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Information at Hand

Designing a Mobile Information Interface for Semi-Autonomous Ferries

Master's thesis in Interaction Design and Technologies

Alfvar Arvidsson

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Department of Computer Science and Engineering
CHALMERS UNIVERSITY OF TECHNOLOGY
UNIVERSITY OF GOTHENBURG
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Abstract

As the maritime industry explores autonomy to improve safety and efficiency, public skepticism remains a barrier for passenger ferries. Cstrider proposes a solution to this problem by maintaining a human navigator onboard while still allowing autonomy to handle routine navigation. Unlike traditional ferries, a central part of this proposal is allowing the the navigator to stay informed of the ferry's status from anywhere inside the ferry through a portable interface, removing the need for a stationary helm.

This thesis investigates how such a portable interface can support human-autonomy team operation in a semi-automated ferry context. Building on theory from the fields of interaction design and Research through Design, this study utilizes a literature review, field observations, and iterative prototyping to identify best practices for designing in this specific context. Two interface iterations were evaluated with maritime professionals, to establish a usability baseline and identify which values from their professional experience are important to include in an interface for this context.

The result is four design guidelines on the topics of situational awareness, system transparency, anomaly detection and actionable information. The guidelines are further exemplified by a prototypical interface, which together with the guidelines contribute to the literature on human-autonomy teaming through exploring a novel operational context.

Keywords: Interface Design, Autonomous Ferry, Interaction Design, GUI

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1

Introduction

In this chapter, the purpose of the thesis is presented and motivated, together with a research question. I also introduce the stakeholders and delimitation.

1.1 Aim

Autonomous ships are attracting the attention of the maritime industry due to promises of improved safety, reliability, and cost-effectiveness (Chang et al., 2021). For implementing autonomy in urban passenger ferries, the only previous research effort required having a navigator on board for safety reasons (Alsos et al., 2024). They also explored moving navigation to a shore control center, proposing that passenger ferries become unmanned (Alsos et al., 2022) similarly to what has been suggested for cargo ships (Chang et al., 2021). Despite this, studies have shown that passengers do not trust the safety of ferries that operate without a human on board (Munim et al., 2022).

Cstrider is a company that develops passenger ferries with a varying degree of autonomy for deployment in urban environments. They are approaching this issue by developing a semi-autonomous ferry that can scale to a more automated approach if deemed trustworthy by passengers. For that goal, an information interface must be designed in such a way that a navigation system is controlling the ferry, but the navigator stays informed enough to be able to take back control whenever necessary. The navigator must be able to attend to other duties while the system is navigating for the solution to benefit from the autonomous navigation, suggesting the need for a portable information system.

To the best of my knowledge, no previous research has explored how to develop an information interface for single-crew semi-autonomous passenger ferries. Therefore, the aim of this thesis is to design a prototypical information interface for this context, with the purpose of continuously informing the navigator of the status of the vessel.

1.2 Research Question

To make a meaningful knowledge contribution to the context outlined above, the following research question has been formulated:

RQ: How should maritime information interfaces be designed to support navigators for semi-autonomous ferry crossings?

1.3 Stakeholders

1.3.1 Chalmers University of Technology

Chalmers University of Technology is the university for which this thesis work is written. This thesis is based on their guidelines, and support in this effort is given by supervisor Ilaria Torre and examiner Morten Fjeld. The experience gained through the Chalmers' Interaction Design and Technologies master's program will be utilized in completing this thesis work. This includes, but is not limited to, methods and concepts from the courses *Graphical interfaces (DAT595)*, *Emerging trends and critical topics in interaction design (DAT540)* and *Information visualization (CIU187)*.

1.3.2 Cstrider

Cstrider is the company who suggested this thesis topic. They are developing a semi-autonomous electric ferry platform intended to scale with the demands of each particular route of operation.

They are targeting sustainability needs by utilizing green electric energy and a low passenger count per vessel, allowing for less empty seats per crossing and matching supply more dynamically with consumer demand. Further, by incorporating non-stationary navigation and information systems, the ferry operation can become more efficient as the navigator can be assigned to other duties. As this is an important aspect of Cstrider's value proposition, they have a significant stake in the success of this thesis work.

1.3.3 Users and proxy users

The users of a maritime information interfaces would have a high stake in its successful development. If automated ferry systems demand its navigators to tend to other tasks than navigation, it is of critical importance that they are alerted when they are expected to intervene. Further, Cstrider has observed a general decline in the availability of certain maritime professionals, but certified captains with a Swedish "Fartygsbefälsexamen klass VIII" license remain relatively accessible on the job market. Since this certificate does not require extensive prior sea service (Sjösportskolan, n.d.), the expected users of the interface may have limited maritime experience. This places high demands on the interface presentation.

This also has implications for the proxy users, or passengers, concerned with the safety of their crossing. Both the safety and the way safety is communicated to the proxy users is assumed to be central to the viability of the outcome.

1.3.4 Delimitation

The aim of the project is not a fully functional prototype, partly because the semi-autonomous ferry where it would reside is still in development and partly because of the project's focus on interaction design. This has to be taken into account during evaluation. While the evaluation should preferably take place in an appropriate physical location (onboard a small passenger ferry), a real navigation context will not be achievable for the scope of the project. I will present a scenario to the users to help compensate for this, but there is still no guarantee that it aligns exactly with real-world usage.

2

Background

2.1 Autonomous ships

Autonomous ships have been defined by the International Maritime Organization (2021, p. 3) as ships that “to varying degrees can operate independently of human interaction”. The classification of autonomous ships is not binary and a four-level scale has been developed by the International Maritime Organization (2021), where the first level involves human collaboration with decision support systems, and the fourth level is a ship that operates completely independently of human involvement.

Autonomous ships have received significant scholarly attention, especially in relation to the transport of goods (Chang et al., 2021). This focus could stem from the complex implications that semiautomatic ships could have for the industry, where both benefits and issues have been identified. Although the initial costs of autonomous ships are higher, they are financially viable long-term (Čorić & Nikšić, 2022). A frequently cited benefit is the reduction of human error (Guo et al., 2023), however some authors argue that while human error during operation might decrease, new forms of error may be introduced while developing autonomous systems (Chang et al., 2021).

2.1.1 Autonomous ferries in urban environments

The goal of dispatching ferries in urban environments is generally to complement and offload established public transport solutions, as well as providing access to areas where water would otherwise be a barrier (Čorić & Nikšić, 2022; Smogeli, 2023). The availability and cost of certified crew significantly hinder the expansion of this infrastructure (Alsos et al., 2024).

Fittingly, the central promises of autonomous ferries in urban environments are reduced costs of operation (Čorić & Nikšić, 2022; Guo et al., 2023) and less reliance on certified crew since they per definition require less human intervention. They are also safer in operation (Guo et al., 2023) and possibly provide environmental benefits (Čorić & Nikšić, 2022) which suggests that autonomous ferries are a well-suited candidate to solve the presented issues.

While some research argues that level 4 autonomy is required to achieve maximum economic, environmental, and sociological benefits (Čorić & Nikšić, 2022), studies have shown that users would not trust ferries with level 4 autonomy (Munim et al.,

2022) despite the safety claims (Guo et al., 2023). Some research suggests exploring incentive mechanisms to mitigate this (Munim et al., 2022), but another possibility is that the public simply needs time to accept new innovation, since design redefines the context it is based upon (Gaver, 2012; Rosson & Carol, 2002).

2.1.2 Ship’s bridge systems

The traditional ship’s bridge is a collaborative work environment from which multiple seafarers operate a ship (Nordby et al., 2019). Further, poorly designed ship’s bridge systems have been linked to human error-related accidents during maritime crossings (Nordby et al., 2019), which suggests that navigational interfaces play a key role in providing successful maritime traffic. Following general technological development in society, the role of the navigator has been altered to become more reliant on external tools (Conceição et al., 2018; Veitch et al., 2022) which in turn alters the context for maritime navigators.

2.2 Previous research on autonomous ferries

While theoretical studies on autonomous ferries exist (as seen in section 2.1.1), at the time of writing the only practical implementation is the Milliampere2 project, an all-electric autonomous passenger ferry developed in Trondheim, Norway (Alsos et al., 2024). Their ferry was deployed for three weeks as a trial operation during working hours and operated on a predefined route as a shuttle or virtual bridge (Alsos et al., 2024). Navigation was done using a contemporary dynamic positioning system to achieve autonomous navigation with collision avoidance, and a technician was on board for all crossings (Alsos et al., 2024). While Alsos et al. (2024) describes a vast amount of data collected including 164 passenger interviews, 884 passenger surveys and workshops with ship technicians, the outcome of the study is instead framed as practical recommendations for conducting similar studies for autonomous ferries. While their study had a different focus than this master thesis, several of their recommendations were taken into account for this study such as *Understand the context and area of operation* and *Start with explorative and broad research objectives and finetune these throughout the process*.

Alsos et al. (2024) provides an authentic context for exploring passenger perceptions of autonomous ferries, something that has been missing from previous studies such as Munim et al. (2022), which explores a similar context from a hypothetical perspective. Similarly to my findings, Alsos et al. (2024) found no other research regarding autonomous passenger ferries in operation.

3

Theory

In this chapter I will cover theories about the relationship between design and research, as well as concepts and theories in other ways related to the topic of this thesis work.

3.1 Interaction design

Interaction design is the practice of “creating user experiences that enhance and augment the way people work, communicate, and interact” (Sharp et al., 2019, p. 9). One of the core premises of interaction design is that a number of benefits in terms of efficiency and adoption come with designing products with their users in mind (Cooper et al., 2014; Sharp et al., 2019). This principle has a number of consequences for the design process and several methods for user involvement are detailed in chapter 4.

3.1.1 Graphical user interfaces

The digital medium has almost no inherent constraints with regards to material characteristics, which has resulted in a natural development of rules and frameworks for the digital medium as a design space (Löwgren & Stolterman, 2004). Similarly to the broader category of interaction design, when the graphical user interfaces (GUIs) of digital products are aligned with the goals of their users, users will be more effective and satisfied (Cooper et al., 2014).

For developing GUIs, Cooper et al. (2014) identifies several properties that should be defined to serve the goals of the users. Cooper et al. (2014) also establishes a hierarchy for when to define these properties. These are the following:

1. **Form factor, posture and input methods:** These are fundamental properties which influence further decisions for the artifact. Form factor regards the properties of the display as well as its surroundings and how the GUI relates to any involved hardware. The concept of posture regards how much attention the user is expected to afford to the interface. Input methods are determined by the previous two properties as well as preferences and needs of the user within the context.

2. **Functional and data elements:** These elements are tightly coupled to the requirements that stem from user needs. Data elements refers to what is displayed and accessible to the user, and these should align with users' expectations and mental models of the information.
3. **Functional groups and hierarchy:** Each element of the interface is divided into a hierarchy with logical groupings. This involves things such as determining which items need more screen space, which items are used together and what information the user needs to know at a particular moment.

3.1.2 Gestalt psychology

Gestalt psychology refers to a theory of visual item presentation that highlights the relationship between visual objects and the parts they are constructed through (Wagemans et al., 2012). The theory is relatively broad but offers a series of principles that have practical implications for interaction design, as effective use of Gestalt principles contributes to effective design results (Interaction Design Foundation, 2016). The theory presents several principles which can help determine hierarchy and logical groupings in humans' perception of forms. For organizing shapes, two key themes are described as "perceptual grouping" and "figure-ground organization" (Wagemans et al., 2012). They complement each other in that figure-ground organization distinguishes figures from their background, and perceptual grouping assesses the relationships between figures (Wagemans et al., 2012). Relevant principles for perceptual grouping in interaction design, as discussed in Wagemans et al. (2012), include:

- **Closure:** When a curve forms a closed or almost closed figure, the curve is perceived as a bounding box for the figure, and the figure becomes the infill of the curve.
- **Common region:** When figures are placed within a confined area, they appear to belong together. They are perceived as being "inside" a larger container.
- **Proximity:** The perceived strength of grouping between multiple figures is amplified as they are brought closer together.
- **Similarity:** Figures with similar properties in terms of appearance are perceived as part of the same group.

While figure-ground comes with its own set of principles in psychology (Wagemans et al., 2012), interaction design practice has chosen to label it as a single principle for effective interaction design (Interaction Design Foundation, 2016). Effective use of figure-ground involves ways to establish some form of contrast between the focal figure and background (Interaction Design Foundation, 2016).

Effective use of Gestalt principles is critical to good design as it aids the user in efficiently navigating and interacting with GUI:s (Interaction Design Foundation, 2016)

3.2 Interaction design for maritime navigation

Maritime navigation is a highly complex system where crew members interact with different interfaces to maneuver and navigate a vessel (Conceição et al., 2018). This can take place via a bridge, from which both monitoring and interaction roles can be executed (American Bureau of Shipping, 2018). The scope of the bridge operation varies depending on several factors such as the purpose of the vessel, but the design of the bridge is of high importance to the success of navigation (American Bureau of Shipping, 2018). With recent technological progressions the role of the navigator has shifted towards monitoring crossings, delegating the operational role to autonomous systems (Conceição et al., 2018).

3.2.1 Human-autonomy teaming

Human-autonomy teaming (HAT) has been defined as a process where at least one human works towards a common goal with at least one autonomous agent, which has some degree of self-governance (O’Neill et al., 2022). The field has seen practical relevance only recently (O’Neill et al., 2022) and a key tool for successful HAT is trust, defined as: “the attitude that an agent will help achieve an individual’s goals in a situation characterized by uncertainty and vulnerability” (McNeese et al., 2021, p. 54). Central aspects for engendering trust in autonomous systems are system transparency and communication of intent (McNeese et al., 2021), which involve informing the human team members of how the autonomous agent operates as well as its plan of action (O’Neill et al., 2022).

3.2.2 Situational Awareness

Situational awareness (SA) has been described as being aware of one’s surroundings, but in research it is generally centered around awareness regarding a current task (Endsley, 2000). The concept is relatively mature as it emerged in the 1980’s, and facilitating SA essentially focuses on presenting relevant information to system users (Endsley, 2000). As it seemingly concerns the same issues as theories on interaction design and GUI:s, one might argue that interaction design theory has superseded SA theory. However, SA theory presents an angle focused on cognitive focus and attention which has important implications for the design of complex systems such as maritime navigation.

Humans focus their attention to gather information deemed to be important, and distraction is the single largest culprit to SA-related user errors in system operation (Endsley, 2000). Endsley (2000) describes both salience of interface cues and the user’s purposeful direction of attention as central components in finding critical information. While purposeful direction of attention stems from learned patterns and broader goals (Endsley, 2000), interface cues seems to be highly addressable through GUI design. SA is not a binary concept, and Endsley (2000) introduces a model that describes SA in three levels:

- **Level 1 (Perception):** The ability to detect cues in the environment and interpret their meaning.
- **Level 2 (Comprehension):** The ability to combine and extrapolate information from multiple cues, providing a more sophisticated overview of a situation.
- **Level 3 (Projection):** The ability to anticipate future events and their implications, which gives operators with level 3 SA the highest level of understanding of a situation. “It is the mark of a skilled expert.” (Endsley, 2000, p. 4).

Further, how much time is available before action needs to be taken is commonly critical for SA, and more dynamic situations (with a higher rate of information change), requires humans to re-evaluate their SA constantly, to not render it out-of-date (Endsley, 2000).

3.2.3 Maritime GUI design

Maritime operations are increasingly relying on digital systems, raising questions about how the state of the vessel is presented to users (Conceição et al., 2018). One central issue is display overcrowding, and several ways to prevent this have been suggested, such as grouping related elements based on location and visual appearance (Conceição et al., 2018) similar to the suggestions found in Cooper et al. (2014). This suggests that interaction design practices translate well into maritime GUI design. Examples of how GUI elements can be “related” in this context include whether they are part of the same task flow, which system they belong to or which function they serve (American Bureau of Shipping, 2018).

3.2.3.1 Openbridge

Since traditional ships’ bridges are typically populated with equipment from multiple vendors, the industry has recognized inconsistent information display as a problem affecting human error and operational efficiency (Nordby et al., 2019). The Openbridge project argues for centralizing the GUI and integrating vendor-specific tools therein.

In this effort, the Openbridge project has released a set of GUI components, design patterns and icons that aim to standardize industry best practices in a well-designed way (Nordby et al., 2019). Further reading on the Openbridge design system can be found at their website: www.openbridge.no.

3.2.4 Alert Standards

Alerts are cues that direct an operator’s attention towards a time-critical task (Lloyd’s Register, 2024). Due to their critical nature they follow strict regulations in the shipping industry, where the International Electrotechnical Commission (IEC) has defined standards that were adopted by the IMO (International Electrotechnical Commission, n.d.-a) which in turn has lead to widespread adoption. IEC is a non-profit organization that develops standards regarding safety, performance

and interoperability of electric and electronic devices and systems (International Electrotechnical Commission, n.d.-b).

Alerts come in four levels of priority: emergency alarms, alarms, warnings and cautions, and their presence in the GUI (see Table 3.1) should be appropriate to the severity of the anomaly they describe (International Electrotechnical Commission, n.d.-a; Lloyd’s Register, 2024). It is also notable that these are adapted for ships large enough to have a dedicated bridge. While caution-level alerts are either present or not present, the other three levels have different states based on if they are acknowledged or the severity of the anomaly.

While the IEC list of events that justify a particular alert are not publicly available for free, example implementations and best practices can be found online, highlighting their usage (American Bureau of Shipping, 2018; International Electrotechnical Commission, n.d.-a). Key takeaways from American Bureau of Shipping (2018) include:

- The user interface needs to clearly distinguish between alarm, acknowledged alarm and no alarm.
- Visual alarms should be presented in a way that is distinct from normal user interface, and flash after being introduced until they are acknowledged.
- Alarms that are audible should be accompanied by a visual cue, and the sound should stop upon acknowledgment.
- Alerts and alarms should be implemented as sparsely as possible.

The last item in the list refers to a phenomenon known as alarm fatigue, which has been studied extensively (Lloyd’s Register, 2024). Alarm fatigue refers to that the quality of the overall navigation can be harmed due to excessive alarm reporting (Lloyd’s Register, 2024).





Symbol	Alert Level	Description	Sound Pattern
	Emergency Alarm	Danger to life or vessel	Constant sound until resolved
	Alarm	Risk of unsafe crossing if not acted on immediately	Three short signals repeated after 7–10 sec
	Warning	Requires immediate attention, action can wait but may escalate	Two short signals repeated at 15 sec–5 min intervals
	Caution	Anomaly, no immediate attention needed	(None)

Table 3.1: Overview of the different alert levels as defined by International Electrotechnical Commission (n.d.-a).

3.3 Research through Design

Research through Design (RtD) as originally introduced by Zimmerman et al. (2007) is described as a research method for gaining knowledge through creation. More precisely, by taking existing knowledge and integrating it into a novel artifact that transforms the world from a current state into a preferred state (Gaver, 2012; Zimmerman et al., 2007). The method allows the use of a design process for research purposes, but abandons the notion of being reproducible (Zimmerman et al., 2007). Because of this, Zimmerman et al. (2007) suggests four new criteria for evaluating the quality of RtD projects:

1. **Process:** While the outcome of a RtD project isn't expected to be reproducible, the process is. The documentation must be detailed enough to show how the project has been undertaken, motivate the methods selection and that it was conducted in a rigorous manner.
2. **Invention:** The created artifact must be different from contemporary solutions in the same domain, to such a degree that it can be considered novel. Further, the documentation must state in what way technical new innovations could improve the novel artifact.
3. **Relevance:** This criterion is presented to be the equivalent of scientific validity for RtD projects. Since results aren't expected to be reproducible, motivating the relevance of the novel artifact is considered central. Further, the relevance has to be contextualized based on what preferred state of the world the researchers aim to create.
4. **Extensibility:** The presentation of the novel design should be done in such a way that further research can extend it. This is central in what makes a RtD project a knowledge contribution, and not just a new artifact.

While design outcomes are typically solutions to problems, within RtD they are also required to serve as examples of how an artifact can transform the world into a preferred state within the selected domain Zimmerman et al. (2007). Gaver (2012) offers a complementary view to the one established by Zimmerman et al. (2007), stating that artifacts themselves do not embody design knowledge in an adequately rigorous way. To highlight features that are central for the success of a design, Gaver (2012) suggests that designs should be presented in an annotated portfolio. This complements the model in Zimmerman et al. (2007) by articulating the underlying rationale behind an artifact.

3.4 Reflective design

Reflective design is an analytical framework for the design process which shifts the focus from usability and efficiency to highlighting the values embedded in design artifacts (Sengers et al., 2005), effectively questioning the previously mentioned *preferred state*. Borrowing its philosophy from critical design, the reflective part is naturally critical and helps redefine the new context established by a design artifact

(Sengers et al., 2005). The design artifact in turn serves the purpose of a *technology probe*, used as a tool to generate reflections about the status quo and make it explicit (Sengers et al., 2005). This makes reflective design particularly useful when there are implicit assumptions within a design context, or when the status quo is deeply normalized.

When adopting the reflective design framework in practice, Sengers et al. (2005) emphasizes that it is particularly important to encourage and embrace skepticism as a natural part of reflective design. While it seems appropriate to align with a solution-oriented outcome for RtD, keeping a reflective and questioning stance during the process is likely to result in a more rigorous outcome.

3.5 Models of the design process

Several models have been created to represent the design process, and while they are often not prescriptive they can be a good way to understand what activities to undertake and in what order (Sharp et al., 2019). However, since the design process is shaped by the context of the specific design situation as well as the characteristics of the designers involved, the process is unique for each design situation (Löwgren & Stolterman, 2004). One could therefore argue that methods *have* to be adapted to the specific context to account for the complexity of the specific design situation.

By the same notion, following a rigid design process could harm the quality of the outcome, especially in experienced or smaller teams where the need for guidance is lower (Sharp et al., 2019); by this notion modifying existing design process models ought to be encouraged. The fact that there is a vast number of different process models for interaction design (Sharp et al., 2019) also supports this argument. Below, a selection of widely accepted design process models are presented.

3.5.1 The Double Diamond model

One model of the design process is known as the Double Diamond model (Design Council, n.d.):

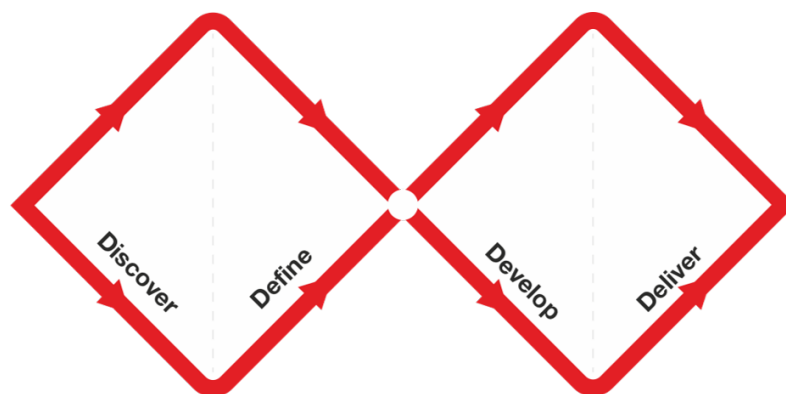


Figure 3.1: The Double Diamond model, as introduced by the Design Council (n.d.)

The Double Diamond model is characterized by four phases of **Discover**, **Define**, **Develop** and **Deliver**. It can be interpreted as two groups (“diamonds”) with two phases, where the first “diamond” is about understanding and defining a problem space, and the second one is about providing a novel solution to the now defined problem (see Figure 3.1). Its authors propose that it is followed in a rather non-prescriptive way: “It’s not an instruction manual on how to design, it’s an invitation to get involved.” (Design Council, n.d.), but one notable characteristic of the model is that it completely leaves out the concept of iteration.

3.5.2 The Agile Manifesto

Contrary to the Double Diamond model, the Manifesto for Agile Software Development (or simply Agile Manifesto) (Beck et al., 2001) advocates for a highly iterative environment. They have published a set of software development principles that at the current time of writing has 5627 citations on Google Scholar, suggesting that while not an outline for a design process, it is a widely accepted mindset for managing a development process. The two most central principles concerning iterative design are principle 1 and 2:

- **Principle 1:** “Our highest priority is to satisfy the customer through early and continuous delivery of valuable software.” (Beck et al., 2001, para. 3)
- **Principle 2:** “Welcome changing requirements, even late in development. Agile processes harness change for the customer’s competitive advantage.” (Beck et al., 2001, para. 4)

Aside from several other principles for software development, these two principles advocate for frequently updating requirements as a strength (Beck et al., 2001).

3.5.3 RtD process model

The RtD method as introduced by Zimmerman et al. (2007) invites the use of a design process for the purpose of gaining new knowledge. To achieve this, Zimmerman and Forlizzi (2014) suggest their own design process consisting of: **Select**, **Design**, **Evaluate**, **Reflect and disseminate** and lastly **Repeat**. Given that these steps were developed by the co-authors of RtD, an implication might be that this design process works particularly well together with RtD. However, Gaver (2012) argues that formulating a standardized, overarching theory contradicts the inherently generative nature of RtD, which further supports the notion that not following a predefined design process is a valid and appropriate approach within RtD.

3.5.4 Interaction Design Lifecycle Model

Sharp et al. (2019) suggests a design process model that references the Double Diamond-model, but labels its four phases **Discovering requirements**, **Designing alternatives**, **Prototyping** and **Evaluating**. The steps revolve in a circle, and each step allows the designers to return to the Designing Alternatives-phase. It also offers a path from Evaluating to Discovering Requirements (see Figure 3.2).

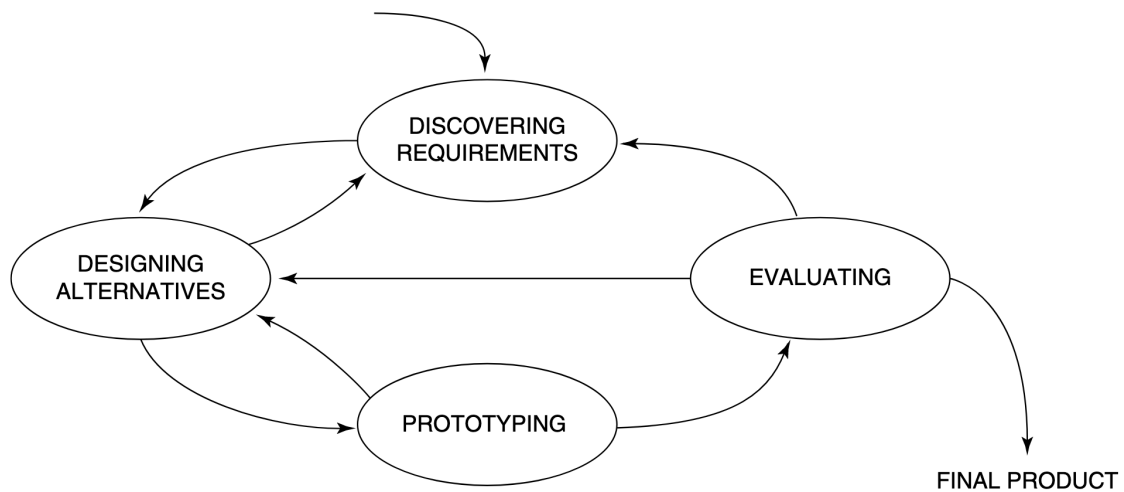


Figure 3.2: Interaction Design Lifecycle Model, introduced by Sharp et al. (2019)

This model references the iterative process of the Agile Manifesto while still being tied to the roots of design. This suggests that it is a suitable model to use as a scaffolding when designing the methodology for this project.

4

Methodology

Following the reasoning from section 3.5, methods should be carefully selected to prevent them from taking a prescriptive role in the design process. In this chapter I describe a selection of methods that are deemed relevant for the context of this project. The methods scaffolding is based on the Interaction Design Lifecycle Model, as seen in figure 3.2.

4.1 Discovering requirements

Creating something novel through RtD requires an understanding of the current state in the relevant domain (Zimmerman & Forlizzi, 2014). From this knowledge, an understanding of the requirements for the novel solution can be formulated (Sharp et al., 2019). Several methods for understanding the current state and discovering requirements can be found in the literature, such as expert interviews or analyzing other solutions in the domain (Kumar, 2013), literature reviews (Webster & Watson, 2002; Zimmerman & Forlizzi, 2014) or user centered, ethnographic methods such as observations and contextual interviews (Blomberg et al., 1993).

4.1.1 Literature review

Specifically when conducting RtD projects, Zimmerman and Forlizzi (2014) suggest starting with a literature review. It is essential for advancing knowledge when doing academic work, as it highlights what areas are saturated with research and where there are still opportunities for exploration (Webster & Watson, 2002). Literature reviews as described by Webster and Watson (2002) commonly take one of two forms: either they holistically synthesize and summarize the existing body of work around a topic or they act as a curated, theoretical foundation for analyzing something novel. Regardless, a scope is established around the topic, so that an appropriate level of detail can be determined for the content. Further, to synthesize content from different sources, the outcome of the literature review should be grouped by concept, rather than by author.

4.1.2 Ethnographic methods

Interviews and observations are commonly used methods for gathering data from users in a way that can translate into requirements (Sharp et al., 2019). To achieve this, a

researcher can take an ethnographic approach and immerse themselves, sometimes both participating and observing a context (Blomberg et al., 1993). Ethnography is founded on the principle that people don't always do what they say they do, so participating in the natural context gives more accurate insights into a situation (Blomberg et al., 1993).

4.2 Designing alternatives

When requirements have been defined, they can form the basis of an ideation phase (Harley, 2017). Several methods for coming up with alternative solutions are identified in the literature. Commonly, a conceptual idea is developed by the designer and is then turned into a concrete suggestion for implementation (Sharp et al., 2019). To identify suitable ideas, a suggested method is to aim for a large quantity of ideas and then pick the ones that are deemed suitable (Harley, 2017). This approach falls in line with the idea of brainstorming, an open-ended method for generating ideas in an environment where the stakes are low and new ideas are welcome (Kelly & Littman, 2000).

4.2.1 Sketching

Sketches are a cheap, disposable means to explore a problem space, which makes it feasible to render a plethora of ideas efficiently (Buxton, 2007). They are a dedicated step in Google's Design Sprint model (Sharp et al., 2019), implying that it is a valued method even for mature actors in the field of design. Sketching can be a way to minimize the risk of committing to an idea that might not be fitting as a solution (Buxton, 2007).

4.2.2 Scenarios

Scenario-based design is a design approach concerned with describing the usage of a future system (Rosson & Carol, 2002) or highlight issues in a current approach (Sharp et al., 2019). Not focusing on technicalities re-frames the problem space from a *what* to a *how* question which can delimit the solution space in a useful way (Rosson & Carol, 2002). Scenarios can address both existing problems and activities that are part of a solution (Rosson & Carol, 2002), making it flexible for multiple stages of a design process.

4.3 Prototyping

Prototypes can be used in multiple stages of the design process, to communicate the rationale of an idea in a way that is cost-effective but still clear (Lim et al., 2008). The concept of prototypes as *filters* is introduced by Lim et al. (2008) as a more nuanced way to reason about prototypes compared to high and low fidelity. Prototypes can for example have a high visual fidelity but a low fidelity for interaction. In the design process, the designer filters out the aspects that are to be explored, and

leaves other aspects in a purposefully under-defined state, as they would otherwise serve as a distraction: “Prototyping is an activity with the purpose of creating a manifestation that, in its simplest form, filters the qualities in which designers are interested, without distorting the understanding of the whole” (Lim et al., 2008, p. 4).

Prototypes usually evolve through various fidelity levels during a project, and can be constructed in different ways depending on what aspects are in focus (Sharp et al., 2019). One example of this is wireframes, a set of documents that show the structure and content of of an interface, at a chosen level of fidelity (Sharp et al., 2019).

4.4 Evaluating

Evaluation within interaction design concerns drawing actionable conclusions from users’ interactions with a product (Sharp et al., 2019). Evaluation commonly starts with gathering data about the product usage, with varying degrees of interference from the researcher (Sharp et al., 2019).

4.4.1 Data gathering

4.4.1.1 Usability testing

Usability testing is a collective noun for methods that measure characteristics of an user’s interaction with a product, to determine its usability (Cooper et al., 2014). The products can range from being fairly complete to being low-fidelity paper prototypes, but Cooper et al. (2014) suggests that it’s most valuable after a candidate solution has been selected. Sharp et al. (2019) suggests a more concrete definition, and elaborates on it as a set of predefined tasks that are completed by participants, possibly asking the user to state their actions verbally as they are completing them. After the tasks have been carried out, a questionnaire is carried filled out by letting the participants rank statements along a scale. At the end of a session, a usability test might be followed up by an interview.

4.4.1.2 Interviews

Interviews are common within interaction design; they are flexible and can be conducted at several stages of the process (Cooper et al., 2014). Related to this, they can also take different formats depending on what type of output is needed (Sharp et al., 2019). Typically, when little is known about the problem space, a more open-ended interview format is suitable (Sharp et al., 2019). On the other hand, they can be used as a more confirming tool later in the process (Cooper et al., 2014). However, the interview context creates a social situation that to some degree shaped what is being said (Blomberg et al., 1993), and data gathered from interviews should be treated with this in mind. Cooper et al. (2014) outlines some key points regarding user interviews, such as conducting the interviews at the same location as the topic takes place, whenever relevant.

4.4.1.3 Cognitive walkthroughs

Cognitive walkthroughs are a way to approximate problematic user interactions without involving users, instead employing UX researchers to walk through a set of steps in an interaction based on a provided scenario or context (Sharp et al., 2019). First, a list of traits of the user group is identified and the artifact is prepared; this is commonly a mock-up or prototype. Then, UX researchers act out a previously identified set of steps that correspond to typical user behavior. While this is happening, the researcher critically analyzes the interaction to look for potential faults that become the subject of revision.

4.4.1.4 Heuristic evaluation

When access to users is deemed too costly, heuristic evaluation can be employed as an efficient method for identifying usability issues (Nielsen, 1994). The method employs a checklist of statements essential to good usability, synthesized from a large number of specific usability problems (Nielsen, 1994). The nine heuristics identified in Nielsen (1994) are:

1. **Visibility of system status:** The system should always keep users informed about what is going on, through appropriate feedback and within reasonable time.
2. **Match between system and the real world:** The system should speak the users' language. This involves using words, phrases, and concepts familiar to the user, rather than system-oriented terms.
3. **User control and freedom:** Users sometimes choose system functions by mistake and need a clearly marked "emergency exit" to leave an unwanted state without having to go through an extended process.
4. **Consistency and standards:** Users spend most of their time on other sites, and are accustomed to design patterns from those sites. Falling in line with those makes for a more usable system. This later turned into "Jakob's law of internet user experience" (Nielsen, 2017),
5. **Error prevention:** While good error messages work, preventing problems from occurring in the first place is better.
6. **Recognition rather than recall:** Making GUI elements instantly recognizable rather than something you learn through usage makes for a better user experience. The user should also not have to remember information from one part of a dialogue to another.
7. **Flexibility and efficiency of use:** Systems that anticipate recurring and frequent use can tailor some functions to the "expert user" group for optimization.
8. **Aesthetic and minimalist design:** Every extra unit of information competes with the relevant units and diminishes their relative visibility. Information which is irrelevant or rarely needed should not be present.

9. **Help users recognize, diagnose, and recover from errors:** Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.

4.4.2 Data analysis

The method for data analysis is generally adapted to the method of data collection (Sharp et al., 2019). and since both quantitative and qualitative data is collected in this project, methods for both approaches are presented below.

4.4.2.1 Quantitative analysis

Quantitative methods excel at establishing cause-and-effect relationship between phenomena and testing defined hypotheses (Verhoef & Casebeer, 1997). In interaction design, they are typically employed to draw generalizable conclusions about users' attitudes and behaviors using methods such as A/B testing, analytics on user interactions, surveys and questionnaires (Interaction Design Foundation, 2016). A prominent method for analyzing quantitative data is Null Hypothesis Significance Testing (NHST), where a hypothesis is formulated that rejects the proposed relationship which is the topic of the study (Nickerson, 2000). While NHST is vastly used, it has also been criticized for oversimplifying the problem at hand and sometimes being misleading as the relationship that is been measured might not always be the most practically relevant one (Nickerson, 2000). When analyzing a quantitative dataset, descriptive and inferential statistics can be used to make the data comprehensible and actionable (Louangrath & Sutanapong, 2015). Descriptive statistics describe the dataset, while inferential statistics concerns how and how accurately the dataset represents the broader population (Louangrath & Sutanapong, 2015).

4.4.2.2 Thematic analysis

Thematic analysis is a popular method for identifying patterns in qualitative data (Braun & Clarke, 2006; Sharp et al., 2019); it begins with a dataset that the researchers search across, with the goal of finding "repeated patterns of meaning" (p. 86). From there, the researchers are obliged to make choices about how to interpret the data, the most prominent choice being whether to let the data speak for itself (inductive approach) or analyze it in relation to a theoretical framing (deductive approach) (Braun & Clarke, 2006). When the approach has been decided, the process as defined by Braun and Clarke (2006) begins as follows:

1. **Familiarizing yourself with your data**, which might include transcription and reading the dataset multiple times. Semantic meaning is generated by the researcher exposing themselves to the information.
2. **Generating initial codes**, descriptive labels that can be attributed to a piece of the data. They are purposefully narrow in scope.
3. **Searching for themes**, recurring patterns and relationships between codes and possible overarching narratives. They are the sum of a group of codes.

4. **Reviewing themes**, the iterative process of analyzing the themes in relation to each other as well as the previously generated codes. Outlying themes and codes can be dismissed if few, but should otherwise be regarded as a sign to reevaluate the grouping.
5. **Producing the report**, for which it is emphasized to use examples and quotes that capture the identified concepts in a rich way, to argue for the validity of the analysis.

While originating from the psychology field, reports generated through this method yield rich, “thick descriptions” (Braun & Clarke, 2006, p. 97) of a dataset. Further, the results are typically accessible, easy to understand and account for unanticipated insights that might exist within the data (Braun & Clarke, 2006), suggesting that the method is particularly good when analyzing novel concepts with no established hypotheses to validate.

4.5 Methods selection

This chapter has presented methods that have been deemed relevant for this project. The methods that were used mostly aligned what is presented here, with a few notable exceptions. The empirical work was conducted through an almost exclusively qualitative approach, which aligns with the strength of qualitative methods such as thematic analysis that excel in finding information where it is not completely clear what to look for, as well as capturing soft values such as the ones of a navigator when altering their professional role.

Further, while there was no formal step where heuristic evaluation was conducted, the heuristics of Nielsen (1994) were re-visited several times during the iterative design process. The heuristics laid a foundation for the design work, rather than used as an evaluative step. A similar approach was adopted for cognitive walkthroughs. In my experience, using these methods as a dedicated step yields the most results when involving multiple designers who need to develop a shared understanding of a problem space, which was not the case here.

- The literature review helped anchor the work to a strong theoretical foundation. Further, reading literature as a complement to ethnographic methods provided a rich picture of the current state of the maritime domain.
- Ethnographic interviews and observations were used to learn about the context in a richer way than what was possible through literature.
- Sketching was used extensively to propose initial versions of design outcomes. This was suitable as it allowed for exploration of several ideas efficiently, central to the design process model used in this work.
- Prototyping was also used extensively to assess the viability of design ideas without having to commit to them fully. This was essential to upholding the flexibility outlined by the Agile Manifesto, see section 3.5.2.

- Usability tests were essential for making sure that the proposed concept were easy to understand, central to the problem space for this topic. Descriptive count data was collected to assess the usability of individual GUI elements.
- Interviews as a follow-up after usability testing allowed exploring the context of navigators through reflective design. This allowed capturing important insights and values when the navigator's role was altered for a semi-autonomous context.
- Analyzing data with thematic analysis was particularly useful for extracting data from interview transcriptions. It also allowed the study to incorporate findings generated by reflecting on the design artifact, used as a technology probe as per the methodology of reflective design (see section 3.4).

5

Iteration One

This chapter describes in detail how I incorporated selected interaction design methods for the purposes of completing the first iteration of work on the presented design problem.

5.1 Literature review

To gain a deep understanding of the context and contemporary work for autonomous ferries, a literature review was conducted. Searches were done in *Google Scholar* and the *Chalmers Library* database. Relevant keywords were uncovered iteratively as part of the screening rather than in a separate step, and in total 48 articles were included. These were primarily peer-reviewed journal articles and conference papers. Several non-scholarly industry reports and guidance documents were also included, as these were deemed to better represent the state of the art of the maritime industry. Recognizing the risk of commercially motivated bias in such sources, they were critically assessed based on source affiliation and alignment with peer-reviewed findings. Further, as the specific topic of autonomous urban ferries was rather unexplored, the review was expanded to include general literature on maritime autonomy and interface design.

While the main results of the literature review are presented in sections 2 and 3, they serve as the theoretical foundation for all the design iterations. The result of the literature review includes definitions, benefits and issues regarding autonomous ferries in urban environments, as well as contemporary design guidelines for maritime information and navigation systems.

5.2 Meetings with the client

Throughout the project, meetings were held weekly with Cstrider's representative Tobias Husberg. At the first meeting, we discussed their context of operation and issues they were trying to solve. Their motivation for exploring semi-autonomous ferries was partly to be able to employ navigators who possessed a "Fartygsbefälsexamen klass VIII" license, which they identified as relatively abundant compared to other types of maritime professionals. This license does not require extensive sea service, and can be acquired in approximately a week by almost anyone (Sjösportskolan, n.d.). Crew experience has implications for the design, as experienced crew members might

have different expectations for how information interfaces might behave. Further, in pursuing modularity in their ferry system, their goal was to separate the navigation interface from the information interface. This out-ruled navigation from the scope of this project.

Cstrider also wished for the information interface to have the posture of a mobile app. While other formats were explored such as smart watches or dedicated custom touch devices, the mobile app posture was deemed suitable for several reasons, mainly:

- Ferry operators likely already carry a smartphone
- Smartphones reduce costs by including more prebuilt “bootstrap” features such as battery notifications and app deployment
- Smartphone usage is likely familiar to the user group

As maritime monitoring GUI:s generally monitor the physical sensors on maritime vessels, the interface has to be tailored to the physical layout of the ferry and its mode of operation. The physical layout of the ferry (shown in Figure 5.1) consists of two propellers at the stern (rear) for propulsion. For turning, the ferry employs a sideways thruster at the bow (front) combined with a rudder. Turning can also be done by operating the stern propellers independently.

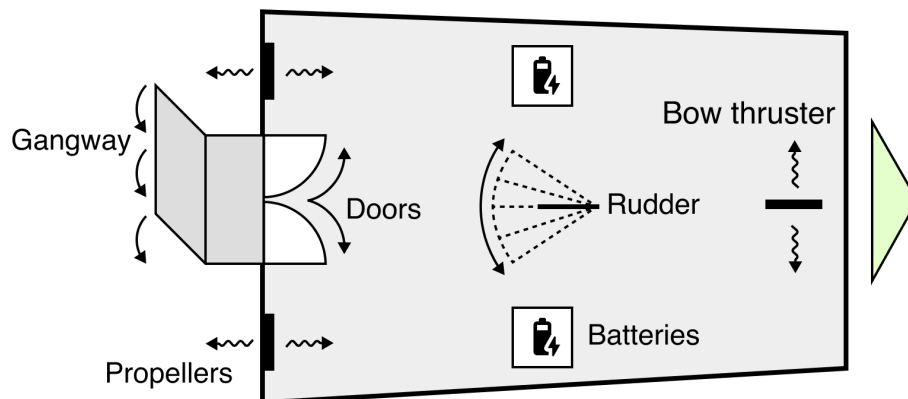


Figure 5.1: The physical layout of the Cstrider ferry.

Apart from monitoring the ferry’s navigation system, other points of measurement include battery status as well as alerts when sensor readings are unexpected or failed. Further, Cstrider wished that interactive features of the ferry (apart from those related to navigation) should be accessible from the interface when possible. Table 5.1 presents the preliminary list of requirements for the design.

5.3 Ethnographic work

To gain experience with the context of maritime operations, I conducted a field visit to *Älvsnabben 4*, one of several public transport ferries operated by Styröbolaget in Gothenburg. The visit was carried out on the 20th of February and lasted for approximately two hours. During the visit, I had the chance to spend time with the

Monitoring	Interaction	Alert
Propeller thrust (percent)	Gangway up/down	Propeller failure
Speed	Doors open/close	Battery failure
Battery percentage	Wipers 1–2–3	Unexpected rudder angle
Battery temperature	Lights	Fire alarm
Energy consumption		
Time table		

Table 5.1: Initial requirements for monitoring, interaction, and alerts.

captain, and also briefly with the deckhand. For safety reasons, it was not possible for me to follow the deckhand and observe their work first-hand. Following the methods outlined in section 4.1.2, I immersed myself in the situation and observed their context of operation, while taking notes. Further, when their time allowed, we would also discuss their work, procedures and important values.

Älvsnabben 4 is distinct from the Cstrider ferry in several aspects. It transports over a hundred passengers per crossing, about ten times as much as the Cstrider ferry, via predefined routes. Their crew consists of the *captain* and the *deckhand*. The captain is responsible for the navigation and safety of the vessel during the entirety of their working shift, even when they have breaks, or if they have to go to land for some reason. They have no other duties. They navigate from the bridge, a physically separate room in the ferry, using both physical and screen-based modes of interaction (example shown in Figure 5.2). The deckhand and the captain do not collaborate in completing their tasks even though they both contribute to operating the ferry.



Figure 5.2: The battery indicator and emergency break buttons on Älvsnabben 4.

In contrast, the deckhand is responsible for all passenger interaction, questions and ticket control. According to my informal interviews with the deckhand, commuting passengers mostly keep to themselves while tourists might ask a very wide range of

questions. The deckhand is also responsible for maintaining the vessel. Proactive inspections of systems on the ferry such as turbines, diesel engines and batteries are done hourly, with more rigorous inspections at set intervals. Abnormal sensor readings are also communicated using light-based indicators on a panel.

Apart from insights into standard procedures for ferry navigation, this step showcased what type of information presentations maritime navigators were used to. Key GUI elements include:

- Mimic panel, where light controls are distributed on an representational diagram of the vessel to communicate where on the vessel they reside physically.
- Timetable showing scheduled arrival times for each stop. Each stop was represented as a card and cards were sorted in order of arrival.
- Prominent battery time remaining indicator, as well as technical measure points used to calculate the battery time remaining.

Some monitoring tools were navigation-centric and thus not central to this vessel-centric concept. However, the visit still played a fundamental role for the remaining steps of the process.

5.4 Sketches

After gathering requirements from Cstrider and the literature review and comparing them with the traditional helm at Styröbolaget, I started sketching different GUI concepts that could satisfy the preliminary requirements listed in Table 5.1.

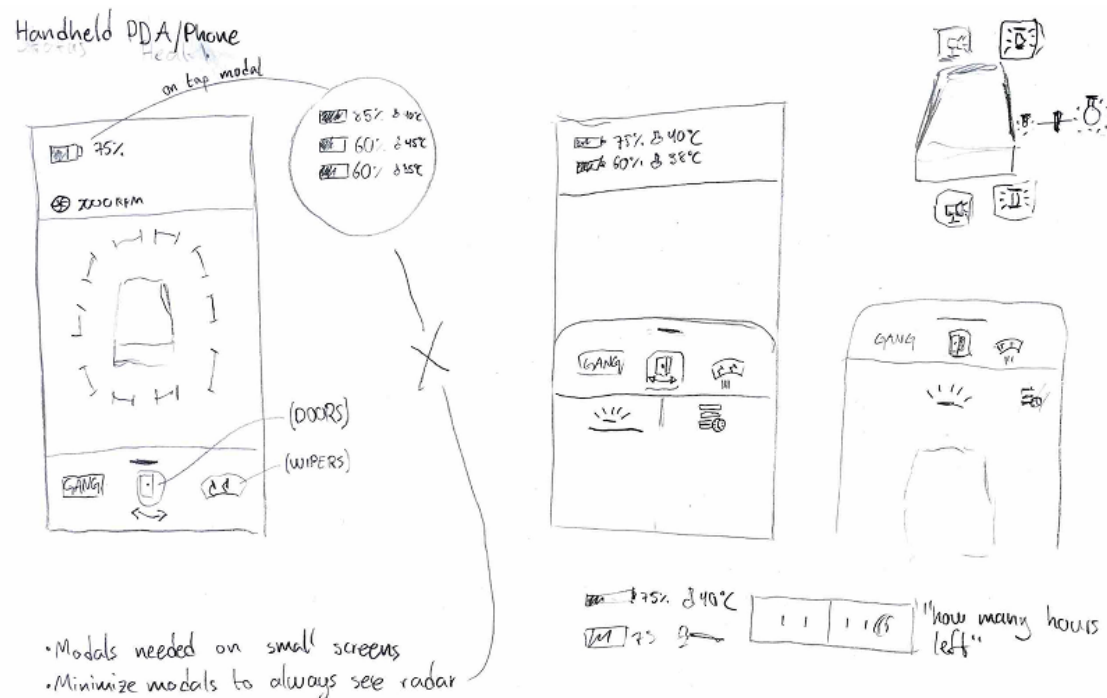


Figure 5.3: Initial sketch of the item layout.

The initial sketch concept as seen in Figure 5.3 divides the features into three segments: status monitoring at the top, autopilot status in the center and control items in a bottom drawer that can be expanded. The layout incorporates a natural hierarchy through displaying battery and propeller status at the top (see Figure 5.4), as well as the autopilot status in a central location. The bottom drawer presents all the interactive features of the GUI: Gangway, doors, wipers and lights. Within the expanded bottom drawer, the user would control the ship's lighting inspired by a mimic panel, and also view the timetable.



Figure 5.4: The top bar also gives a natural position to the alerts menu.

These initial sketches were presented to Cstrider, who wished to place autopilot and chart functionality outside the scope of the project. Other elements were selected as candidates for occupying the central space of the GUI from this point forward.

5.5 Final prototype

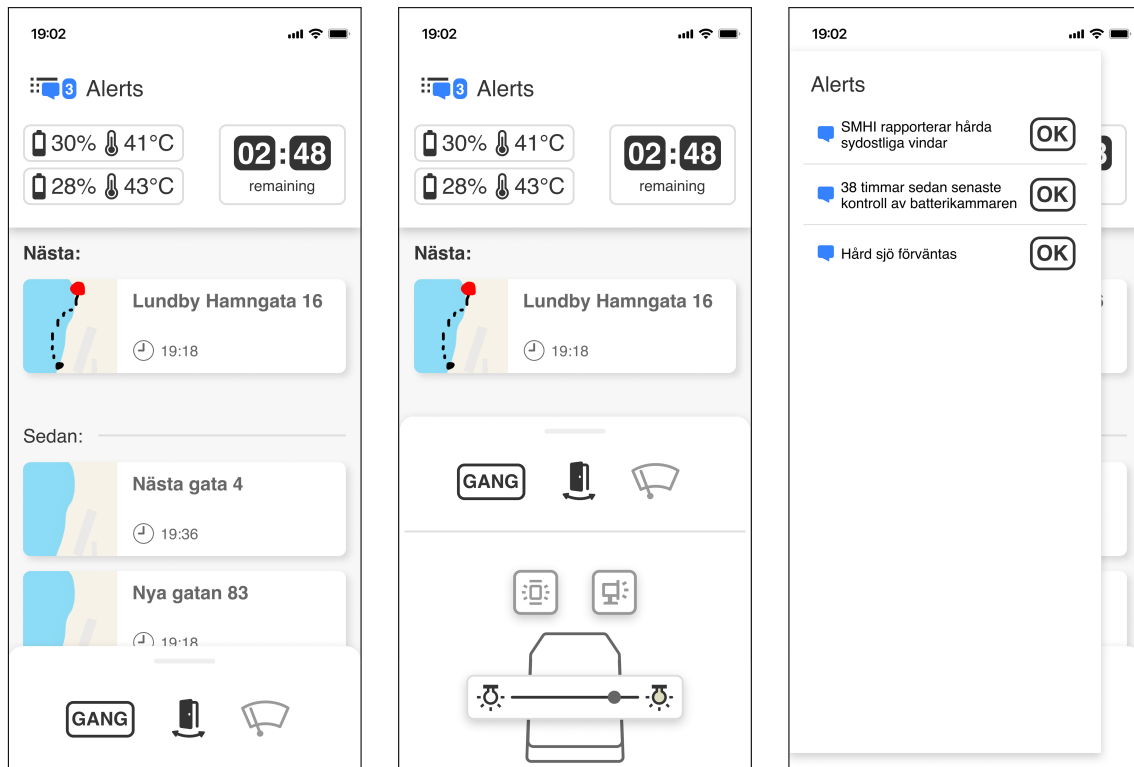


Figure 5.5: The three main views of the finalized first iteration.

The final prototype of iteration one (Figure 5.5) is divided into three main sections from the top to the bottom. The bottom section is a drawer which can reveal further actions when the user swipes from the bottom of the screen. The top bar has a side menu which provides detailed information about alerts. The GUI uses Helvetica as its typeface as per the suggestion by American Bureau of Shipping (2018), and icons were derived from the Openbridge design system whenever possible (Nordby et al., 2019). Some icons had no appropriate representation in Openbridge, for example the icons in the bottom control panel had to be designed specifically for this context.

5.5.1 Top information panel

The top information panel (Figure 5.6) concerns the status of the ferry and is tailored to the specifics of the ferry's construction. The ferry's two battery bays are presented through icons displaying their respective percentage left and the battery temperature. An hours/minutes countdown displays how much operating time is left. Related elements have been moved close together to incorporate

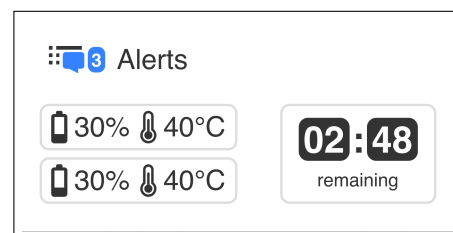


Figure 5.6: Top information panel.

the gestalt principle of proximity, and a border to facilitate the gestalt principle of common region (see section 3.1.2).

5.5.2 Timetable

The central space in the GUI houses the timetable, indicating where the next stop is, estimated time of arrival as well as a mini map of the navigation (see Figure 5.7). The next stop is presented centrally by being further apart from the other stops, as per the gestalt law of proximity.

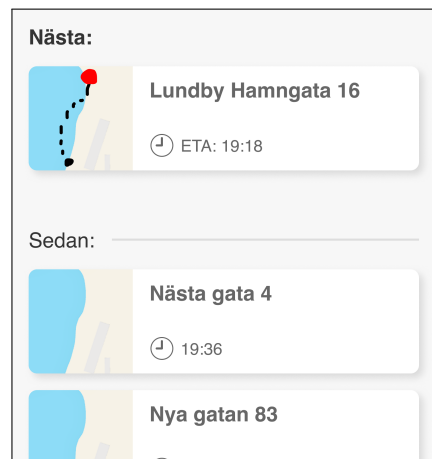


Figure 5.7: Timetable element.

5.5.3 Control panel

The bottom part of the main screen (Figure 5.8) presents the control panel and is tailored to the specifics of the ferry’s construction. The functions are (from left to right) to toggle the ferry’s gangway, doors and windshield wipers. A “pill” shape indicates that this menu can be dragged up to reveal further actions.

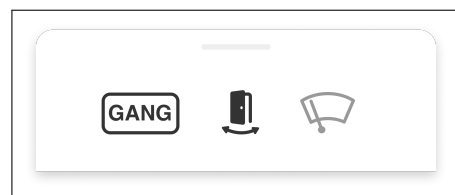


Figure 5.8: Bottom control panel.

5.5.4 Light control panel

The light controls of this prototype aimed to mimic the physical layout of the boat’s lights in something known as a “mimic panel”, a common maritime GUI element according to my field visit at Älvsnabben 4. It includes a stripped-down version of the vessel’s outlines, to give the user a frame of reference for the locations of the lights (Figure 5.9). The icons aimed to provide distinct visual appearance for beam lights and lanterns, and the central slider controls the inside cabin lights.

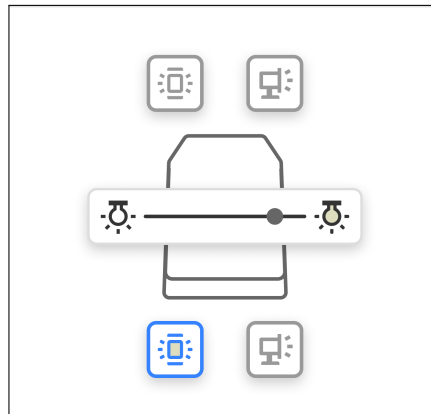


Figure 5.9: Light control panel.

5.5.5 Alert panel

The alert feed (as seen in Figure 5.10) would appear from the left when clicking the top left GUI element, and give the user a basic overview of information they might want to know, related to the current situation. It would also be possible to acknowledge notifications, and depending on their severity they would be removed from this list. The examples in the prototype were rather trivial as the focus for this prototype was more centered on the GUI.

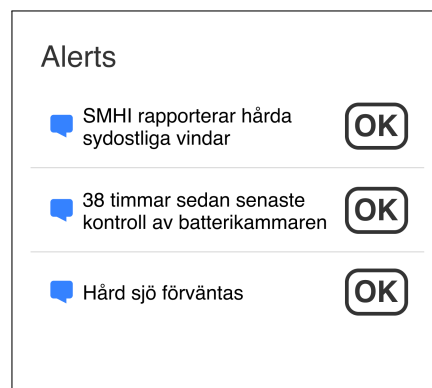


Figure 5.10: Alert feed.

5.6 Evaluation

The first round of evaluations was held with seven participants, each participating at an individual session ($n = 7$). Each participant self-assessed that they were experienced with the maritime domain. Six participants were male and one was female. Two participants were nautical science students, two were educators and three were professional operators. At four of the sessions it was possible to conduct the evaluation onboard the Cstrider ferry, in the hopes that it would make the sessions more immersive. The evaluation setup is depicted in Figure 5.11.



Figure 5.11: The evaluation setup on the Cstrider ferry.

5.6.1 Evaluation design and premise

The evaluation was designed with two goals in mind: assessing the usability of the prototype and inciting reflection regarding the viability of semi-autonomous single-crew ferries. Both of these goals were to inform further development of the design concept. Since Cstrider is exploring several varying modes of operation, an explicitly defined example premise was made as a starting point for the evaluation. The full version is available in appendix B, but it emphasizes the following:

- Normal operation utilizes only a single crew member
- The route is pre-programmed or decided by an external system
- The navigator is not expected to place their constant attention to the ship's status monitoring system
- The role of the navigator is that of a fail-over mechanism as well as for passenger assistance
- Vital systems have a physical version present on the ship for redundancy

5.6.2 Evaluation procedure

To begin the session, participants signed a consent form that allowed me to process information from the session for the purposes of the study (the full consent form and evaluation plan is available under appendix B). The participants were then introduced to the context around the ferry and basic information regarding its construction and modes of operation. They were also informed of the supporting systems around the information display concept and what role it was supposed to fill.

Initially, participants were asked to share details about their maritime background and if they had experience with navigation or passenger safety. Beginning the

semi-structured interview, we spent some time talking about how they handled that role and what is especially important for that context as well as what maritime responsibility meant to them.

After this, a usability test was conducted. Participants were presented with the prototype with no explanation of its features. They were asked to try its features and think out loud as they navigated, to see if their interpretation of the elements aligned with my intention. After they had familiarized themselves with the prototype, they were presented with a scenario meant to immerse them into how operating the ferry would feel. The original is available under appendix B, here is a translation (translated by the author):

You are tasked with operating the Cstrider ferry on a weekday. It is raining but you still have passengers to pick up. The waves are somewhat high and a passenger asks if the crossing will be calm. Since you have the Cstrider information app you can see there is a notification about strong weather, but that the crossing will commence according to schedule.

They were then provided with three simple tasks of controlling lights, windshield wipers and controlling when the next stop was taking place. Since they were tasked to think out loud, it was possible to assess whether these tasks were ambiguous. fas

After this, a semi-structured interview was resumed, to continue discussing the responsibility of a captain towards their passengers, and how that could work in the suggested novel context. Since the participants all had a maritime background, they were allowed to provide direction for this part of the discussion, to capture topics that were aligned with contemporary maritime training. We also discussed prerequisites for safe crossings and how it would work in this new context, such as which information was missing or redundant.

Finally, I presented a list of features where some were already incorporated into the prototype and others were not (e.g. battery temperature, estimated time to arrival, radar) to act as an example for what things could be relevant for the captain. I also presented sketches of other design variations if they brought up related suggestions.

5.7 Data analysis

Each evaluation session was subject to the method outlined in Braun and Clarke (2006) for thematic analysis. The audio of each evaluation session was recorded and transcribed using a speech-to-text AI model that has been made publicly available from the National Library of Sweden (Kungliga Bibleoteket, 2025). The model was ran on a local machine to ensure that participant information was not processed in a way that wasn't described in the signed consent form (see appendix B).

The transcribed evaluation sessions were then read through several times and annotated on a virtual whiteboard tool called Miro. These annotations were color coded to each participant (e.g. P1 was always bright yellow) and this process corresponds to the step of generating codes in Braun and Clarke (2006). The annotations were then clustered semantically as foundational elements for building themes.

Since the interview participants were instructed to think out loud when interacting with the prototype, it was possible to assess whether they had understood GUI components from the audio recording alone. When annotating the audio clips, I annotated all GUI interactions to ensure there was foundational data for a comparison, which resulted in the insights available under section 5.8.1.

5.8 Results

5.8.1 Usability insights

While various insights could be drawn from the prototype and its implications for semi-autonomous ferry operation, several usability insights were identified which were used to inform the second iteration of the prototype. Table 5.2 is derived from all GUI elements that were ambiguous to participants at first glance, even though participants typically understood more after interacting with them. Only if participants' think-aloud explanation of an GUI element aligned with my intention would the GUI element be considered "clear".

GUI Element	Clear	Unclear
Gangway	2	5
Battery remaining	3	4
Door	6	1
Wipers	6	1
Battery	7	0

Table 5.2: Participant understanding of selected GUI elements in Prototype 1.

As per Table 5.2, most of the initially ambiguous GUI elements were still understandable to a majority of participants. Other GUI elements that were brought up include the light control element. While the purpose of the light control element was generally understood, its icons were somewhat ambiguous to the participants. Participants also requested logical groupings of lights: the two lanterns and the top light are almost always activated together (they are legally required during normal operation) and could form a logical group.

Five of the participants did not think that the timetable would be of central interest to the navigator, and that it would be appropriately seated somewhere else. Three of the participants mentioned propeller usage as a relevant metric for monitoring a safe crossing.

Three participants also questioned the metric of battery temperature, as it implicitly requires an understanding of what an appropriate battery temperature range would be.

5.8.2 Implications for semiautomatic ferry operation

In addition to usability considerations, the evaluation was essential for determining the viability of the proposed new paradigm of ferry operations. The viability was

assessed by the maritime professionals participating in the evaluation, and is thus based on their training and experience. Note that all translations in this section are done by the author.

The main topics that interested participants focused on safety aspects of the ferry operation, which was generally equated with successful operation. P3 elaborated: “Since I am responsible for passengers, just like I am on a cruise ship, passenger safety becomes priority one” [“Eftersom jag ska hantera passagerare, precis som jag gör på ett kryssningsfartyg, blir ju säkerhetsaspekten prio ett”]. This illustrates a core premise in maritime training which was undisputed by the participants of the evaluation, and is foundational for the themes presented below.

5.8.2.1 Theme 1: Safety before service

Operational safety emerged as a primary concern during the evaluations; participants worried that this might be compromised if their role shifted towards other tasks. This was exemplified through the timetable GUI element, where several participants suggested that passengers would have a better experience reading the information from a display rather than asking the navigator. In the words of P5: “You should have a rotating display on the wall to inform the passengers about the stops. It raises the question whether this information really is important to me?” [“Ni borde ha en sån display som snurrar på väggen, som säger när man är framme vid nästa ställe. Då kommer frågan om den information egentligen är så viktig för mig?”].

Further, participants were concerned that their treatment of passengers would not be as friendly if they were suddenly expected to perform navigation tasks. P2 elaborated: “It’s not distracting from lookout or navigation tasks to talk to others, but sometimes you might come across as a bit brief [i.e, less socially engaged or welcoming]” [“Det distraherar ju inte från utkiken eller navigationen att prata med någon, men man kan ibland bli ganska kort”].

This theme highlights that while participants are not unwilling to assist passengers, they view operational safety as their primary responsibility. Further, they assume that the navigators will have to intervene in various ways to uphold the operational safety of the ferry.

5.8.2.2 Theme 2: System transparency

While not explicitly mentioned by the premise set in section 5.6.1, participants assumed that the navigator would be held accountable in the event of an incident. Based on this premise, they felt an obligation to stay informed enough to be able to justify the system’s actions. For the system’s actions to be justifiable, they had to be:

- In line with the navigator’s professional judgment
- In line with standard practice
- Lawful in the current context

Ways to reach this system transparency were suggested by participants, such as monitoring options to make sure navigation lights are turned on when they are required, and that the ferry does not exceed the speed limit. This theme also includes more complex operational decisions such as allowing the navigator to approve the predefined route. P3 captured this in a rather vivid way:

I would not feel comfortable with someone else handing me a route if I don't get to approve it myself. This is not a problem on a ship where you have multiple officers and one responsible for creating the route [...] It's also my head that rolls if something goes wrong.

[Jag skulle nog inte vara trygg i att någon annan ger mig ruten om jag inte har fått godkänna den. På ett fartyg är det ju inga problem, du har flera styrman och en nav-styrman som gör ruten [...] Det är ju också mitt huvud som rullar om någonting går fel].

This illustrates that participants still view the navigator as ultimately responsible, even though several operational tasks are being carried out automatically and without the navigator's approval. Conversely, if the navigator was not to be held accountable, transparency may be less critical to the interface design.

5.8.2.3 Theme 3: The more reaction time, the safer

Alerts and alarms can be essential for drawing the navigator's attention to tasks that need action. However, many of these tasks can be executed more effectively if the navigator is given more lead time to anticipate them. According to participants, trained navigators can pick up on subtle anomalies and cues earlier than an alert system could. P7 elaborated on interpreting vessel metrics: "I'm wondering if the propeller usage had been an interesting metric. You would get a feeling for how much effort it puts in, and that should line up with the speed. You would see if something is off there." ["Jag funderade på om propellervarvtalet hade varit intressant. Det kanske hade varit bra, då får man en känsla för hur mycket motorn jobbar, det ska matcha med hastigheten. Då kan man se om något är galet där"].

Since alarms demand attention by design, they do more harm than good if they are not raised at the appropriate time. A common example which was brought up by three participants are collision alarms. When ships make a turn close to other ships it is usually inevitable to have a brief collision course (both ships' courses intersect) until the turn has been completed. Alarm systems are not sophisticated enough to discern these from a potential collision situation, therefore raising an alarm. A human navigator knows the cause of the collision course and can therefore judge that the situation is non-critical.

This illustrates that the system's interpretation of a situation might be less nuanced than human judgment, which in turn can be the cause of false alarms and decreased safety in navigation.

5.8.2.4 Theme 4: An actionable resolution of information

Taking on passenger service tasks gives navigators less time to monitor vessel status. This in turn places new demands on the information presentation, and puts pressure on implementing a suitable information hierarchy. While participants had varying opinions about how much detail the navigator should be given at a glance, it was emphasized to make sure the information was actionable. P5 suggested a way to translate metrics into actionable information: “If there are eight batteries, how many battery icons are relevant to have? I think it’s irrelevant, I want to know how much usage time is left.” [“Om det är åtta batterier, hur många batteriikoner är det relevant att ha? Jag tycker det är ointressant, jag vill veta hur mycket batteritid det är kvar”].

Conversely, other participants were concerned about overly abstracted information. They wanted access to deeper information such as how the battery usage time left number had been calculated and stated that they would not trust the metric without an explanation. They found it reasonable that deep explanations could be hidden inside modal views.

This theme illustrates that when navigation becomes a part-time task, the interface must prioritize actionable information as a default option, while offering deeper and more technical information on demand.

6

Iteration Two

This chapter describes the process for the second iteration of the design. For iteration two, I developed a reworked prototype to address the issues found in the first iteration, based on the insights from the first evaluation. The first iteration revealed several usability issues in the prototype as well as general requirements for a feasible implementation within the maritime domain. Because of this, several components of the design were iterated including icons, layout and functionality. While the first iteration was of an exploratory nature, this iteration focuses more on validating design changes. Further, since there was a stronger empirical foundation for the design at this stage, it was possible to slowly move the prototype into a higher visual fidelity.

6.1 Prototype

6.1.1 Gangway

Based on the usability findings outlined in table 5.2, the gangway functionality needed a rework to improve clarity. Further, clarifications from Cstrider emerged during this time which meant that the gangway functionality actually needed four states corresponding to different angles, rather than binary on/off. A round of sketching revealed that this could be controlled using a modal overlay element (see Figures 6.2 and ??), and a “hold to confirm”-action would ensure that the gangway wasn’t activated by accident.

To address the usability issue with the gangway icon, a new one was created to mimic the physical gangway design of the Cstrider ferry and create an association that was understandable. The issues with the previous icon were made quite clear during the iteration one evaluation sessions which made it relatively straightforward to come up with a more clear variant.

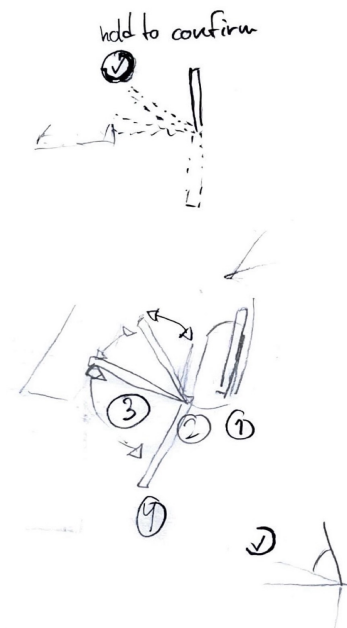


Figure 6.1: Rough sketch of the reworked gangway element

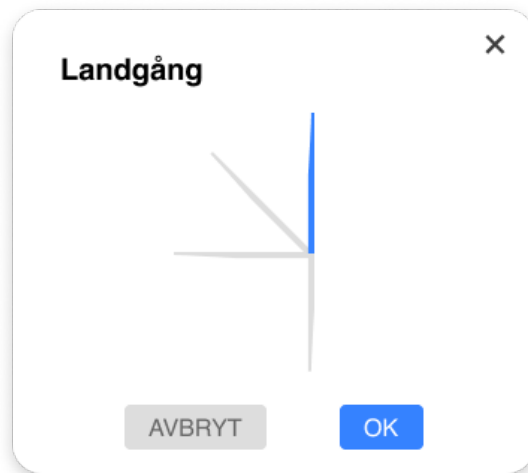


Figure 6.2: The gangway modal that was included in iteration 2.

6.1.2 Top information panel

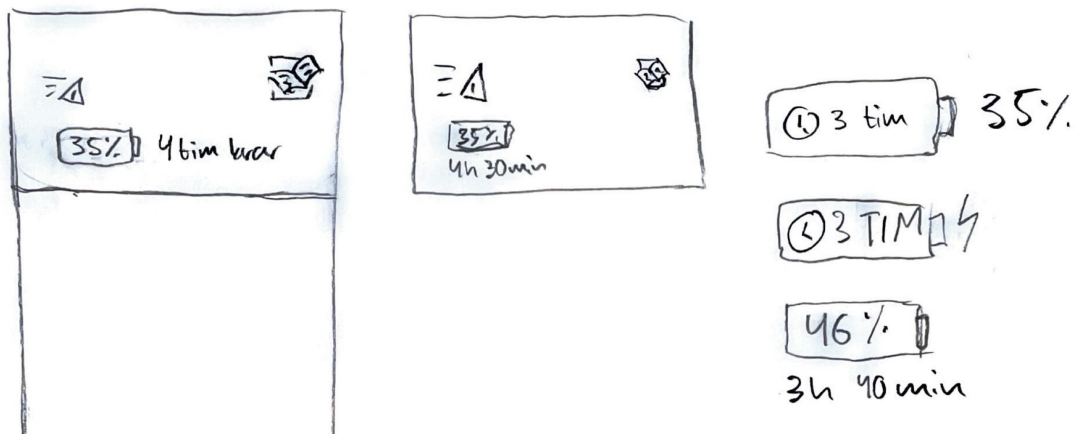


Figure 6.3: Initial sketches of the new top information panel

The top information panel (Figures 6.3 and 6.4) was redesigned to clarify the relevant information as well as removing the unnecessary metrics for multiple batteries and battery temperatures. Due to “Alerts” being the conventional name for one specific level of notifications, it was relabeled to “Händelser” (events) for clarity. Propeller usage is incorporated into the right side of the top information panel using conventional icons from Openbridge, as this metric was deemed relevant based on the evaluation sessions. The labels “SB” and “BB” are abbreviations for “Styrbord” and “Babord”, the Swedish nautical terms for starboard and port respectively.

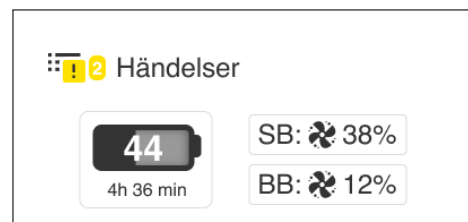


Figure 6.4: The top information panel of the second iteration.

The battery time remaining indicator was reworked to more strongly associate the time with the battery. This was done by more deliberately following gestalt principles of proximity and common region: moving the items more closely together and enclosing them in a shared border. The time remaining statement is therefore more tightly coupled to the battery icon itself. Further, the amount of batteries were not deemed interesting to the navigator, so the percentage instead displays the status for the least charged battery, provided that they deplete in parallel (as opposed to in sequence) during operation.

6.1.3 Light control panel

The layout structure of the second iteration is mostly kept intact from the first iteration, but the light control panel has traded places with the timetable, as the timetable is now located in the bottom drawer. This is in accordance with the usability results from the first iteration, where the timetable was not deemed to be of central priority for the navigator. A clarification from Cstrider meant that the physical light configuration on the ferry was different from the one shown in the first iteration, and therefore the GUI element needed to reflect this (see Figure 6.5).

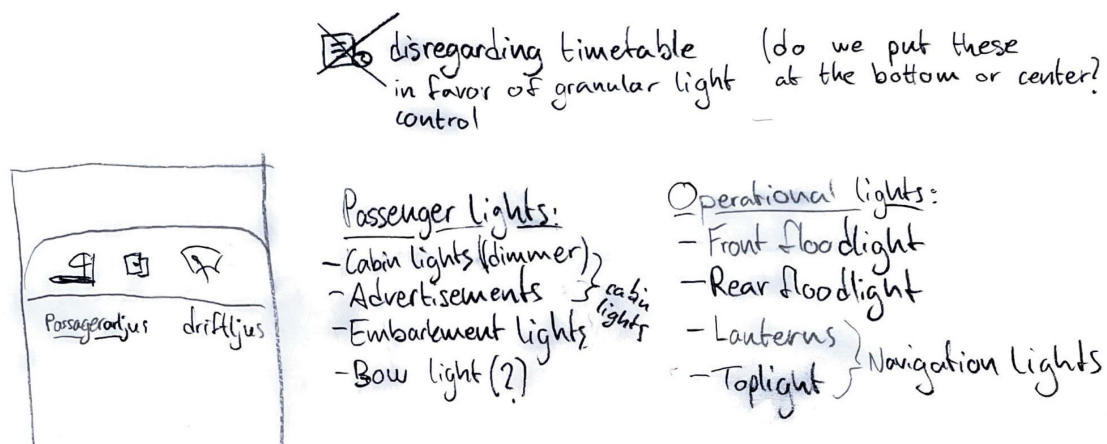


Figure 6.5: Making sense of the revised light requirements.

A new format was deemed necessary to accommodate for controlling a larger amount of lights. A session of sketching revealed that it was possible to logically group the lights into two tabs, "Passenger lights" ["Passagerarljus"] and "Operational lights" ["Driftljus"]. This in turn allowed the mimic panel illustration to depict an outside view of the ferry for the operational lights as well as an inside view of the ferry for the passenger lights (Figure 6.6).

Since the icons on the light control panel were deemed ambiguous by participants, they were removed in favor of labeled checkboxes. This element draws heavy usage of gestalt principles: lights that were part of a hierarchical group were placed close together based on the gestalt principle of proximity and slightly scaled down to facilitate the gestalt principle of similarity. Further, light groups correspond to a

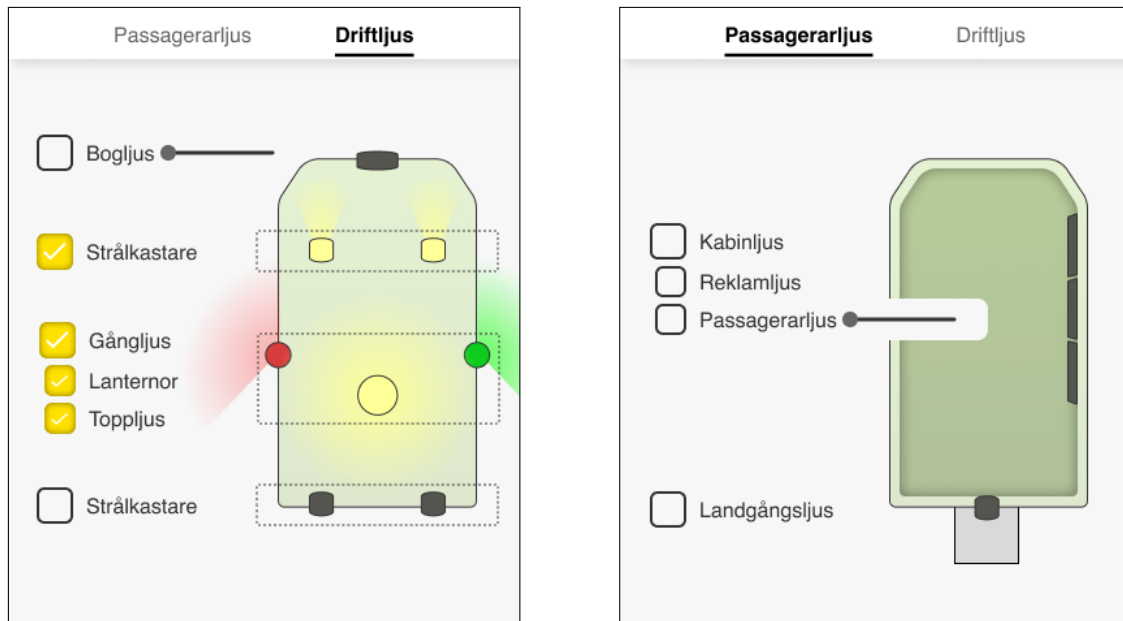


Figure 6.6: Different states of the revised light control panel.

particular segment of the ferry illustration, depicted by the illustration lighting up when the checkbox is checked.

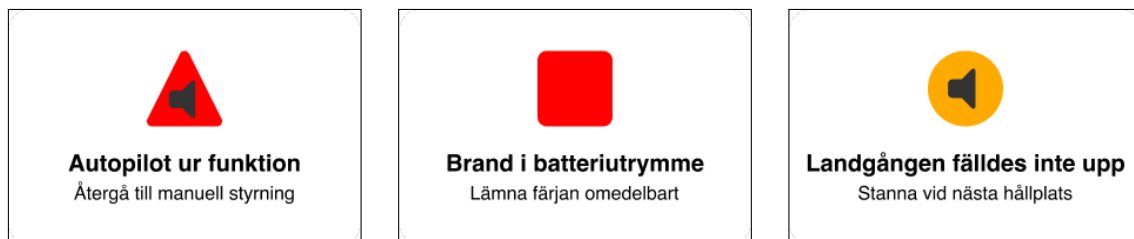


Figure 6.7: The three example notifications that would show up in the app.

Finally, the events menu was revised to use contemporary iconography as outlined by the alert standards in Section 3.2.4. They also illustrate how events are grouped by severity. Three example modals were created to illustrate how the notifications could look. The figures read (from left to right) “Autopilot is malfunctioning, please return to manual navigation”, “Fire in battery compartment, exit the ferry immediately”, “Gangway did not return to upright position, abort at the next stop” (Figure 6.7). With these revisions, the second prototype (Figure 6.8) was completed and ready for evaluation.

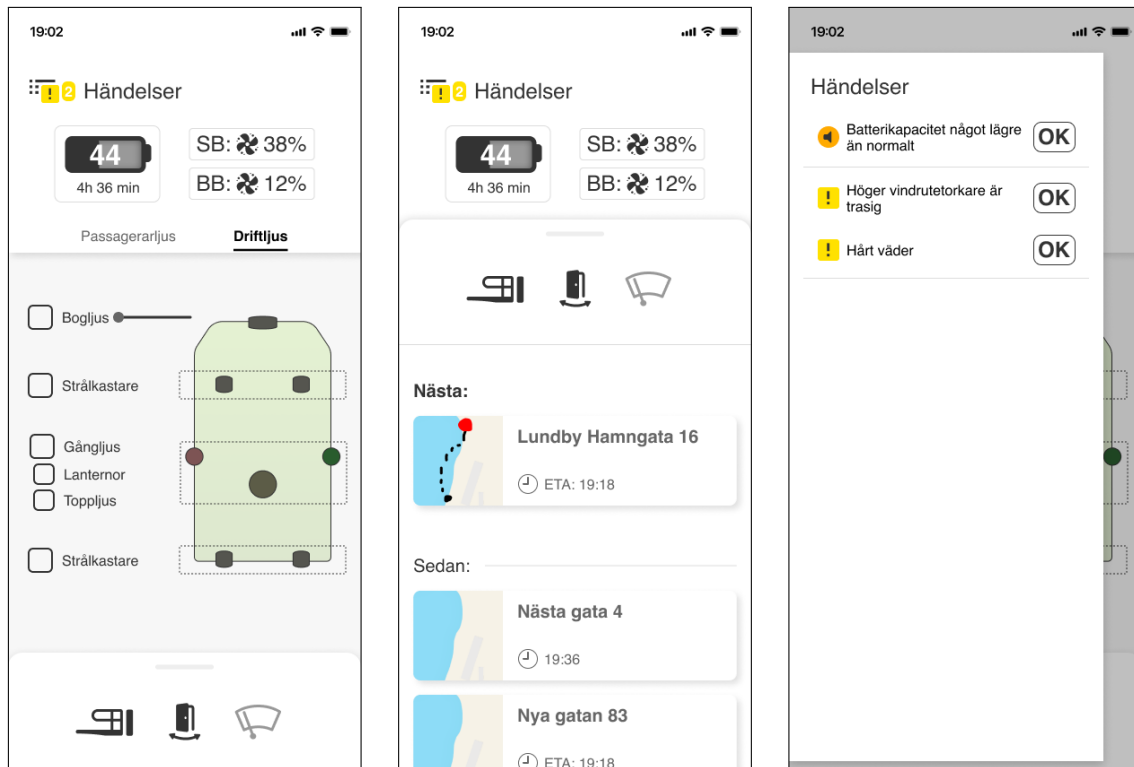


Figure 6.8: The three main views of the finalized second iteration.

6.2 Evaluation

The second round of evaluations was held online as it was unfortunately timed with the Easter holiday, which also made it harder to reach participants. While all participants from the previous round of evaluations were invited, only two participants participated in the second iteration ($n = 2$). One worked as a maritime educator and the other was a nautical science student. One participant was male and the other was female.

6.2.1 Evaluation design

The goal of this iteration was largely to validate the changes from the previous iteration, but also to discuss safety and alarm design, as this had been central to Cstrider. The alarm design was tightly coupled to the standards described in chapter 3, and presented to users via a table, as seen in Figure 6.9. As the design of alarms is mature and highly regulated in the industry, the focus of the evaluation was on how a small ferry would adapt to the conventional alarm design system, rather than alarm design itself.

6. Iteration Two

"Överge skeppet"	Emergency Alarm	Fara för liv eller farkost	Konstant ljud fram till åtgärd	brandlarm
"Kör till nästa hållplats"	Alarm	Risk för osäker överfart om åtgärd inte tas direkt	Tre korta signaler som upprepas efter 7-10 sek	
"Kör klart ditt pass"	Varning	Kräver uppmärksamhet direkt men åtgärd så småningom, kan eskalera till alarm	Två korta signaler som upprepas med intervall 15 sek-5min	Avvikande batteri-temperatur
"Informera tekniker"	Notis/Caution	Något avviker, men kräver ingen direkt uppmärksamhet	-	

Figure 6.9: The different notification levels, with some pre-filled events, aimed to serve as inspiration.

6.2.2 Evaluation procedure

The evaluations were held via Zoom, as a video call with screen sharing. Firstly, participants were re-briefed about the ferry concept. They were asked what they remembered from last time, and were then presented with the new prototype via screen sharing. The participants were asked to describe the element under my cursor, and if their interpretation was the same as the intention, it would be considered a successful implementation.

Further, we discussed the new light control panel as well as the logical groupings of the light controls, to determine if they were reasonable and if the labels were suitable. I would interact with the prototype in a slow and demonstrative way and users were encouraged to question the design throughout the demonstration. Here, there was an opportunity for participants to suggest and motivate further features that would be relevant for a navigator.

Finally, I presented the users with the alarm severity table, with two pre-filled sticky notes to serve as inspiration. We discussed what the navigator is expected to do during different alarm escalation scenarios, and filled in other potential situations in the table. We also discussed other ways that the app could provide support to the navigator.

6.3 Results

Similarly to the first iteration, the intention for iteration two was to process the data according to the thematic analysis method. Interview recordings were processed using the local AI model from the National Library of Sweden and annotated for usability feedback and general viability remarks. However, due to the low amount of participants, it was not deemed viable to synthesize viability remarks into broader themes. Despite this, it was deemed possible to incorporate the usability data

since usability issues are valid *if* they occur, rather than after a certain occurrence threshold (Nielsen, 2000).

Overall, both participants were positive to the changes introduced by the second iteration and the elements were understood clearly by the participants. The battery time remaining indicator was clear and unambiguous, despite not including the %-sign in the element. The propeller abbreviations were also clear, and one participant noted that it would be even clearer when they would display dynamic data.

The reworked mimic panel was deemed understandable, but it was not clear that the sub-items belonging to one light group would activate together, despite them being moved closer together. The gangway symbol was also clear, possibly due to participants having previous experience with the Cstrider ferry.

Further, the participants agreed to my pre-filled placements of items in the notification table, and continued to fill in more items (Table 6.1). This gives insights into what severity levels are typically associated with what type of system feedback.





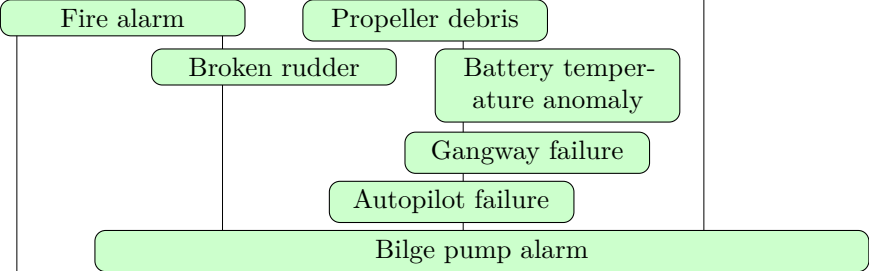
Symbol				
Alert Level	Emergency Alarm	Alarm	Warning	Caution
Description	Danger to life or vessel	Risk of unsafe crossing if not acted on immediately	Requires immediate attention but action can wait; may escalate to alarm	Something is abnormal, but no immediate attention is required
Sound Pattern	Constant sound until resolved	Three short signals repeated every 7–10 seconds	Two short signals repeated every 15 seconds–5 minutes	—
Incident type				

Table 6.1: Overview of user assessment of anomaly severity. Anomalies typically do not fit clearly into one category.

Both participants stated that assigning an event to a notification level is highly context-dependent, exemplified by several events residing between multiple notification levels. The bilge pump alarm for example spans across all the levels, depending on severity. Further, one of the participants stated that any practical advice received from notifications would also be highly context dependent, especially for notifications based on sensor readings that were non-binary (temperature, bilge pump). Another

6. Iteration Two

factor that would influence any practical advice to the navigator would be vessel location, for example abandoning the ship is a much more severe suggestion if the ferry is far from the coast.

Despite the small amount of participants, it was possible to validate the effect of the redesigned GUI elements and highlight the remaining ambiguous ones.

7

Discussion

This chapter discusses the project in retrospect, as well as assessing which ways the study design did or did not contribute to answering the research question in a rigorous way. Further, the results are discussed and synthesized into design guidelines, to answer the research question. It also suggests opportunities for future work on the topic.

7.1 Process

Through chapter 3, RtD was introduced as an appropriate method for integrating design methods into research projects. Chapter 3 also explains and argues for incorporating a design framework flexible enough for populating with project-specific design methods (see Figure 3.2). This allowed for incorporating methods such as reflective design into this project, which worked especially well for the maritime domain since it was discovered to bring a strong and established tradition. Reflective design practice proved especially fruitful in assessing the viability of semi-autonomous single crew ferry operation as a new paradigm. This together with usability testing and reflective interviews created a foundation for rich results, comprised of maritime professionals' attitudes towards this new proposed paradigm as well as theoretically grounded usability insights for the prototype.

7.1.1 Iteration One

7.1.1.1 Discovering requirements

While the initial plan did not include executing this project through more than one iteration, it proved to be a useful structure for getting multiple types of user feedback on the design choices made throughout the process. Starting with a literature review proved useful for understanding the domain, but it also suggested that the domain of maritime operations is largely driven by industry research and practical domain experience rather than academic research. The literature review was therefore less central for the specific design of the domain-centric prototype, but was still essential for laying a rigorous theoretical foundation for the methods used, theories on design and integration of research and design through RtD.

While the initial suggestion that central knowledge for maritime design came from the fact that academic sources frequently cited industry documents, this was further

confirmed through meetings with Cstrider as well as the ethnographic field trip at the ferry Älvsnabben 4. Discussing helm design and ferry operation with maritime professionals revealed that their academic training includes a significant amount of practical training, which was explained to be essential for their learning. This notion suggests that written reports of best practices would not provide the full details needed to develop the prototype. Participants and other stakeholders also recommended new literature on the topic. This illustrates the non-linear nature of the design process as described in Figure 3.2, where one phase informs the other phases.

7.1.1.2 Designing alternatives

Likely because of the narrowly specified design problem, there was to the best of my knowledge no previous examples of monitoring GUI:s for small, semi-autonomous single operator ferries. This made it natural to dedicate resources to exploring different alternative solutions, but guidance from Cstrider eventually narrowed the format down to a mobile app.

A deliberate focus was put on keeping the prototype as low-fidelity as possible, while still communicating the GUI features in a clearly understandable manner. I found that having committed less to the design choices, there were less stakes in the design and it was therefore easier and more flexible to rework, keeping the Agile Manifesto in mind (section 3.5.2). In practice, this was done using sketches as the main mode of communication, only bringing the GUI into digital space before it was presented to users.

7.1.1.3 Prototyping

The digital prototype was a translation of the previously defined sketches into a medium-fidelity digital space. In doing this, an act of commitment was made to the layout and chosen format defined by the sketches, which would have made it useful to validate the low-fidelity sketches with users before translating the prototype to digital space. This would also have been possible if there was a broader potential user group (more on this in section 7.1.1.4). Figma was used to design the digital prototype as I had experience with it and know it to be flexible and capable to produce high quality results. Further, it includes features to simplify design handover to developers, which was valued by Cstrider.

7.1.1.4 Evaluation

A premise set by Cstrider was that the intended user group would be novice maritime professionals with limited training. In an attempt to replicate the user group in the evaluation participants, an invitation email was forwarded to maritime students of Chalmers, as Sjösportskolan were unresponsive to my communication efforts. Further, a contact list was assembled using Cstrider's professional network and these were also invited to participate. In the end, the participant group was predominantly male with a mostly lifelong experience with maritime work in some form. While this seems to be representative of the target demographic, an interesting opportunity

would be to conduct this work with another demographic, such as inexperienced maritime professionals. While generalizability is not the focus of RtD research (Zimmerman et al., 2007), the current participant group should still be considered when interpreting the results.

Apart from this, the semi-structured interview guide and evaluation plan (appendix B) worked well and participants were generally very curious about the Cstrider concept, but some were less interested in the prototype. Adhering to the philosophy of reflective design meant that skepticism and self-reflection was encouraged, which highlighted the responsibilities of a ferry navigator which in turn made it explicit what issues could come up if these responsibilities were offloaded to a support system. Recording and coding the interviews according to thematic analysis allowed for the nuanced data quality that are stated to be the strength of the method.

7.1.2 Iteration Two

For the second iteration, the focus was largely on refining the concept that had been validated from the evaluation of iteration one. As usability insights had been collected through the previous evaluation, it was clear which parts of the GUI were effective and which parts were ambiguous. As no fundamental changes were required according to the evaluation participants, this iteration mostly concerned repeating the last two steps in the Interaction Design Lifecycle Model (Figure 3.2).

Besides iterating the ambiguous GUI components, through evaluation one I was recommended new literature on alarm design, leading to an incorporation of alarm standards in prototype two. This meant creating example notifications for events that could potentially require a notification.

7.1.2.1 Evaluation

The evaluation sessions took place online, to accommodate for travel needs during the Easter holiday season. While all participants from iteration one were invited, only two were interested in participating for the second round of evaluations. Since they did not reply to my invitation or reminder e-mail, it's impossible to know if it's because of the Easter holidays or if their curiosity was simply saturated from participating once. It was still possible to draw conclusions regarding the usability since usability issues are (as previously mentioned) valid as long as they turn up at least once. Several reflective design findings also surfaced, and while it was deemed to be too little data for conducting thematic analysis it could still be used to nuance the findings from iteration one.

Working online with screen sharing went well, especially considering that the participants had used the iteration one prototype in person.

7.2 Results

The evaluation design was done in a way that allowed both iteration to have knowledge outcomes that complemented each other. While the usability insights were of a

more iterative nature, the reflective design discussions would cover topics that could nuance or complement what had been said earlier. In this section, the empirical results are discussed explored in relation to existing literature. Based on this, design guidelines have been formed, to answer the research question:

RQ: How should maritime information interfaces be designed to support navigators for semi-autonomous ferry crossings?

7.2.1 Theme 1: Safety before service

Maritime professionals view operational safety as their core responsibility. Study participants were concerned that there would be safety implications if the operator's role was altered to involve other duties. While they were not unwilling to aid passengers, they stated that they would always prioritize safety if they were required to choose. This relates to Endsley (2000) who presents distraction as a primary contributor to user errors, which aligns with test participants' stated priorities. Both participants and Endsley (2000) suggested that the most critical data should be the most salient, leading to the first design guideline:

G1: Give safety-critical information salience over other tasks.

While interfaces might include many types of information which could be useful during routine operation, they must always be designed to ensure that safety-critical information can take over at a moment's notice.

7.2.2 Theme 2: System transparency

Participants expected the navigator to be held accountable in the event of incidents, which has several implications for the design of an information system. In the interest of safe crossings, they demanded insight and control into aspects which could have legal or safety implications such as route planning and speed limits. Trusting automated systems requires that the system's actions can be justified through professional maritime training. An interesting comparison can be drawn here to autonomous vehicles (AV:s), where a core premise is that the vehicle itself needs to be accountable for decisions (Omeiza et al., 2021). In exploring ways to let the vehicle be accountable, Omeiza et al. (2021) argues that explaining the reasoning of the AV can be a means to this end.

In Human-Autonomy Teaming (HAT) theory, system transparency is a means for making the autonomous agent's reasoning understandable to the human team member (O'Neill et al., 2022), which in turn is a prerequisite for trust and fruitful collaboration (McNeese et al., 2021). Since both HAT theory and study participants highlight the topic of transparency, it appears to be central for semi-autonomous ferry operation. This is the foundation for guideline 2:

G2: Ensure traceability of automated actions.

If the navigator is ultimately responsible for the operation of the vessel, information interfaces must allow for reviewing and justifying the autonomous agent's critical decisions.

7.2.3 Theme 3: The more reaction time, the safer

According to participants, human intuition often outperforms automated alarms. Participants valued the possibility to detect anomalies as early as possible, since increased reaction time enables them to correct emerging issues efficiently. Through experience, maritime operators get a feeling for the normal state of a sensor reading, and developing a strong feeling for the sensor's baseline could give an early lead on an anomaly that might become an issue later.

Similarly, level 3 SA as proposed in Endsley (2000) describes that expert operators can project future system states based on cues and their comprehension of a situation. Endsley (2000) argues that expert users rely on this type of strategy to make informed and effective decisions.

This suggests that navigators who gain enough experience with the navigation system to become expert users could potentially address emerging issues before alarms are triggered, raising the skill ceiling of the ferry operation. Furthermore, as the IEC alarm standards propose that alarms should be implemented as sparsely as possible (American Bureau of Shipping, 2018), providing interpretable signals could let navigators anticipate anomalies earlier, in turn leading to safer crossings.

G3: Allow users to detect anomalies early.

Navigators who have more time to respond can make safer and more effective decisions. Cues that could warrant alarms if they escalate should be visible to users in advance, enabling expert operators to act before an alert is triggered. Supporting early interventions of anomalies could reduce alarms and enable safer crossings.

7.2.4 Theme 4: An actionable resolution of information

While analyzing system metrics might give a more complete picture of the state of the crossing or vessel (see G3), navigators cannot be expected to allocate cognitive resources to analyze vessel data at all times. In a context where navigators have less time to monitor the vessel status, salient information needs to be immediately interpretable and actionable. Participants stated that the immediate views should indicate how the information could be used, rather than displaying metrics about the vessel status.

Similar principles are well-represented in design literature, such as information hierarchies which should serve the users' needs, as defined in Cooper et al. (2014) or minimizing distractions to allow the human's purposeful direction of attention in SA theory (Endsley, 2000). Nielsen (1994) similarly notes that each new piece of information diminishes the relative visibility of the sum. Interpretable, high-level components could act as a summary of the underlying metrics that could otherwise be explored when time permits.

G4: Ensure that salient information is actionable.

Given less time to monitor vessel status, navigators need quick access to information that could support their decision-making, even under time pressure. Detailed system metrics are still valuable, but should not compete with actionable, high-level

information.

7.2.5 Final iteration prototype

In contrast to the evaluation prototypes developed to evaluate specific aspects of the interface, this final prototype serves as a finalized example of how the design guidelines can be implemented in practice, as well as aligning with constraints imposed by the specific context of Cstrider.

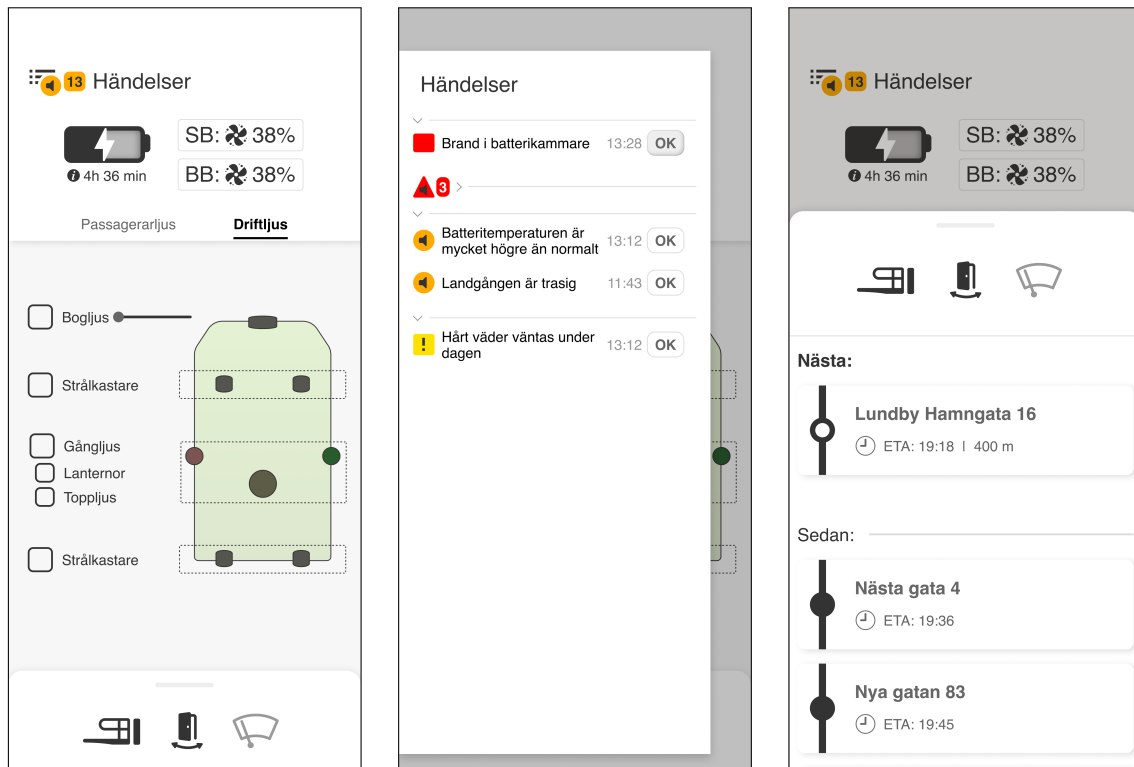


Figure 7.1: The three main views of the finalized second iteration.

Most of the changes in this iteration are done to accommodate for G4, in incorporating detailed information while keeping the salient elements actionable and overview-oriented. This justified the redesign of the notification side menu (7.1), which has been reworked to allow collapsible groups of notifications as well as a time stamp.

Further, in accordance with G4, an information button was incorporated in the battery area to give the user a more detailed explanation of the state of the batteries. This information button reveals a modal, seen in figure 7.2. From there, the user can see individual status reports for each battery.

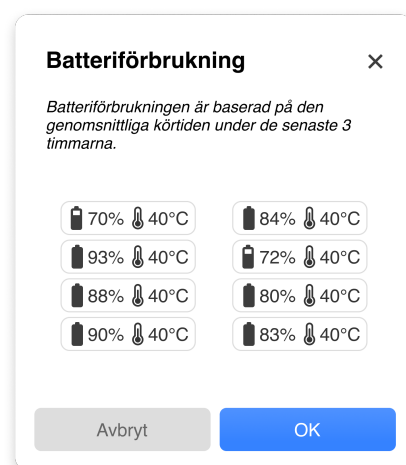


Figure 7.2: The battery modal of the final iteration.

The light control panel remains mostly unchanged for this iteration, with a minor change. The sub-checkboxes of each light group were made smaller to further indicate that they are grouped to their parent light, as per the findings from evaluation 2.

Both the gangway modal and the bottom navigation bar were moved into a higher fidelity state for this prototype. The bottom navigation bar (figure 7.3) was simplified to remove the miniature map, now replaced by a conventional line with a stop indicator. The upcoming stop card also incorporates a distance measurement.

The gangway modal was updated for this iteration to include the outlines of the ferry, as just the profile of the gangway itself might not have been clear enough to be understandable (figure 7.4).

With these changes, the prototype would now act as an example of how to put the four guidelines into practice. However, as status and operation of the autonomous navigation system was outside the scope of this thesis, **G2: Ensure traceability of automated actions** could not be exemplified through the prototype.

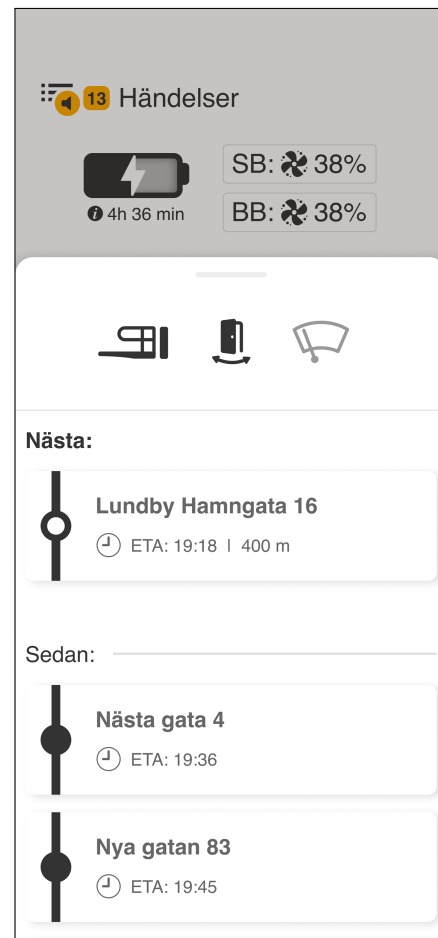


Figure 7.3: The bottom navigation bar of the final iteration.

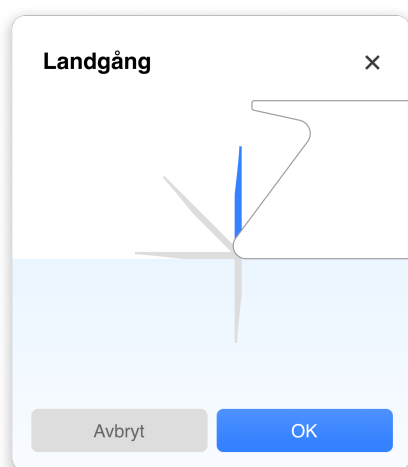


Figure 7.4: The gangway modal of the final iteration.

7.2.6 Research contribution

By identifying how to support ferry operation where a single crew member collaborates with an autonomous agent, this thesis lays an initial groundwork for HAT operation in this specific context. Compared to contemporary research such as Alsos et al. (2024) or Munim et al. (2022), moving to human-autonomy team operation instead of removing the crew altogether is a novel approach which might mitigate the identified issues with crew-less operation and trust (Munim et al., 2022). Further, by combining a literature review with reflective design methodology, this study exemplifies how best practices can be identified and made explicit in a domain where knowledge is largely practical and experience-based rather than theoretical.

Based on the findings of this thesis, several opportunities for further work can be identified. Since the work done thus far has been exploratory and speculative, a natural next step would be to implement the proposed HAT context for real ferry crossings, to understand if the theoretical design guidelines are viable in practice. Furthermore, while the literature on maritime GUI design has been clear that ships' interfaces have to be adapted to the physical design of the ships, the presented design guidelines could be adapted to different types of semi-autonomous passenger ferries to test their generalizability.

Other channels for communicating with navigators could also be explored such as wearable technology for notifications. This could provide a different angle since it might be less obtrusive while the navigator is working on other tasks, but might also provide a lower resolution of information. These options were not explored for this project due to constraints of financial viability.

7.3 Ethical considerations

This thesis work supports the implementation of decision support systems which aim to reduce the need of human intervention, which is required in the pursuit of efficiency and shareholder value. This could at the same time lead to a de-skilling of maritime professionals, partly as they gain less work experience but also because the demand for their work decreases (Veitch et al., 2022). If test participants have considered this and agree to the sentiment, it might be reflected in their participation in the study possibly resulting in bias. Further, I will follow established ethical guidelines when collecting and processing data from participants, such as gathering informed consent and stating that it can be withdrawn at any moment (Vetenskapsrådet, 2024). I will also only use the collected data for the purpose of the study.

8

Conclusion

The purpose of this thesis work has firstly been to identify the goals of passenger ferry operation, through relevant literature and through the values and experience of maritime professionals. Secondly, the thesis has aimed to explore how those goals can be supported practically in a semi-autonomous context. The work on these topics have been permitted by the following research question:

How should maritime information interfaces be designed to support navigators for semi-autonomous small ferry crossings?

The work on answering this research question was carried out using the RtD methodology, which allows the use of design methods in the efforts of making a knowledge contribution. The design literature indicated that the choice of methods should align with the requirements of the design problem, which informed the methodology in this project. Most notably, the use of sketching and prototyping was chosen as the outcome was expected to be a GUI, and reflective design was incorporated as the project was expected to redefine the context of ferry operation.

The different iterations of the prototype served two purposes in the study. Firstly the prototypes served as foundations for usability tests, to determine what features of the design were usable or needed iteration. Secondly, the prototypes served as research probes, carrying values and implications to evoke reactions in participants regarding the proposed new context of ferry operation. The final version of the prototype also exemplifies the main outcome of the thesis work, the following design guidelines:

- **G1: *Give safety-critical information salience over other tasks.*** While interfaces might include many types of information which could be useful during routine operation, they must always be designed to ensure that safety-critical information can take over at a moment's notice.
- **G2: *Ensure traceability of automated actions.*** If the navigator is ultimately responsible for the operation of the vessel, information interfaces must allow for reviewing and justifying the autonomous agent's critical decisions.
- **G3: *Allow users to detect anomalies early.*** Navigators who have more time to respond can make safer and more effective decisions. Cues that could warrant alarms if they escalate should be visible to users in advance, enabling expert operators to act before an alert is triggered. Supporting early interventions of anomalies could reduce alarms and enable safer crossings.

- G4: ***Ensure that salient information is actionable.*** *Given less time to monitor vessel status, navigators need quick access to information that could support their decision-making, even under time pressure. Detailed system metrics are still valuable, but should not compete with actionable, high-level information.*

By identifying these design guidelines for the novel context of semi-autonomous passenger ferry operation, the research question of this thesis has been answered. As autonomy continues to evolve in the maritime domain, this thesis has exemplified a novel context where the human remains an active collaborator with an autonomous system. Given the passenger skepticism associated with fully crew-less operation, the suggested context could act as a necessary transition phase to ensure passenger safety as maritime passenger transport enters the automated era.

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A

Project plan

This section contains the plan of the project before it was carried out, as well as the time plan. The project plan follows the Interaction Design Lifecycle Model as defined by Sharp et al. (2019) as a scaffolding of phases populated with relevant methods. These are presented below.

A.1 Discovering requirements

For this part, I have focused my efforts on conducting a literature review on the topics of semi-autonomous ferries, human-autonomy teaming and GUI design and visualization for maritime navigation. I considered user-centered methods for this part, but as the artifact I am designing does not yet have an established context, it was deemed less relevant to explore users' previous experiences on the topic. I have conducted a literature review and this in dialog with Cstrider will be the basis of the product requirements.

A.2 Designing alternatives

By brainstorming I intend to come up with a multitude of ideas that could be suitable to addressing the issues identified in the project's context. These are visualized with sketches of GUI concepts and scenarios. Both parts are vital to communicating functionality and usability, as the GUI would respond to external events simulated by the scenario. Sketches are a good way to generate many ideas efficiently before settling on an alternative (Buxton, 2007).

A.3 Prototyping

When a concept is deemed fit for further development, I will refine it as a basis for evaluation. This is likely to result in a screen-based wireframe GUI with a focus on what pieces of information are relevant to the users in what context. I will also include a more developed scenario to illustrate how the interface might respond to external events.

A.4 Evaluating

For evaluation, I will initially prepare the prototype by conducting a cognitive walkthrough. When I feel confident that it can yield useful data, I intend to conduct task-based usability tests with participants following a scenario. While conducting the usability test I will observe participants and note eventual errors that they make. This will be followed up by a questionnaire as well as semi-structured interviews. The interviews will be analyzed using thematic analysis. Collecting data using different methods is known as methodological triangulation and is good practice for collecting reliable data (Sharp et al., 2019).

A.5 Time plan

The time plan for this thesis project was established in the process of creating the thesis proposal.

Timespan	Task
Weeks 1-2	Systematic reading and researching relevant theoretical frameworks
Weeks 3-4	Writing of background, introduction and project methodology
Week 5	Study design based on the defined methods
Week 6	Benchmarking contemporary systems, writing about process so far
Weeks 7-8	Creating a prototype in dialogue with industry partner
Weeks 9-10	Data collection and preliminary processing (interview coding)
Weeks 11-14	Data analysis and writing about the evaluation process
Weeks 15-18	Discussion, conclusion and proofreading

Due to a schedule mismatch, the data collection weeks had to be rescheduled to one week later. While not ideal, it allowed more time to be allocated for writing about the theory around maritime operations:

Timespan	Task
Weeks 1-2	Systematic reading and researching relevant theoretical frameworks
Weeks 3-4	Writing of background, introduction and project methodology
Week 5	Study design based on the defined methods
Week 6	Benchmarking contemporary systems, writing about process so far
Week 7	Refining the theory and methods section
Weeks 8-9	Creating a prototype in dialogue with industry partner
Weeks 10-11	Data collection and preliminary processing (interview coding)
Weeks 12-13	Data analysis and preparing a second iteration of the prototype
Week 14	Data collection and preliminary processing (interview coding)
Weeks 15-18	Discussion, conclusion and proofreading
Weeks 19-20	Thesis defense and presentations

B

Evaluation Plan

SAMTYCKE

Denna studie är en masteruppsats för Interaction Design-programmet på Chalmers. Jag undersöker om det är möjligt att framföra en liten färja med endast en personal ombord, och i så fall hur ett informationssystem skulle kunna stötta denne i sitt arbete.

Genom din medverkan samlar jag in en ljudinspelning samt anteckningar av ditt användartest. Genom att medverka godkänner du att denna information samlas in och används för syftet som anges ovan. Datan behandlas enligt standardpraxis för GDPR, den kommer att anonymiseras och förvara på ett sätt så att endast jag (Alfvar) har tillgång till den. Du har när som helst rätt att avbryta ditt deltagande utan att ange en anledning. Kontakta gärna mig eller min handledare om något känns oklart, eller om du vill få informationen om dig raderad.

Jag som genomför studien är Alfvar Arvidsson alfvar@chalmers.se
Min handledare heter Ilaria Torre ilariat@chalmers.se

Namn och plats

Datum

Välkommen

Vem är du? Namn/Ålder/Kön
Vad har du för relation till sjöfart?

Sammanhang

Cstrider-färjan tar 12 passagerare. De vill undersöka om det går att framföra färjan med endast en (1) personal ombord. En utgångspunkt är att rutten är förprogrammerad eller sätts dynamiskt av ett separat system. Kaptenens uppgift blir därför förändrad, och finns tillgänglig för att ingripa när något avviker snarare än för att navigera. Ett manuellt styrsystem finns för redundans/backup, monterat på innerväggen i båtens akter. Kaptenen förväntas inte ha en konstant överblick på skärmsystemet, utan ljudbaserade notiser stöttar i att förflytta kaptenens uppmärksamhet rätt.

Appen visas. Användaren får prova att navigera.

Scenario

Du ska framföra Cstrider-färjan en veckodag. Det regnar men du har ändå passagerare att plocka upp. Sjön gungar något och passagerarna frågar dig om överfarten kommer vara lugn. Du använder informationssystemet och ser att du har fått en notis om hårt väder, men att överfarten kommer gå enligt tidsplan.

Usability test!

Kan du förklara hur du tolkar skärmen du har framför dig? Är syftet med alla komponenter tydligt för dig vid första anblick? Berätta gärna högt hur du tänker och vad du gör, medan du:

- styr vindrutetorkarna?

- styr ljusen ombord?
- Berättar när vi är framme vid nästa hållplats?

Uppföljning

- Har du en sjökaptensutbildning?
- Vad har kaptenen för ansvar?
- Kan man upprätthålla det ansvaret med denna prototyp?
- Hade du känt dig trygg för passagerarna trots att du inte styr själv?
- Saknas något i prototypen? Vad hade kunnat läggas till/ tas bort?

Om det kommer på tal, visa alternativa gränssnitt

Informationshierarki

Vilken information är extra viktig att ha lätt tillgänglig under en överfart?

Här inkluderas inte alerter eller interaktiva element.

Batteriprocent
Batteritemperatur
Batteritid kvar
Radar
Kollisionssystem
Rodervinkel
Propelleranvändning i %
Tid till ankomst