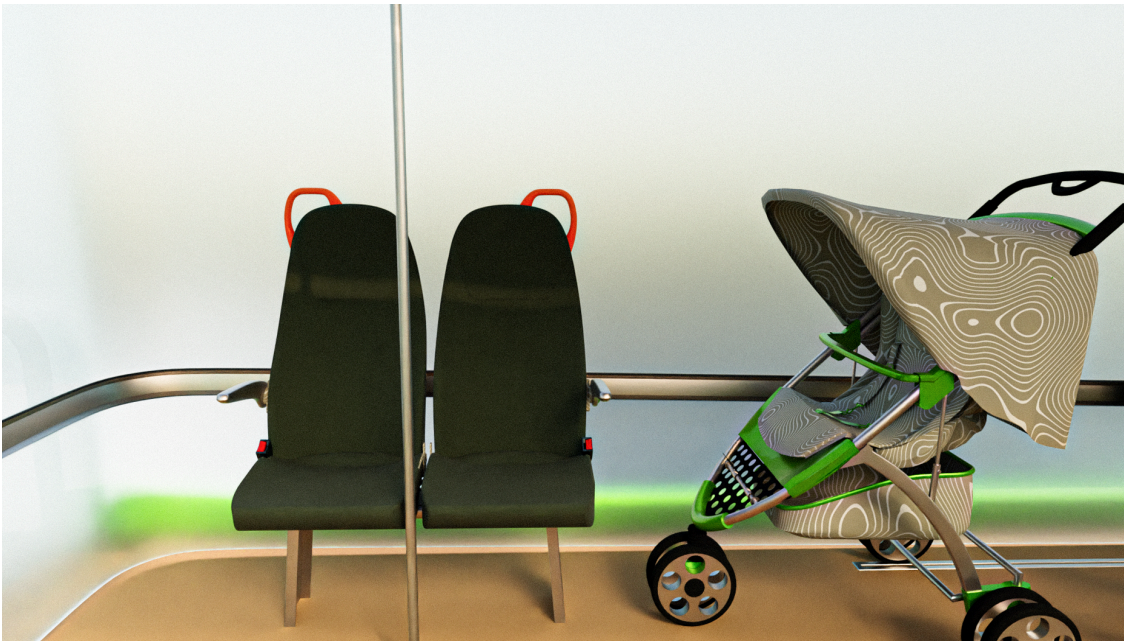
The decision to implement less than 12 ordinary seats comes from the results of the evaluative user study. It became evident from the study that passengers valued space, mobility and versatility above being guaranteed a place to sit. Many explicitly mentioned that they would even prefer to stand during short transits out of convenience and in order to disembark faster. These results align with the project's main theme: creating an accessible interior that satisfies diverse user needs. With the proposed layout, eight out of twelve passengers are always guaranteed a seat, while the remaining four can choose to sit if there are no bicycles on board, thanks to the added foldable seats. This constellation prioritises the allocation of more space for wheelchairs and strollers, which also doubles as luggage storage areas or spaces for standing passengers. By designing the areas to have multiple purposes, they are always ensured to be used, regardless of passenger constellation.

The final concept also includes the implementation of rails in various places around the vessel to support standing passengers and offer mobility aid throughout the vessel to those who need it. No testing has been done to evaluate and determine the exact placement of these rails, but with other public transit solutions as reference (mainly bus and tram) and the insights from the observational field study, an approximation has been made. Overhead rails have been implemented on either side of the aisle, running along the vessel, with the intent of acting as support for passengers standing anywhere in the areas without ordinary seats (Figure 23). The height of the rail should be high enough that most people can walk under it without bending, which also requires loops on the rail so shorter individuals can utilise the rails as intended (not shown in the render).



*Figure 23. 3D render showing overhead rails*

Additionally, a floor-to-ceiling rail has been envisioned to be placed by the priority seats to aid individuals in sitting down and standing up (Figure 24). The placement of this rail has been carefully considered so as not to block passenger flow or hinder the mobility of bicycles, wheelchairs or strollers.

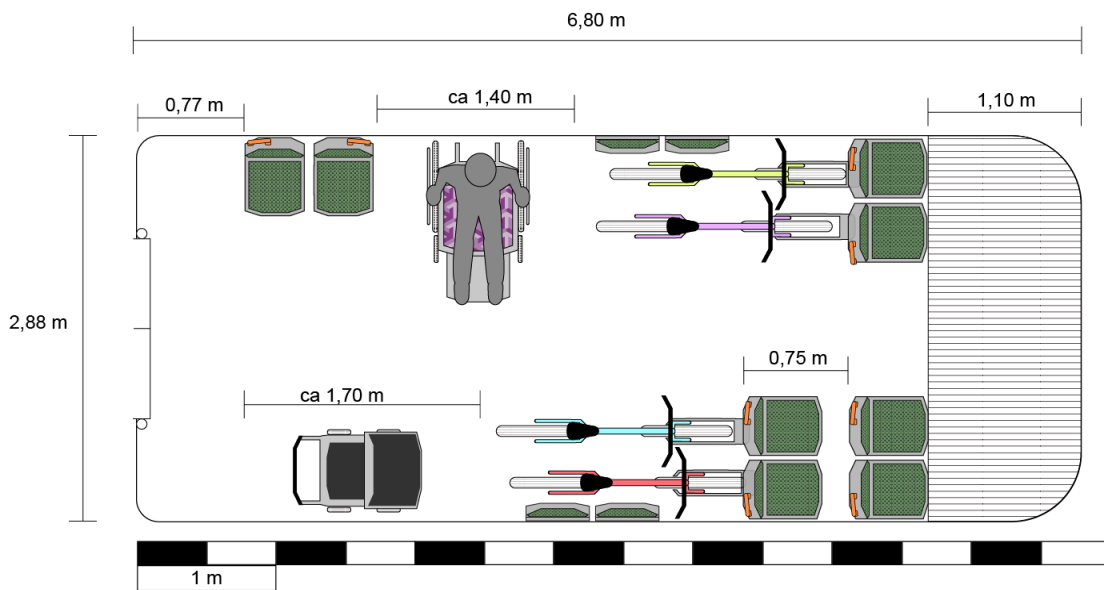


*Figure 24. 3D render of priority seats and floor-to-ceiling rail*

There are additional rail placements to consider, but these are the ones that have been immediately identified as useful and easy to implement. Since no testing has been done on the subject, the most straightforward solutions have been selected for the time being.

## 5.2 Dimensions

As dimensions of the real life interior might be subject to change, it is important to note these measurements are based on CAD files with geometry that, from the authors' understanding, are not finalised for construction. It is assumed the final implemented interior layout will be in the same ballpark, but make note that these recommendations might have to be altered to fit slight changes to the dimensions in the final construction. The measurements recommended based on the results sections of previous chapters are as follows:



*Figure 25. Vector representation of the recommended layout with relevant measurements*

### **Bow space**

A distance of 110 cm was measured from the front seats to the front edge of the floor (Figure 25). This was based on tests during the construction of the test environment with tall (2.02 m) and slightly above male average height (1.84 m) passengers. The limiting factor is the slant of the front window and its effect on passengers when taking a seat. The distance of 110 cm was observed to be adequate and thus rationalised to work for anyone shorter.

### **Stern space**

The stern space is balanced around priority seating and doors. Priority seats are placed as far back as possible to reduce the distance for people with impaired mobility and allow more space for wheelchairs, standing passengers, luggage, and bikes. With the current door solution opening inwards, the priority seats should be placed 77 cm from the doorframe.

### Wheelchair space

From the availability test, it was evident that the priority seats could double as seats for anyone travelling with passengers using mobility aids. A space for wheelchairs in connection to it is of great help to assistants as well. The test showed that the space provided, even with the bikes present, was enough for a child's wheelchair. From discussion with parents, it was also deemed big enough for a full-size wheelchair as well. When asked about mobility, they responded positively. The measurements are as follows: the wheelchair space measures 142 cm along the wall directly in front of the priority seats (portside), as seen in Figure 26, and the space across from the priority seats, on the starboard side, measures 170 cm, as visualised in Figure 25.

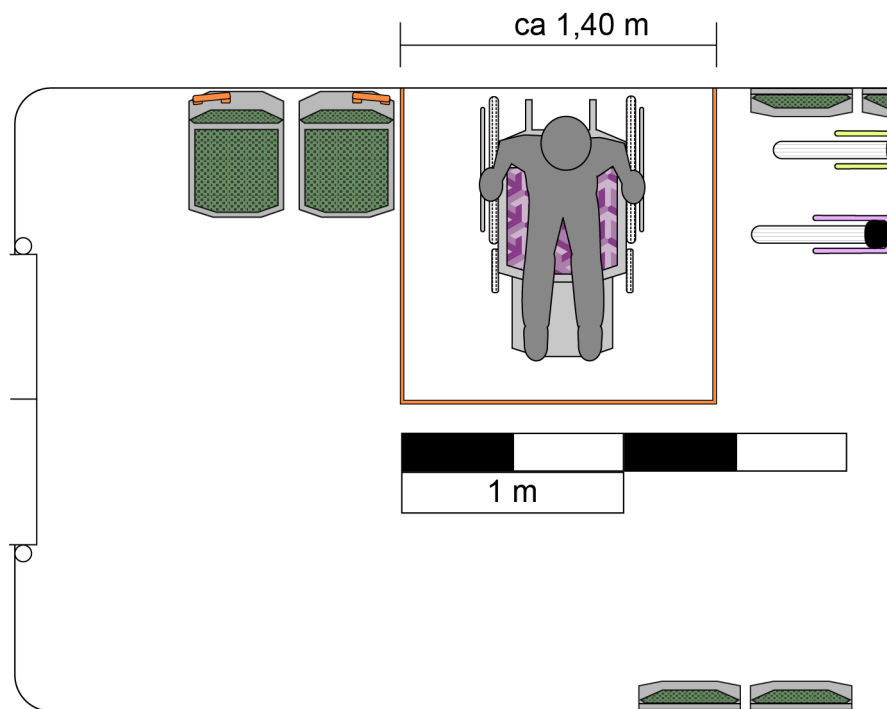


Figure 26. Image of vector drawing over wheelchair space

### Bike space

Begins directly behind the front-facing seats and stretches backwards approximately 180 cm. Based on the max capacity evaluative test, bike rests were enough to indicate the location of bikes on board. It was noted that the layout functions for occasions where bike stands are full, with one stroller and one wheelchair aboard. It is experienced as being a bit cramped. Assuming such scenarios will be unlikely to occur, it is deemed sufficient that the layout only works while not allowing for the best user experience.

### Seating distance

The distance between seat rows was measured to 85 cm. However, a smaller distance is recommended based on results from the evaluative tests combined with results from the observational field study in the research phase. As a suggestion, 75 cm would be enough, being more than *Älvsnabbare* but still allowing for more space dedicated to wheelchairs, bikes and standing passengers. See Figure 25 for the full floor plan.

## 5.3 Complimentary suggestions

At several points during the course of the project, there has been mention of a fully open and empty layout with no interior elements. These mentions occurred in combination with the discussion with and about a particular user group: cyclists. During the CARE test, several expressed that it was not out of line to expect many cyclists on trips this vessel is designed for. This was also supported by the observational field study. Bikes occupy much space, and from testing with real-size bikes inside the mockup, it was evident that more than 4 would be difficult to fit while still offering other amenities, like seats or wheelchair space. Participants, especially cyclists, expressed and were observed to have no issues standing, presuming the trip was the length expected of a Gothenburg river crossing. Additionally, foldable seats can be integrated as well, and wheelchairs or strollers in spaces empty of bikes. With this in mind, a test to fit twelve bikes into the interior was successfully made, still leaving some space in the back and middle for standing passengers, see Figure 27.

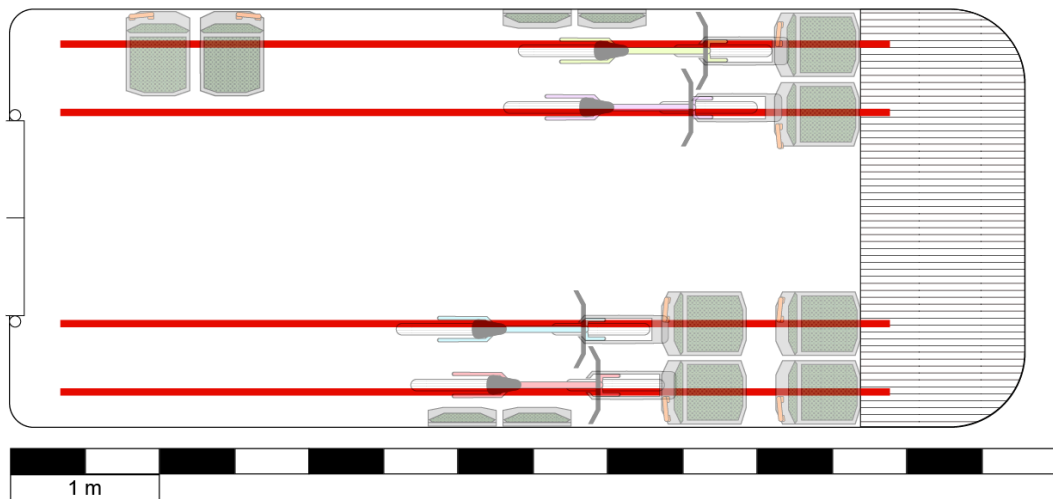


*Figure 27. 12 bikes in an open interior*

This, in combination with the fact that the Cstriders' boats are planned to be sold as a system, suggests this empty layout is viable on particular routes in combination with vessels containing seated layouts. In the layout tested, bike racks were used, but not of any variety planned on being implemented in any real-life solution. Factors such as the extent of the vessel's rocking during travel will affect which racks are viable if they are needed in the first place. As seen in the observation study, other ferry solutions rely on kickstands on the bikes, which seem to be working fine. The weight distribution was not factored into this proposal, as representatives from Cstrider had said the vessel would be very stable and that balance would not be an issue.

## 5.4 Layout implementation system

As part of evaluating the interior solution, a suggestion of how this layout should be installed into the vessel is valuable. Judging by the suggested layouts, both a floor rail system and locations with anchor points are viable. Floor rail systems, such as the ones used for seating in buses, were part of the discussion from early on in the project. As can be seen from Figure 28, floor rails could be implemented in the locations marked. Anchor points with screws could just as well be used to fasten seats, which could then be unfastened if an empty layout is desired. It is therefore suggested to relay this choice to a manufacturing team to decide what best suits their needs, using our recommendations of dimensions as a basis.



*Figure 28. Vector representation of floor rails*

## 6. Discussion

The discussion section is split into three parts. The first part, Reflection, discusses general topics relevant to the project. The second part, Methodology, discusses choices in methods and study design. The third and last part discusses the final concept and its eventual implementation.

### 6.1 Reflection

#### **Qualitative vs quantitative approach**

The literature review led to a series of questions that needed to be answered through other means of research. The authors hypothesised that an observational study, an interactive user study and a survey should be carried out as means to answer the questions that had arisen. After a discussion, however, it was concluded that none of the questions could best be answered by a survey, which led to another question - was there at all any need for quantitative information gathering? The conclusion was no, because what was actually sought were qualitative factors contributing to a pleasant user experience that could not be read from simple statistics. Thus, quantitative information gathering was discarded from the process altogether to give room for more extensive and profound qualitative research.

This approach, however, came to an extreme during the evaluation phase when determining which layout to choose for the final concept. When collecting all of the data, the amount of quantitative feedback from the post-test forms was not enough to depict an accurate representation of the experiences, but still, these results were considered in the selection process. For example, very few data points from standing passengers gave the layouts scores that may not have been accurate. The total average score also took into account all three semantic word scales from the cyclists, whereas standing and sitting passengers only produced one semantic word scale each. This means that the input from the cyclists was largely dictating the end results. The weighting of these scales should have been considered to give a more fair representation of different experiences, but qualitative feedback also showed that Layout 3 was favoured in many instances, so it is not clear whether a different evaluation method would have changed the outcome.

#### **Experiences, values and their universality**

Studies and participant selections in this project could be altered to explore another group or context and would probably yield different results. The mix of people is especially interesting, as the method of analysis pays attention to how many times something is expressed. Accepting the idea of experience as divisible down to some atomic level explained at the beginning of the thesis, the mix of participants matters for the result, as the concentration of experiences observed matters. A homogenous group

with a similar frame of reference in some aspect can be presumed to provide more similar answers, which will, in turn, be perceived as them sharing a similar experience during the analyses. For example, a group of students living in Gothenburg will presumably have more recent experience with bikes and *Älvsnabben* than a family living slightly out of town with a disabled child. This will result in a very different discussion within each group, leaving noticeably different material to analyse. This points towards the results being hard to compare, as they are relative to each session and each group analysed.

Also, the authors' frames of reference should be considered. Swedish men, aged 25, living in Gothenburg studying Industrial Design Engineering will definitely have a frame of reference that limits the extent to which the experience of several user groups can be understood. For example, the probability of two 25-year-old men being aware of and properly understanding the situations exclusively women might find themselves in public transport would be naive. Thus, even though there are women well represented in the tests, to what extent are we fully capable of representatively assessing their answers?

It is interesting to speculate on how the participants' experience and the authors' frames of reference could have affected our results and designs. One immediate thing that stands out, at least to the authors, would be the lack of insight into the experience of passengers with limited mobility. More specifically, passengers without mobility aids that fall somewhere in between significantly impaired and typical mobility. Say, for example, a senior passenger. It is safe to say it is more common with limited mobility among seniors, and that is why there is priority seating with symbols of the elderly in trams and buses. If someone with such experience had been involved, they would have generated quotes and supplied perspectives influencing the design process. What relative effect could this perspective of one limited mobility passenger have on the author's analysis of the shared user experiences? What would be found if a study was conducted exploring a group belonging to this demographic, relating and making sense of people with similar experiences? But also, what perspectives would be lost in a study with such a homogenous group? And one final question, always relevant: What would the difference in patterns and details found when analysing these studies be if they were conducted by people with different experiences?

### **Limits of collecting atomic experiences**

During the project the discussion around experience was characterised by a focus on experience as consisting of many smaller elements of experience, dubbed atomic experiences in the introduction section. For example, many participants could have a different total experience and take-away from the test but still experience aspects of the test environment in the same or similar way. These aspects were then discussed in isolation, such as the perceived tightness of the space or the premium experience of boat travel. Some immediate benefits of assuming this perspective are the ease of approach and assessing one aspect of the interior at a time. But it is easy to be sceptical

of this narrow perspective, not able to account for the complexity of a user's total experience. It was learnt from the perspective of atomic experience that it tends not to account for important factors only visible in the full picture of a use situation.

Let's say the majority of participants expressed satisfaction with the layout's feeling of spaciousness. The residual minority provides an explanation which is recorded. Say most of the people feeling cramped were cyclists who had to stand and chose to do so by their bikes. During the analysis, this might imply cyclists dislike this choice of layout. But one of the participants who agreed was a cyclist who managed to get a seat in the back. This exception might imply the cyclist's dislike can be counteracted by providing seating in the back, or moving them to another part of the interior. Disregarding that this satisfied cyclist's experience might not be representative at large illustrates some issues. We see the possibility of many factors affecting a so-called atomic experience. It was also noted that aspects of the interior other than the one analysed can have an effect on the user's experience of the current aspect of interest. When sorting and analysing atomic experiences pertaining to a given aspect of the design, it is impossible to paint a full picture of why such an experience was had.

But a line has to be drawn somewhere. It is impossible to map the entire network of interaction between different aspects of the interior and all dispositions of possible users. What should be considered is how much of a simplification can be made, still providing answers true enough for the specific situation.

### **Limiting factors**

A significant factor that impacted the project was the budget. Since the project was carried out in collaboration with a start-up company they were, understandably, unable to offer advanced resources as the cost of development had to be held low. With very few employees dedicated to the project, it also meant that most of the labour of building the prototypes and test environments for the evaluation had to be carried out by the authors themselves, limiting the fidelity level for the mock-up. It is reasonable to assume that a mockup representing more aspects of a finished concept would affect the participants' experiences in the test, e.g. if the panels were true glass or if the motion of the ocean could be replicated. However, it is difficult to assess whether or not this impacted the final concept.

Despite the limitations of working in a start-up environment, there were also upsides. The company's small scale meant that information could be passed around quickly throughout the organisation, and decisions could be made on short notice. It also meant that the thesis students could work independently and had more control over the process and outcome of the project, which was a motivating factor.

### **Novelty of concept**

Since the project concerned the development of a novel product concept, there were no existing products to evaluate and compare against, and, to the authors' knowledge, no

prior research on the topic of small autonomous boats for public transit, which meant that assumptions had to be made in regards to how the product would be perceived and experienced by future users by comparing it to other modes of public transit during research and evaluation. If the assumptions were correct remains to be seen if the concept goes to market. Limited research was done on behaviour around autonomous cars, but no inquiries into the subject were made during the user studies, as it would be difficult to simulate, given the fidelity of the test environment.

### **Designing for a system in motion**

During the course of this thesis, the development of the Cstrider vessel progressed. Information about the occurrence and placement of certain essential elements in the boat changed alongside parallel development, which affected the layout of the passenger space. These were never definitively defined, meaning the studies had to be carried out without these constraints in mind. It is reasonable to assume that the additional knowledge of and adherence to the fixed placement of these essential elements (emergency steering, skipper area and placement of life vests) could have altered the results and generated different layouts.

## **6.2 Discussion of Methodology**

The methods chosen for this project align with what can typically be expected from a user-oriented design project. The studies conducted during the research phase all aimed to increase knowledge of the field, and both the literature review and observation are familiar tools that produce consistently reliable results. The CARE study, however, was a novel tool for the authors during this project. The doctoral dissertation containing the CARE approach was recommended as material for this project's research and seemed applicable as it was a tool meant to explore user experiences of not yet existing technology. The description of the method was interpreted and executed as an early user study to generate ideas as a basis for discussion and development in the later ideation phase. It is unclear whether the details of the study were interpreted correctly as the author of the CARE method was not consulted, but the results yielded were deemed satisfactory and useful for the continued work.

### **Discussion of ideation**

When ideating solely on paper, as was the case prior to the construction of the mock-up, a considerable amount of time was spent on developing ideas that were impossible to implement in the 1:1 scale version of the interior. An example of this was the idea to have 5 seats in the front row, which looked good on paper but very suboptimal in real life. Had the mock-up been built before the ideation, such ideas could have been quickly tested and discarded. Rather than deciding on structured brainstorming sessions, the ideation phase was characterised by spontaneous creative sprints and discussions whenever an idea popped up. This allowed for parallel work in the meantime, and no time was wasted trying to push out ideas. The drawback of this

approach, however, was that it was difficult to keep orderly track of everything that had been done, and thus, each idea may not have been as thoroughly explored as would have been preferred, especially with regard to possible variations. To counteract this, it was later decided that all possible combinations would be considered by dividing the boat interior into six sections: one dividing line in the middle, splitting the interior into left and right, and then perpendicular lines split the interior into a front, middle and rear section. This helped visualise all possible constellations in each section, but it generated too many possible combinations and did not directly lead to any useful results by itself. Rather, it helped paint a picture of how certain combinations of elements worked well together while other combinations proved lacklustre.

### **Discussion regarding the construction of the mock-up**

The construction of the mock-up took significantly longer to complete than initially planned. Careful adherence to dimensions gained from the CAD files provided by Cstrider required precision and calculation to translate correctly in the real-life model. Attention to structural integrity for the safety of the test participants also contributed to the increased construction time. The initial timeline for the construction was set to two weeks. However, an additional week of building was required to complete the mock-up fully, which resulted in less time left for the planning and execution of the UX study for which the mock-up was built. It can also be argued that the mock-up should have been built earlier in the project to assist the ideation.

### **The low diversity of participants in CARE and Evaluative user study**

The CARE study's participants were selected based on convenience and proximity. They were all students in their 20s and recruited on the university premises close to where the testing environment was built. Thus, they were not representative of the entire range of passengers likely to travel with the boat in a real-life scenario. Therefore, the study's results only reflected the experiences and expectations of young, healthy adults, which had to be considered in the ideation and evaluation phases to ensure that diverse user needs were being met. In an ideal scenario, the study would have also included children, elderly people, and people with disabilities or special needs to give a nuanced picture of all existing passenger experiences that needed to be considered in the final design of the boat interior. This meant that the layouts generated in the CARE study were somewhat one-sided, even though many participants explicitly mentioned that they were mindful of people with diverse needs when generating their ideas.

It is possible this caused a cascading issue, as part of the basis for the study design of what was to be evaluated was largely based on the CARE study results. This in turn, made it so it was less likely there was a spotlight on things important to some user group not represented in the CARE study. This highlights the importance of awareness about the effects of low diversity in several stages of the project.

When recruiting participants for the max capacity evaluative user study, efforts were made to include different age groups and have a roughly equal male-to-female ratio. While attempted, it was not possible to include a participant with a disability in the max capacity test as was originally intended, and it ended up being a rather homogenous selection in several aspects. As the test site was only allowing large groups during working hours, it was hard to get adults, most of whom are employed, and in the end, the selection ended up being students and some young adults with the ability to work remotely and a senior. The senior participant representing the elderly was observed not to exhibit many issues associated with the group, as he was an exceptionally healthy 80-year-old, gladly walked and had no issues with standing or manoeuvring the interior like anyone younger.

### **Discussion of the accessibility testing**

The efforts made to include perspectives from potential passengers with real-life experiences of disability did not give the results initially expected. Getting in contact with a network of potential participants was the first hurdle, then getting in contact with someone willing to participate, and then travelling to the somewhat inaccessible location where the test environment was built proved difficult. The only available participant proved to be a child, which was initially viewed as problematic as interviews with children were presumed to be difficult. When a test had been arranged, it proved on-site that the participant also had intellectual disabilities, rendering him unable to speak. The layout of the study had to be adapted on-site, and an interview was conducted with the parents of the participant instead. The results from this study should not be seen as enough or representative of potential passengers with a disability as a whole but as an effort to gain insight to the extent that was possible.

## **6.3 Discussion of the final concept**

There were some contradicting results between the different studies that, to some extent, compromised confidence in the final concept. One example is that most participants in the earlier user study did not consider space limitations, as there was no physical representation of barriers. The authors noted this as a potential source of error during the study. Because of this, many of the resulting ideas from the CARE study have a higher density of elements than would be physically possible to maintain a comfortable amount of free space in the real version of the boat. When conducting the max capacity test during the user study with the 1:1 mock-up, concerns about mobility issues and crowding were much more prevalent. Since the latter study was conducted with higher fidelity, those results have been regarded as more relevant in dictating executive decisions for the final concept.

The layout selected for the final concept aligns with conventional interior constellations found in other modes of public transit, such as buses and trams. There is nothing inherently novel about the concept: all of the elements are familiar to everyone who has

ever used public transit before, but familiarity contributes to comfort (Van de Walle, Turner & Davenport, 2003) and the way that the elements have been placed has been carefully calculated to satisfy as many different users' needs as possible. The downside, however, of trying to satisfy everyone is that there is always a risk of not fulfilling any criteria completely. One example of this is that the selected layout was only the best-performing concept on two evaluation points. It was appreciated by cyclists and sitting passengers but did not stand out as the clear winner, as it just barely scored better than the second-best option on the total average. It did, however, show the most promise in terms of utility, which is why it was ultimately picked.

It is difficult to completely predict users' behaviour and interactions with the interior in a real-life scenario. The evaluative study tried to accomplish this to some extent, but the participants knew they were in a study to evaluate the interior and behaved accordingly. An example of this is the culturally rooted behaviour of preferring to stand up rather than sit next to a stranger. In the proposed layout, this has not been taken into consideration, but a scenario where only half of the seats are occupied and the rest of the passengers stand is not an unlikely occurrence. How to accommodate more standing passengers needs to be further looked into before a full-scale implementation, as it has not been researched for this proposal.

## 7. Conclusion

### **How should the interior of a self-steering boat for public transport be designed?**

A proposal for an interior suited for public transport was presented in Chapter 5. Through an iterative design process, an interior layout suited for urban public transport was created based on results from research, ideation and evaluation. The solution achieves the following objectives:

- The layout is feasible to implement and can be realised in a near-future scenario with current technologies and production methods.
- The solution is innovative in the sense that it differs from any current solutions encountered in the research part of the project. It dares to defy the notion that everyone should have the possibility to sit, but still achieves higher user satisfaction than solutions with more seats.
- The interior allows users access to key features such as priority seating and inclusive wheelchair solutions while not sacrificing efficient boarding and disembarking times.
- The layout accommodates 4 bicycles while still allowing for the maximum number of passengers, a wheelchair, and even a stroller or a second wheelchair.

### **Which aspects of the experience do users perceive as important?**

The proposed solution, selected with regard to user feedback in the evaluation, focuses heavily on accommodating the comfort and utility requirements. By implementing fewer seating modules, mobility throughout the vessel is ensured, and open areas offer more utility as they can be utilised as cargo areas, standing passenger areas due to the rail implementation, and spaces for wheelchairs, strollers or other items requiring empty space. The layout, with its fewer elements, contributes to less cluttering and therefore caters to the “feng shui” requirement more than other concepts, which was confirmed by comments made by test participants in the user study. Moreover, it received praise for being the most accessible and inclusive option. The open layout also implies easier access to emergency exits via the windows.

One requirement, offering the majority of seats facing the direction of travel, has been somewhat fulfilled, as the proposed layout offers exactly half of its seats facing forward. This decision again comes back to the utility of the concept, as the priority seats, facing perpendicular to the direction of travel, offer more space for walking aids.

The only requirements that were unable to be evaluated were solar protection, fortifying the boat experience and making sure that designated spaces (bicycle, wheelchair, etc.) are clearly marked. These requirements are more suitable to be tested in a setting of higher fidelity, i.e., a working prototype on water

**How can a design problem about a non-existent concept be solved in a startup setting with resource efficiency?**

Using methodology from Chalmers' Design and Human Factors department research about eliciting user experience information early on in the design process, a foundation for evaluating something no user has yet experienced was achieved. From the results of this first user study, interior layouts were generated. The insights also affected the design of a second higher fidelity evaluative user study consisting of scenarios and a 1:1 physical mockup. The first user study generated ample material to both guide and be incorporated into the design process, while the second study gave high-reliability data of the full interior experience when evaluating the concepts. These two choices of approach were, in this case, successful and well suited for the startup setting, given there is appropriate competence. This is because their complexity lies in implementing processes and skills in user testing, not in expensive test equipment.

## Recommendations for future work

Listed below are several relevant points of interest that would have been interesting to investigate during the project, but for scope, lack of time or other resources had to be excluded.

During the research phase, it was discovered that public transit passengers generally regard boat travel as a premium alternative to bus or tram travel. This can partly be accredited to the elevated enjoyment of travelling on water, but it was also explicitly expressed during the CARE study that the smaller size of the Cstrider vessel also contributed to this because a vehicle designed for fewer people felt more exclusive. The user tests conducted during this thesis only concerned the spatial aspects of the interior because it was simply impossible to create a 1:1 scale visual representation of the finished product as well during the given timeframe. Therefore, it would be interesting to conduct further testing once a real environment has been constructed, with the correct materials, colours and lighting, to evaluate further what contributes to or enhances the premium feeling associated with marine travel.

Adding to the previous point, while constructing the user tests, it was also discussed how an inviting environment could be constructed for people without much boating experience. Understandably, being on water may be stressful for some people who are not used to marine travel. It is, therefore, in Cstrider's interest to investigate how to make the interior feel safe and reliable for all.

Being secluded on a small vessel in the water with strangers and without any direct escape route may compromise the feeling of safety or induce claustrophobic reactions. Personal safety concerns have been discussed and considered during this project, but further research should be done to determine how personal safety can be improved by adding additional interior elements, such as physical modesty barriers, for example. This should be tested in a live environment with a vessel in the water since the seclusion cannot be accurately simulated using a mockup on land. This aspect is very important to consider during further development, especially since the vessel aims to become autonomous in the future, requiring further assurance from passengers that they are in safe hands. Other elements that are recommended for evaluation in a live environment are the implementation of sun protection, a concern raised during the studies of this project, and how the rocking of waves affects the comfort onboard the vessel.

Finally, the authors recommend further development to improve the physical ergonomics of the Cstrider vessel by determining additional rail placements to improve mobility throughout the craft and support standing passengers. To counteract possible

confusion, symbols, such as floor markings and signs, should be introduced to mark designated areas for bicycles, wheelchairs, and priority seats.

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# Appendices

## Appendix A: Observational field study template

### Observational field study template

#### What kind of people are travelling?

- Disabled people, cyclists, parents, regular people
- In what company do they travel? Alone or in groups?
- What do people bring on board?
- Observe movements and flow of people during boarding/off-boarding.

#### What are people doing on board?

- Being productive?
- Looking out the window?

#### Are there any other important social factors?

- Be on the lookout! Are people behaving as expected, or can we observe something that surprises us?
- Why, in that case?

#### How is the flow at the stops?

- Where do people choose to spend their journey? In what order do the seats get filled?

#### How much room for passage is actually needed?

- How is the flow through:
  - Doors
  - Aisle
- How do people move depending on if it is empty/full in the vehicle?

#### Is there any difference in how people travel on city buses and commuter buses?

- Activities on board?
- How people sit?

#### What is the ratio between priority seats/wheelchair spots and regular seats?

#### Remember: How are different user needs prioritised?

#### Sketch layout and seating solutions

- When observing with a sketching eye, you see things you would normally miss!

#### Other observations

- See anything else of interest? Take note!

## Appendix B: CARE test document template

### Setting the stage for MAB (mini-autonomous-boat)

**Welcome! We are happy you want to help us with our project. This is our first user test, during which we study how participants experience the interior space of a small, autonomous watercraft being developed by Cstrider.**

**First, some formalia:**

Do you consent to being documented, leaving your real name out, in imagery and the answers you provide? Anything related to your person will be stored and discarded in accordance with regular GDPR practices. Please sign your name on our makeshift list of conditions. Further permission will be asked if we want to use any imagery in the report/presentation.

It's time for testing! This is how we will structure this session: First, we will put you in a context, then ask you to act and interact with the available test material. Finally, we will give you time to reflect.

**Context:**

This is Cstrider's small autonomous waterborne vessel, or the MAB (short for mini-autonomous-boat) as we will refer to it in this study for simplicity's sake (name still pending). It is a small boat where 12 passengers are allowed onboard. This space marked before you is the available indoor flooring area. Here, we want you to act and interact with the material available to you. Please do speak your thoughts. There is no right or wrong, we only want one thing, and that is your experience of the space and situation!

But before this, we want to prime you a bit. Imagine you are travelling over Göta Älv. Which public transport options have you used to achieve this? Have you traveled by bus, ferry or tram or all of them? How is that experience? Tell us.

**Act and Interact:**

You are down at Stenpiren. It is a regular day, and you are standing at the edge of the dock. You enter the boat from the back. The boat's interior area is marked by the yellow tape on the floor. The marked area in the front is under a sloping front windshield where you cannot stand up straight. The markings on the rear edge indicate the doors. How do you want to sit? Tell us some positive and some negative elements of what you end up making. Ask us questions.

*Ready-made questions to keep the process going:*

- *There are cyclists on the boat. Where would you put their bikes? Positives and negatives?*
- *There is a wheelchair on the boat. Where would you put them? Positives and negatives?*
- *You are alone/the vessel is full. How should people sit? Positives and negatives?*

**Reflection:**

Play around with your constellation. Give us the best parts, the ones you remember, of your boat travel experience. Give us your worst experience from the inside. Think back, did it feel like something was lacking from inside the boat? What surprised you about the experience?

# Appendix C: Pugh matrix evaluation of concepts

Concepts	C1	C2	C3	C4	C5	C6	C7	
<b>Requirements</b>								
(3) Complete access to emergency systems	0	-	-	-	0	+	+	0
(4) Allows for safe and convenient bike storage	0	0	-	-	-	0	-	0
(3) Provides priority seats for the elderly/disabled	0	0	+	+	+	+	0	0
(3) Provides a sense of being spacious & ease of movement	0	0	+	+	+	0	+	0
(3) Support for standing passengers	0	+	0	0	0	0	+	0
(4) Provides space for luggage	0	+	0	0	0	+	+	+
(3) Provides easy supervision of luggage	0	+	0	+	+	+	+	0
(3) Provides all passengers with a good view of the outside	0	0	0	-	-	-	0	0
(4) Forward facing seats where possible	0	-	-	-	0	-	-	0
(1) Offers social space	0	+	+	0	0	+	0	+
(4) Provides physical or cognitive shelter from other passengers, i.e., "modesty barriers"	0	0	-	+	+	+	0	0
(3) Has "hug shot"	0	-	-	-	+	+	0	-



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