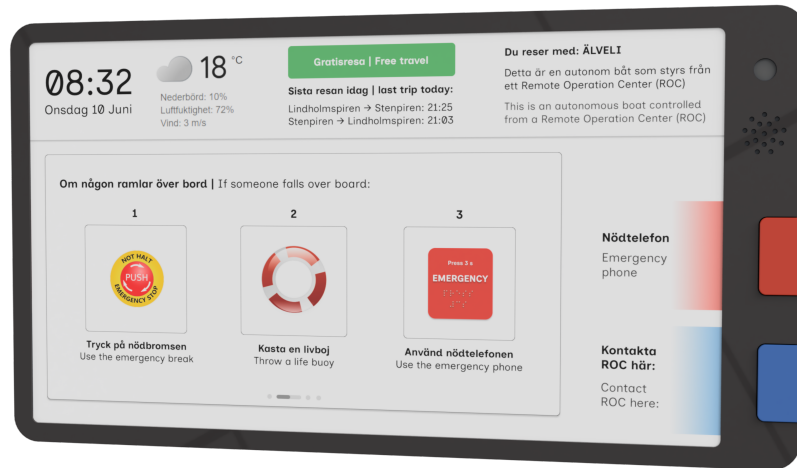




Emergency communication onboard uncrewed ferries

Exploring the Requirements and Challenges of a Passenger Information and Communication System for Emergency Situations on Autonomous Uncrewed Ferries

Master's thesis in Industrial Design Engineering and Interaction Design

PHILIP AGNESKANS FALK
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CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2026
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Abstract

The maritime sector, like many other industries, is seeing a development in automation; with this, RISE and Trafikverket have started the EMERGE project to explore what a transition to uncrewed ferries would entail. This thesis aims to explore the requirements and challenges of a passenger information and communication system for autonomous uncrewed ferries during emergencies, focusing on man overboard (MOB), fire and evacuation scenarios. First, a literature review was conducted to establish the perceived safety today, relevant design theories, existing solutions, and common procedures for emergency scenarios. This was followed by user studies that explored passengers' expectations for communication and action from crew and ship if an emergency were to occur, as well as their perceptions of autonomous and uncrewed ferries. The findings indicate that passengers require clear, timely, and trustworthy communication during emergencies. Information should be provided through multiple communication channels, combining auditory and visual cues to improve accessibility and situational awareness. Passengers also expressed a strong preference for human communication during emergencies, highlighting the importance of maintaining a connection to remote operators even in highly automated systems. Furthermore, the findings suggest that passengers are generally willing to assist during emergencies if provided with clear instructions, although emergency procedures should be designed around simple and familiar tasks that do not require specialised knowledge. The absence of onboard personnel also increases the importance of intuitive interfaces that inspire trust, reduce uncertainty, and support informed decision-making under stress. With these findings, a list of requirements was created to guide the ideation and evaluation process. Using design methodologies such as brainwriting, the ideation process yielded many different ideas, which were further developed and assessed through a combination of design methods, workshops, user tests, and expert interviews. This culminated in a final concept consisting of several complementary solutions that together meet the requirements to a level sufficient for use without a crew present, though it requires further development and evaluation before being ready for real-world testing.

Keywords: Maritime Autonomous Surface Ships; Autonomy; Automation; Remote Operations Centre; Man Overboard; Evacuation; Fire; Emergency Procedures; Public Transport.

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Philip Agneskans Falk & Anya Toftefors, Gothenburg, August 2026

List of Acronyms

The following list presents the acronyms that have been used throughout this thesis in alphabetical order:

CAD	Computer-Aided Design
FFF	Fused Filament Fabrication
HDF	High-Density Fibreboard
IMO	International Maritime Organization
MASS	Maritime Autonomous Surface Ships
MES	Marine Evacuation System
MOB	Man Overboard
PECU	Passenger Emergency Communication Unit
PLA	Polylactic Acid
PMMA	Polymethyl Methacrylate, aka. Acrylic
PNI	Positive, Negative & Interesting
ROC	Remote Operations Centre
RISE	Research Institutes of Sweden
SA	Situational Awareness
SOG	Speed Over Ground
SRK	Skill, Rule, Knowledge
SSRS	Swedish Sea Rescue Society
STW	Speed Through Water
UI	User Interface
UX	User Experience

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1

Introduction

Many industries are quickly developing automation and moving towards autonomous systems, replacing manual labour with the aim of increasing efficiency and reliability while reducing operational costs and emissions. This presents many challenges tied to technology, regulations, and the human element. The maritime shipping sector is no exception to this, where the use of automation on ships is growing. For example, the concept of MASS, or autonomous and uncrewed vessels, has been under investigation and development, and this brings about new challenges, such as the management of emergencies onboard vessels, particularly those that carry passengers.

This thesis is conducted in association with the Research Institute of Sweden AB (RISE) as part of the research project: Emergency preparedness on autonomous passenger ferries and remote operation centers (EMERGE) that is funded by the Swedish Transport Administration (Trafikverket) [Diarienummer TRV 2024/30563; Ärende-ID 8055]. The EMERGE project aims to answer questions about passenger information and communication during emergencies aboard autonomous uncrewed ferries (RISE, n.d.).

1.1 Background

There is a global trend towards digitalising systems and automating tasks in most industries. In the car, shipping, and public transport industries, the development of autonomous vehicles has been rapid (Abdulwahab & Abdul Sukor, 2026). Specifically in shipping, automation should partly allow for a reduced need for crew onboard, which could potentially lead to a reduction of operating costs. In addition, autonomous systems have the potential to perform navigation tasks, such as docking, more efficiently than humans, thus reducing costs while also supporting the reduction of CO₂ emissions and environmental impact. (DNV, n.d.; Kongsberg Maritime, n.d.; Kretschmann et al., 2017; Liu et al., 2016).

By implementing autonomous systems, some types of human errors may also be reduced. One example is skill-based errors, where lapses can occur as the operator forgets a procedure due to fatigue or slips due to a distraction (Reason, 1991). There is also a personnel shortage in the Swedish ferry and shipping industry, as fewer people are pursuing maritime education (Blume, 2025; Mikulic, 2025). Another contributing factor to the shortage is that personnel lose their qualifications/license if they have not worked on board for five years. In those cases, personnel are required to complete a 6- to 8-week education, which they must pay for themselves (Blume, 2025; Mikulic, 2025).

Onboard uncrewed ferries, no personnel will be available to inform and assist passengers directly. Thus, the need for clear, intuitive, and interactive passenger information and communications systems able to communicate with shore has become even more important. Thus, utilising autonomous or remotely operated systems has become increasingly sought after, prompting, among others, Trafikverket to invest in projects and research in this area. With funding from Trafikverket, RISE started the research project *Emergency preparedness on autonomous passenger ferries and remote operation centres* (EMERGE), which investigates how emergencies on board passenger ferries are affected and transformed by autonomous systems and how procedures can be revised and information systems and onboard equipment and technologies used to support relevant stakeholders, including passengers in emergency management (RISE, n.d.; Trafikverket, n.d.). Within their project, RISE aims to reevaluate emergency procedures and teamwork dynamics onboard autonomous ferries in relation to the integration of a Remote Operation Centre (ROC), from the perspectives of the ROC, passengers, and rescue services. The goal is to produce recommendations and innovative designs that promote preparedness and safety on board autonomous ferries.

Figure 1.1 shows an adapted graphical overview of an autonomous ferry and the actors involved in the context of emergency response, using a man overboard (MOB) emergency scenario as an example, which was produced by RISE. The left circle shows the operator and ROC centre at a distance, while the right circle shows the ferry itself and the things inside its immediate vicinity. Outside the circle are other actors who could be involved in or affected by an emergency and its handling. For this thesis, most of the focus will be on the actors within the right dotted circle. Other actors, primarily ROC operators and rescue services, have also been considered; more on this in the following sections.

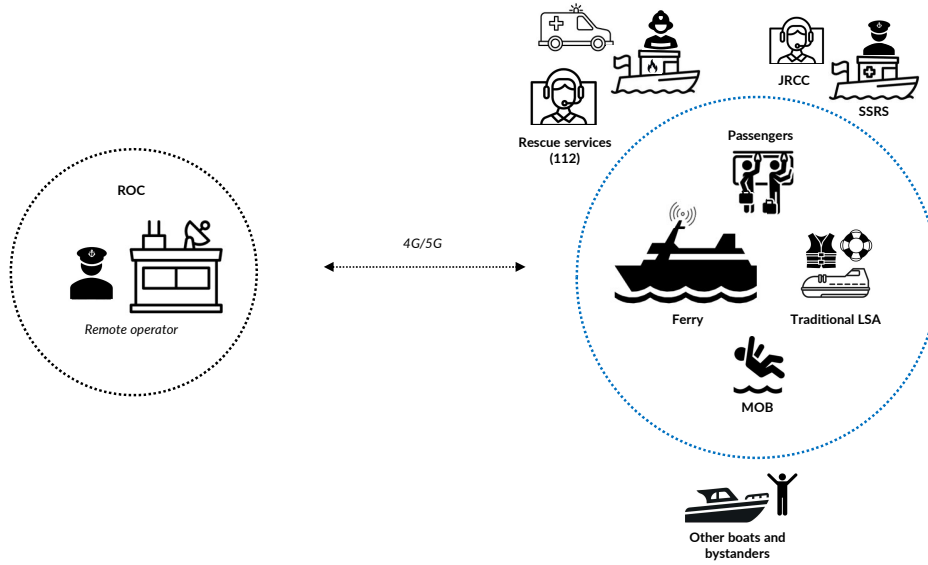


Figure 1.1: System overview of an autonomous ferry and the actors involved in emergency response, using a man overboard (MOB) scenario as an example. Figure originally produced by RISE (2026) and adapted for the purposes of this thesis with permission from RISE.

1.2 Aim & Objectives

This thesis investigates passenger needs and requirements for information and communication onboard uncrewed ferries during emergencies such as MOB and proposes feature concepts for a passenger information and communications system. Without a crew on board, there is both a reduction in perceived safety, as seen in the literature review (see chapter 3), and a lack of guidance in emergency scenarios. Thus, this thesis aims to investigate system-concept features that can support passenger information provision and communication with shore crew during emergencies, including Man Overboard (MOB), Fire, and Evacuation scenarios.

This work's overall objective is to understand the current state of passenger information and communications systems and then to develop a novel concept. The developed concept focuses on enabling qualitative interaction between the system and the passenger and providing clear information exchange between the passenger and ROC or other Rescue personnel. The work can be divided into 5 tasks:

- Performing a literature review of current passenger information systems and UX practices in autonomous transport.
- Conduct user research of passenger expectations, needs, and concerns.
- Explore the potential and limitations of automating information.
- Develop concept(s) for interactive information and communication systems that promote passengers' situational awareness and communication in emergencies while maintaining passenger safety and providing trust in the system.
- Evaluate concepts and prototypes through user testing.

1.3 Target Group, Users & Stakeholders

The main target group is passengers on near-coastal ferries travelling in rivers and archipelagos in and around cities; these passengers are considered the users, and the concept is developed for this context. Furthermore, as the implementation of an information and communication system coincides with the conversion to autonomous ferries, there are additional stakeholders beyond those for crewed ferries. It is hard to say exactly who the stakeholders will be, as autonomous and uncrewed ferries and associated regulations are under development. However, based on the system overview in Figure 1.1, actors outside the primary target group will be considered, including ROC operators who monitor or control the ferry from an ROC and the rescue personnel, as they are also a part of the emergency response system. Though not directly affected by the information and communication system, other vessels travelling in the same area could also be affected by other vessels' autonomy levels and become involved in supporting during an emergency.

1.4 Demarcations

Currently, the legal framework for operating autonomous or uncrewed maritime passenger vessels is still under development; thus, regulations to guide design decision-making in this context are scarce. As a result, the work will largely be based on insights and conclusions drawn from user studies and a literature review of existing research. The scope is limited to smaller ferries operating nearshore in rivers and archipelagos, where rescue services are readily available. The user studies, requirements, and concepts will be adapted to the conditions of these ferries.

As the purpose of the developed concept is to propose possible solutions rather than to be deployed, subsequent prototypes will be at a level of fidelity sufficient for testing and evaluation. Inclusiveness is considered in developing the concept, though it may not be well suited to all user groups due to time constraints.

2

Methods & Procedures

This project adopted a human-centred design approach in which users informed design decisions throughout the development process. The overall process broadly aligns with the Double Diamond design framework as described by Sharp et al. (2019), alternating between exploratory and convergent phases across the project's stages. Accordingly, the design process is divided into five main stages, presented below in chronological order as subsections. First, a literature review was conducted to establish a theoretical foundation and to understand existing research and solutions. This was followed by a user study phase to gather insights from potential users and experienced workers on possible needs, experiences, and expectations. The collected information was later analysed and used to identify key findings that would serve as a basis for establishing the design requirements. Finally, ideas were generated, developed, prototyped, and evaluated in an iterative ideation and evaluation process.

2.1 Literature review

The literature review combined a review of academic literature with an examination of existing emergency systems and related solutions. It aimed to provide a theoretical and contextual understanding of the design challenge before conducting the user study and ideation process. The literature review focused on five main areas: perceived safety, related work, existing solutions, misuse of communication systems, and design principles.

2.2 User studies

A user study was conducted to complement the findings from the literature review and to provide insights that could not be obtained from the available literature alone. As the project aimed to address passengers' needs and experiences, it was important to include their perspectives. In addition, interviews with experienced ferry personnel were conducted to gain a practical understanding of current and future procedures and challenges. Together, these perspectives contributed to a broader understanding of the setting and provided valuable input for the subsequent analysis and the definition of design requirements.

2.2.1 User studies – Methods

Qualitative data collection methods were used as the objective was to gain a deeper understanding of experiences, perceptions, procedures, and contextual factors rather than collect statistical data. Three different kinds of interviews were used depending on the purpose of the interview: structured, semi-structured and unstructured.

Structured interviews contain predetermined questions; a benefit of this is the ability to compare answers across participants, since they were asked the same questions. However, it does not leave room for follow-up questions, which can limit the collected information. Semi-structured interviews have predetermined questions but allow for follow-up questions at the interviewer's discretion. This was used when specific topics needed to be addressed while still allowing further exploration of emerging subjects. In situations where prior knowledge was limited, unstructured interviews were conducted to encourage participants to freely describe procedures, experiences, and contextual factors relevant to the project.

All interviews conducted on board the ferries with crew and passengers were carried out in a similar manner. One interviewer asked the questions while the other took notes. Audio recording on board was avoided since it took place in a public setting, making note-taking a more practical and less intrusive method of documentation. Note-taking also helped keep the interviews brief, which was important given the limited duration of each ferry crossing.

In addition to interviews, observations were carried out to gain a direct understanding of existing environments, systems, and practices. These observations complemented the interview data and provided contextual insights that could not always be captured through verbal descriptions alone.

2.2.2 User studies – Process

Six different data collection activities were conducted during this stage of the project: a field study, pilot interviews, passenger interviews, crew interviews, an expert interview, and a study visit to a road ferry. An overview of the data collection activities is presented in Table 2.1. Unless otherwise stated, all ferry-based activities were conducted onboard public ferries operating in Gothenburg.

Table 2.1: Overview of the conducted data collection activities.

Name	Type	Place	Participants
Field study	Observations	Line 286 (Stenpiren to Lindholmospiren)	No external participants
Field study	Observations	Line 285 (Stenpiren to Klippan)	No external participants
Pilot	Semi-structured interviews	Line 286 (Stenpiren to Lindholmospiren)	3 Passengers Ages 66–80 2 Female & 1 Male
Pilot	Semi-structured interviews	Line 287 (Stenpiren to Lundbystrand)	1 Passenger Age: 65; Male
Pilot	Semi-structured interviews	Line 286 (Stenpiren to Lindholmospiren)	1 Crew member (Deck hand)
Passenger	Structured interviews	Line 286 (Stenpiren to Lindholmospiren)	10 Passengers Ages 23–66 6 Female & 4 Male
Crew	Semi-structured interviews	Line 286 (Stenpiren to Lindholmospiren)	2 Crew members (Deck hand) (5 & 6 years of experience 1 Female & 1 Male)
Expert	Semi-structured interviews	Video call (audio recorded)	Master Mariner and R&D Engineer
Study visit	Unstructured interviews & Observations	A Road ferry in west Sweden	9 Crew members (From Early-career to Senior workers)

Field study

A field study was conducted to better understand how ferries currently operate and mainly involved observing from a passenger’s perspective. The ferry service operating between Stenpiren and Lindholmospiren (line 286) in Gothenburg was selected as a case study based on its geographical accessibility. The observations focused on documenting existing safety equipment and emergency resources available onboard, such as life buoys, life rafts, and fire extinguishers, as well as identifying how safety information and emergency procedures were communicated to passengers through signage and other onboard information. Due to differences between ferries, the ferry between Stenpiren and Klippans Färgeläge (line 285) was visited as well. This ferry had similar equipment, although with the addition of safety videos displayed on the screens onboard. Some of the equipment was located in other places as well, such as the life vests.

Pilot interviews

A few semi-structured pilot interviews were conducted with passengers and a crew member to test questions before conducting the passenger and crew interview study.

The pilot interviews were carried out on board the ferry routes between Stenpiren and Lindholmospiren (line 286) and between Stenpiren and Lundbystrand (line 287). They were conducted during late morning, which may have influenced the participant sample, as all interviewed passengers were over 60 years of age.

The pilot interviews primarily explored passengers' perceptions of the transition from conventional ferry operations to autonomous ferries. Questions addressed topics such as passengers' interactions with deckhands, their perceived sense of safety with and without onboard personnel, and how they expected to receive information during an emergency. Although these questions generated valuable insights, they provided limited information about passengers' expectations and likely behaviour during emergencies. Based on these findings, the interview guide was revised by removing or refining less relevant questions and introducing new ones focusing on where passengers would seek information, how they expected emergency information to be communicated, and what actions they believed would be taken during different emergency scenarios.

The pilot study also informed several practical aspects of the interview procedure. Although passengers generally had sufficient time to answer the interview questions during the journey, the shorter crossing on line 287 left limited time to approach passengers, introduce the study, obtain their consent and complete the interview before arrival. Since it was considered unreasonable to ask passengers to continue the interview after disembarking, line 286 was selected for the main interview study, as its slightly longer crossing provided greater flexibility during the interview process. Furthermore, the pilot study indicated that conducting interviews at different times of day would likely result in a more diverse participant sample in terms of age.

Passenger interviews

Based on information from our literature review and pilot study, a more elaborate interview structure was designed; see Appendix A. All interviews were structured and conducted on board ferries travelling between Lindholmospiren and Stenpiren. Although the interviews aimed to be randomised in terms of participant selection, age and gender were considered when approaching people to obtain a wider range of interviewees. The interviews were held on two weekdays at different times of day to reach a broader sample. The first round was held early Tuesday afternoon, while the second was held the following morning. Additionally, two crew members were interviewed. Unlike the passenger interviews, these interviews were semi-structured, allowing for follow-up questions based on their answers.

Expert interview

An online interview with a subject-matter expert in maritime operations was conducted to gain an understanding of onboard communication systems and emergency procedures. The interview participant is a Master Mariner employed at RISE Research Institutes of Sweden, with extensive experience in maritime operations and the development of digital and automated shipping solutions. Throughout their ca-

reer, the expert has been involved in projects related to maritime digitalisation, remote vessel operations, and autonomous shipping technologies. The expert's knowledge of crew responsibilities, passenger behaviour during an emergency, and the information required by the Remote Operations Centre (ROC) was considered essential for developing a concept suitable for a real-world context.

Rather than following a predefined set of questions, the expert was encouraged to explain the current procedures and routines associated with the project's focus scenarios: man overboard (MOB), fire, and evacuation. This allowed the expert to clarify technical concepts, explain the reasoning behind existing procedures, and adapt the explanations to the researchers' level of prior knowledge. The interview provided valuable contextual knowledge that complemented the literature review and supported the interpretation of findings from the user studies.

Study visit at a road ferry

Lastly, a study visit was conducted on a road ferry operated by Färjerederiet. As part of the national road transport system, Färjerederiet operates ferries where passengers drive their vehicles onboard. The visit was made possible through the project's collaboration with RISE and was performed to observe their regular safety routine training. Procedures such as MOB retrieval and using water cannons were demonstrated and explained. The crew members answered questions about current routines and shared their thoughts regarding the development of autonomous ferries, both expectations and concerns. This crew will be referred to as the road ferry crew later in chapter 3.

2.3 Analysis & Requirements

Following the interviews and observations, all the data were analysed using a KJ-analysis, named after the developer Jiro Kawakita (Plain, 2007). It is a qualitative analysis tool that can be utilised to analyse large amounts of unstructured data into groups based on similarities between the collected data. In this process, individual comments from the interviews were transferred onto separate sticky notes, with each note representing a singular statement or idea. These notes were then reviewed one by one and grouped according to perceived similarities and relations with other notes rather than predefined themes. As larger clusters of sticky notes formed, the groups were assigned descriptive names. These themes can be seen in chapter 3. This approach provides a way to identify underlying themes that would not have been found by grouping answers by question or person.

The design requirements were extracted from the themes/categories that emerged from the KJ-analysis, serving as a conclusion to what was learned and gathered from the user studies. The purpose of defining design requirements was to ensure that insights gathered during the data collection could be incorporated into the design process. Therefore, the requirements both acted as design goals during the ideation and as criteria during the evaluation process. Together, the requirements described

the design needs to be resolved, creating corresponding design features that inform and communicate with passengers in a way that promotes onboard safety during operations, particularly during emergencies.

2.4 Ideation & Evaluation

The ideation and evaluation phase consisted of several iterative activities aimed at generating, developing, and refining design concepts. The process began with brainwriting sessions, followed by evaluation using a Positive, Negative, and Interesting (PNI) analysis (Österlin, 2016). Key features were then identified and used as a basis for generating concept variations through a second brainwriting. These variations were developed into the first concepts and visualised through low-fidelity prototypes. A feedback session and evaluations against the established requirements were conducted to guide concept selection and refinement. The selected concept was further developed into a mid-fidelity prototype, which was evaluated through user testing interviews and a user testing focus group before the final concept was established.

2.4.1 Ideation methods

The purpose of the initial brainwriting was to capture as many individual ideas as possible without the participants influencing one another. Since brainwriting is an individual method in which participants generate ideas independently, it encourages a wider variety of ideas rather than multiple variations of the same concept (Österlin, 2016). Putting ideas on paper also helps identify both opportunities and challenges associated with different design solutions.

The brainwriting session was done with a modified version of the 6-3-5 method (Österlin, 2016). The method is named after its original format, in which six participants each create three ideas each in five minutes. The ideas are then passed to the next participant, who continues to develop them during the following five-minute round. In this project, the method was adapted to accommodate the two authors, who each generated six ideas in six minutes, resulting in a 2-6-6 method. The modifications were made to encourage as many ideas as possible during the early stages of the design process. The exercise was conducted twice to ensure that ideas were generated for all selected scenarios. The first session focused on the man overboard (MOB) scenario, while the second focused on the fire and evacuation scenarios.

Additionally, brainstorming was utilised during later stages of the ideation and development phase. Brainstorming can be done using different tools, including sticky notes, papers, drawings, whiteboards, and discussions, provided that the established rules are followed. The brainstorming sessions for this thesis were conducted according to the rules proposed by Österlin (2016). These rules, translated to English, are presented below:

- Criticism and evaluation during the session are strictly prohibited (including self-criticism).
- A large number of ideas is encouraged, as a broad range of ideas increases the likelihood of generating high-quality solutions.
- Participants are encouraged to think beyond conventional solutions; wild and unconventional ideas are welcomed.
- Combine and build upon existing ideas.

2.4.2 Positive, Negative, and Interesting (PNI) evaluation

With a series of sketches from Brainwriting, we grouped similar concepts/solutions. This was then put into a PNI table (see Table 2.2), where each concept got its own row, and the columns consisted of positive, negative, and interesting aspects. In addition, we added a column for questions about aspects that are unclear on how to solve or develop that particular solution. This method evaluates and puts words to each concept’s strengths, weaknesses, and quirks by identifying the positive, negative, and interesting aspects of each concept (Österlin, 2016).

Table 2.2: Example of a PNI Table.

Concepts	Positive	Negative	Interesting
Concept 1			
Concept 2			
Concept 3			

2.4.3 Identifying key features and creating variance

With the PNI showing the aspects of the different concept groups, this step focuses on examining the individual features of the sketches. The goal is to identify the key features and create more detailed variants through another brainwriting session and by taking more time to think through the features and draw them at a higher fidelity. This way, one can create many variants and iterate without needing to draw all possible combinations. Thus, one can quickly see what works and what does not.

2.4.4 Prototyping

During the project’s development phase, numerous mock-ups and a prototype were created. For the digital interfaces, Figma, a user interface (UI) design tool, was used to create graphical mock-ups with interactions. Meanwhile, the physical parts were made using Autodesk Fusion, a CAD (Computer-Aided Design) software.

Using the 3D-printing method FFF (Fused Filament Fabrication), most of the components from the CAD could be printed in PLA (Polylactic Acid). With this method,

complex parts could be manufactured accurately with minimal effort. For some of the simpler “flat” parts, a CO₂ laser could be used to create numerous components much faster from sheet materials. For the mock-ups, some scrap pieces of MDF (Medium Density Fibreboard) and Plywood were utilised, both due to their simplicity and affordability, and because they allow the use of indoor wood glue, which is odour-free and safe to handle. When making the prototype, PMMA, also known as Acrylic, was used as it provides a rigid component with a good surface finish and colour.

2.4.5 Feedback and evaluation

Throughout the project, external participants were involved at three stages to evaluate and refine the proposed concepts: a feedback session, user testing interviews, and a focus group. These activities were conducted at different stages of the design process to provide perspectives from participants with varying levels of domain knowledge. Together, these evaluations supported concept refinement and informed the selection of the final concept.

The low-fidelity prototypes as well as the sketches for the first concepts were evaluated through a feedback session with experts from RISE and an Associate professor from Chalmers. The purpose of the session was to gather early reflections on the proposed concepts before investing additional time in further development. By presenting physical mock-ups rather than sketches alone, the participants were able to better understand the concepts and discuss their potential strengths, weaknesses, and practical implications. The feedback gathered during the session, together with an evaluation against the established requirements, formed the basis for selecting which concept to develop further.

Table 2.3: User test participants – Feedback session.

Position	Background	Gender
Senior researcher	Human factors; maritime technology and safety	Female
Researcher	Industrial design engineering; human-computer interaction	Male
R&D engineer	Autonomous maritime transport; remote vessel operation	Male
Doctoral researcher	Maritime safety; fire safety; risk management	Male
Associate Professor	Design & Human Factors	Male

The user tests consisted of three individual semi-structured interviews conducted with the support of a scenario, a prototype, and visual materials such as images of a ferry’s interior and an image of how the concept would look when placed in the

correct context. These materials were used to guide the discussion and encourage participants to reflect on how they would interact with the proposed concept in a realistic situation. The participants (students) are listed in Table 2.4 below. The interviewees were first asked what they expected the procedures to be in case of MOB, a fire or evacuation. Then they were asked about what they thought about the concepts presented to them and how they would use them.

Table 2.4: User test participants – User interviews.

Field of study	Year	Gender
Industrial Design Engineering	2 nd year Master	Female
Civil Engineering	2 nd year	Female
Civil Engineering	3 rd year	Female

A focus group was conducted with three employees from RISE who had relevant expertise in maritime operations and autonomous shipping. The participants and their backgrounds are presented in Table 2.5. Similar to the user tests, the participants were presented with the scenarios, prototype, and visual material to provide context. The session was conducted as an open discussion rather than individual interviews, allowing the participants to discuss the proposed concepts together. They were also presented with selected findings from the user tests and asked to reflect on users' perspectives, discuss the differing opinions expressed, and evaluate the concepts through their professional experience. The discussion provided additional insights that supported the selection of the final concept.

Table 2.5: User test participants – Focus group.

Position	Background	Gender
Senior advisor	Master mariner/chief officer; worked on-board for many years	Male
Researcher & Developer	Master mariner; worked onboard and teaching	Male
Researcher	Worked onboard	Female

3

Findings

This chapter presents the findings from both the literature review and the user studies conducted during the project. Previous research, existing solutions, and relevant design theories are reviewed to establish an understanding of the current situation as well as future possibilities. Insights from pilot interviews, passenger interviews, crew interviews, the expert interview, and additional input from crew members at a road ferry in west Sweden were analysed using a KJ-analysis, resulting in the themes presented in this chapter. Each section concludes with a summary of the key findings and insights identified in the respective area. Together, these findings form the basis for the design requirements and concepts developed later in the project.

3.1 Existing safety and communication solutions

Existing solutions and concepts related to passenger safety and emergency communication were examined. The purpose of this review was to identify design approaches, communication methods, and interface elements that can later be considered during the design stage. The analysed examples span both maritime and non-maritime settings, as well as autonomous and non-autonomous transport systems, providing a broad basis for identifying design principles applicable to the present study.

3.1.1 Interface characteristics

Observations of existing public transport systems were conducted to identify common characteristics of emergency communication systems that passengers may already be familiar with. This can provide input on what users may expect from the interface of an emergency communication system. As can be seen in Figure 3.1, there is a common theme of using the colours red and grey in existing emergency systems. The Emergency breaks as well as the emergency communication buttons use these colours. When looking at system placed on platforms and at stations colours such as green and yellow are commonly present together with grey. Symbols such as phones, someone speaking, a bell, or a hand using a break are commonly used. Some systems also have a diode to indicate whether the system is currently in use or when to speak and when to listen.



Figure 3.1: Images of emergency systems in trains, trams, and on platforms.

3.1.2 Intuitive emergency interface

One example that incorporates several of the interface characteristics identified during the observations is the passenger emergency communication unit (PECU), shown here as a redraw in Figure 3.2. The design was awarded the Singapore Good Design Award (SG Mark) for its microphone-like shape while still clearly identifying itself as an emergency device. These features allow passengers to intuitively engage with the device in an emergency.

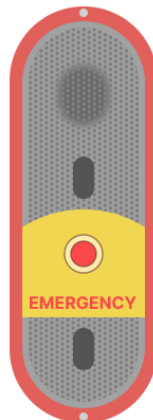


Figure 3.2: Redraw of the rewarded emergency communication unit.

3.1.3 Automation and user acceptance

While the previous examples focus on the design of emergency communication interfaces, it is also relevant to examine how emergency features contribute to passenger acceptance of automated transport systems. Because there are currently few operational autonomous ferry systems available for study, examples from other automated transport systems were also examined. Elevators are one example of an automated transportation system that has become widely accepted by the public. While personnel were once required to operate and supervise elevators, their operation is now working autonomously, and most people use them without hesitation. However, this transition was first met with scepticism, and many users felt uncomfortable riding without a human operator (Henn, 2015).

To enhance user acceptance, several design measures were introduced to increase users' sense of safety and control. Examples of such measures include installation of emergency stop buttons, safety doors, voice messages, and emergency telephones. These features provide users with a sense of control by allowing them to take action or contact qualified personnel during emergencies. The systems reduced feelings of vulnerability and increased trust in the automated service (Henn, 2015). This illustrates how user-centred design can be utilised to enhance feelings of safety and acceptance when introducing new automated technologies. Some examples of elevator emergency interfaces observed during the thesis work are presented in Figure 3.3.



Figure 3.3: Images of emergency systems in elevators.

3.1.4 Autonomous ferry concept

Despite the insights gained from other automated transport systems, relatively few concepts specifically developed for autonomous ferries were identified in the reviewed material. One such concept is Porathe's design suggestion for a passenger interface on an autonomous ferry, illustrated in Figure 3.4 (Porathe, 2021). Although this interface focuses more on day-to-day use, it still contains buttons specifically designed for emergencies. The buttons are grouped into three categories: manoeuvring, contact ROC, and emergency. The manoeuvring group contains "depart" and "hold the gates", while the "contact ROC group" consists of a button labelled "call" and explanatory text that says, "To talk to the remote operator, press the call button".

If the passenger pressed this button, it would initiate a video call with a help centre operator.

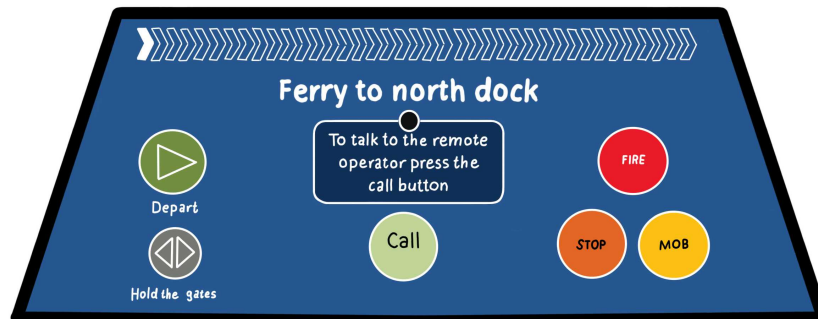


Figure 3.4: Redraw of Porathe’s UI suggestion.

The emergency group in Porathes’ design suggestion is particularly relevant for this study, as it relates directly to emergency communication on autonomous ferries. It consists of three buttons, which are named “STOP”, “FIRE”, and “MOB”. If any of these buttons are pressed, a video call with the help centre operator will start, just as when the call button is pressed. If the stop button is pressed, the ferry will hover at the same geographic location, while the MOB button will cause the ferry to stop and drift with the current. Pressing the fire button will start the automatic fire procedures.

3.1.5 Preventative safety information on ferries

The systems described above are primarily intended to be used during an emergency. However, passenger safety is also supported through information provided before an emergency occurs. One way of providing such information is through the onboard information systems found on today’s ferries. Onboard Skarven (line 285), two TV screens display information to passengers. Both screens show the same content simultaneously, with different types of information presented in a continuous loop. A complete loop of all information takes about 7 minutes and 30 seconds, and the display always shows information regarding tickets, time, date, and the weather. Among the displayed information are safety instructions presented in both Swedish and English, taking approximately 2 minutes and 45 seconds of the full information loop. The safety information that is displayed can be seen in the list below:

- “Keep aisles clear of luggage and belongings.”
- “Press the button to contact the crew.”
- “Smoking is not permitted on board, inside or outside.”

- “Fire extinguishers can be found at the designated points on board.”
- “First aid kits and defibrillators are available. Contact the crew for assistance.”
- “If someone falls overboard, throw the life buoy towards the person in distress, keep your eye on them and attract the crew’s attention” & “Life buoys can be found outside on the top deck and on the fore- and aft deck.”
- “In an emergency situation, you will hear information over the speakers and then the ship’s alarm system.”
- “The safety plan can be found towards the front of the lounge.”
- “If you need to evacuate the ship onto a raft or other vessel, put on a life jacket and follow the crew’s instructions” (the video shows taking a life vest from the boxes above the seats).
- Life vest instructions with images:
 1. “Undo the buckle.”
 2. “Pull the jacket over your head.”
 3. “Pull the straps around your back.”
 4. “Close the buckle.”
 5. “If you jump. Hold onto the life jacket.”
- “These are the ship’s evacuation routes. Board life rafts from the after deck” (image on the layout of the boat with arrows that guide passengers towards the fore or aft of the ferry).
- “For questions about the ship and safety or other information, contact the crew on board.”

Conclusions:

- Allowing users to contact authorities gives them a sense of control that can be useful in emergencies.
- Emergency communication systems often use a specific set of colours, shapes, and symbols to help users find and use the systems.
- Emergency stops are important to consider on ferries.
- Emergency communication and information can both help passengers in an emergency and prepare users beforehand.

3.2 Information channels

In human-machine systems, silence usually indicates that everything is normal, whereas sound signals that something has happened (Osvalder & Ulfvengren, 2009). A benefit of the auditory signal is that it can be heard even when not seen, which is especially useful for warnings. However, there is a risk that the sound, especially if it is speech, becomes masked by other noise. As a rule, Osvalder and Ulfvengren (2009) suggest that verbal cues should always be repeated, since they last only short-term and disappear after they are spoken.

Wickens et al. (2015) suggest that a good instruction must fulfil two requirements; it should be easy to understand but also easy to remember. It can easily occur that information is only available for a short moment if the passengers need to move away from the instructions to perform an action such as putting on life vests. If the information is only available for a short amount of time, it would be easier to remember if it is verbal rather than visual (Wickens et al., 1983). The reason for this is that the brain can “repeat” verbal information to itself, which benefits the working memory.

Although verbal information is a good way to inform passengers during emergencies, visual information should not be discarded as it is also a helpful source. While sound may only exist temporarily, visual information lasts as long as it is within sight. Vision is our dominant sense, with almost 80% of all sensory impressions taken in through the eyes (Osvalder & Ulfvengren, 2009). As of now, alarm systems often include both visual and auditory signals, and when designing visual cues, it is important to consider contrast, colour, lighting, and angle. Another benefit of visual communication is the ability to use symbols. However, they must be well-known and clear. Otherwise, they are more likely to cause confusion, which is unhelpful. Other benefits of using symbols are that they are easy to spot and they often communicate independently of language (Osvalder & Ulfvengren, 2009). Using colours can help people perceive information even faster. For example, if one is looking for a fire extinguisher, it is usually helpful to look for the symbol or the colour red.

The literature highlights both auditory and visual channels as important means of communication. To better understand passenger preferences, interviewed passengers were asked how they would expect information to be communicated during an emergency. Their responses included auditory information through speakers, visual information displayed on the current screens, or information delivered directly by a crew member. Several interviewees mentioned more than one communication method, and the responses were generally brief rather than detailed. For example, one translated response was: “sound, light”. Auditory communication was mentioned by 13 of the 14 interviewees. The 14 passengers included ten from the passenger interviews and four from the pilot interviews, since this question was asked during both instances. The auditory suggestions ranged from general references to sound or speakers to more specific suggestions such as announcements and alarms. However, many responses referred only to speakers or sound, without specifying the type of auditory signal. Five interviewees also thought it would be beneficial to com-

bine auditory signals with visual cues, such as information on screens or blinking lights, especially for passengers wearing headphones. Visual signals were mentioned by 6 of the 14 interviewees.

Some passengers said they would prefer a crew member to inform them. For example, one passenger said the best way to get her attention would be eye contact from a crew member. In total, 4 out of the 14 passengers thought a crew member would be one of the most efficient ways to catch their attention. However, one passenger said she did not think a crew member could be the answer, since the context was fully autonomous ferries. As the interviews did not ask specifically about crew members, other passengers may also have excluded this option for the same reason, so it is unclear how many would actually have preferred it.

Translated answers to the question “What is the easiest way to get your attention?”:

- Auditory: 13 (*Announcements, Alarms, Loudspeakers, Sound*).
- Visual: 6 (*Blinking Lights, Screens, Lighting, Lamps, Flash*).
- Crew: 4 (*Crew Members, Eye Contact, Personal Interaction, The Personnel Informs*).

When asked where they would look for information, the answers varied. The most common answers were at the current ticket booth or the Västtrafik application, which is used to find connections and buy tickets. Other answers included not knowing where to look, or to look at the screens at the bow or stern. Six passengers also said they would not search for any information, but expected a verbal announcement in the event of any abnormality during the trip.

Conclusions:

- Passengers think that auditory communication is an effective way to get their attention, and it is also an expected form of alert for some passengers.
- Using both visual and auditory channels can be beneficial for passengers who wear headphones while also making the communication more accessible and inclusive.
- Passengers do not rely on a single source of information and would search in both physical and digital environments; therefore, information should be available through multiple channels.

3.3 Passenger information

Previous studies cited by Huang et al. (2021) have shown that voice alarms can significantly reduce pre-movement time in evacuation scenarios compared to traditional

bell alarms. To better understand what makes a voice alarm effective, Huang et al. (2021) investigated how different attributes of a voice message affected the evacuation process in train carriages. They found that the recognition phase, lasting from the onset of the emergency until the first passenger stood up, was influenced by the length of the alarm cycle, the distance of the voice, and the rapidness of the message. Short alarm cycles, a nearby sound source, and a slightly rapid tone reduced the time needed for passengers to recognise the emergency. The transfer phase, lasting from the last passenger standing up until the first passenger left the train, was also affected by the distance of the voice, but the directiveness of the message played a role as well. A close and directive voice helped passengers find the exits more quickly. Based on these findings, Huang et al. (2021) concluded that an effective voice alarm should be: “short, directive, with a bit rapid tone and close to passengers”.

To investigate what information passengers wanted or expected, the interviewed passengers (10 from the passenger interviews) were given a brief scenario in which the boat had to stop during the trip and were then asked what information they would like to receive. Some passengers gave multiple answers, but the most common answer was what to do as a passenger in the situation (5/10), followed by what had happened and how long the stop would take. Some passengers also wanted a calming message and to know if help is on its way, as well as how the situation will continue and be resolved. The information requests expressed by the passengers are summarised below:

- What to do - 5
- What has happened - 4
- Time estimation - 4
- What will happen next - 3
- Calming message - 2
- If help is on its way - 1

The interviewed crew members also noted that there may be language barriers for those who do not speak Swedish. Being able to provide information in other languages, such as English, is important, especially during the tourist seasons. When asked how they spoke with passengers, they said it was always important to remain calm, regardless of the situation. Another point mentioned by the crew, the expert, and the passengers was to give short, precise information or instructions to passengers, which would prevent errors and save time in emergencies. Both the expert and some passengers mentioned that they would prefer to have a live connection with a human being and did not want an animated character, AI, or a pre-recorded message/video playing in emergencies. Having a person speak live would assure the passenger that someone knows about their situation, rather than the “boat acting on itself”. However, both the expert and the roadferry crew said that the ROC

operator would have many responsibilities and would probably not have the time or opportunity to have a focused one-to-one call with a passenger during an emergency.

Conclusions:

- Passengers want information about the situation as well as instructions on what to do if action is required.
- A voice alarm should be: short, directive, with a bit of a rapid tone and close to passengers.
- Information should be available in multiple languages to accommodate passengers with different language backgrounds.
- Passengers want human connection in emergencies rather than a digital recording, as this would assure them that someone knows something has occurred.

3.4 Passengers Jumping Into The Water

Despite the interviews taking place during the Swedish winter, with ice covering parts of the canal, a few passengers stated that they would leave the ship in an emergency. However, the situation often becomes more complicated for crew members and rescue teams when people are in the water compared to when they remain onboard. Both the interviewed crew members and the expert emphasised the importance of passengers staying onboard to ensure their safety. Despite this, three of the interviewed passengers stated that they would leave the ship if they believed the situation required it. The reasons given differed between the passengers. One passenger said that they would jump into the water to assist someone who had fallen overboard, while another considered leaving the ship as an option if the vessel itself was sinking. The third passenger made a distinction between different locations. In the archipelago, they would try to remain onboard for as long as possible. In contrast, in the river where the interview took place, they considered swimming to shore a reasonable alternative due to the short distance to land.

Both the expert and the road ferry crew explained that a MOB should ideally be rescued within 5–10 minutes, and that ten minutes is a very long time for a person to remain in the water. The expert mentioned that drowning accidents among fishermen who fall overboard are not uncommon. According to him, people sometimes overestimate their ability to swim in cold water and believe it will be easier to swim a short distance to safety than it actually is. This can lead to poor decisions and, in some cases, drowning accidents. He thought that ferries on the river run a higher risk of people trying to save themselves by jumping overboard since they are close to land.

The risk of a passenger accidentally falling overboard is very low, according to our expert. There are many safety measures in place today that prevent anyone from

falling into the water, especially the fences around the boat. The expert speculated that the highest risks are if a child is climbing on the rails and falls overboard, or perhaps an intoxicated adult is doing the same thing. Neither of the crew members interviewed had ever experienced a passenger falling overboard during their shifts. Nor had any of the road ferry crew members, even though some of them had worked for over twenty years with boats and ferries. It may be less common on the ferries this paper aims to study, though there are cases of people jumping into the water, unwilling to be rescued.

Conclusions:

- Passengers may underestimate the risks associated with entering the water during an emergency.
- It is important to discourage passengers from entering the water unless absolutely necessary.
- MOB situations require a rapid response to maximise the chances of survival.
- Accidental falls overboard appear to be rare on the studied ferry services.

3.5 Feeling unsure or unsafe

Some of the passengers stated they had never considered the possibility of an emergency during their trip and would not know what to do or where to find information. One passenger said that they did not want to be on board a boat that could break or sink. Half of the interviewees (5/10) did not believe that they could manage any emergency by themselves, among whom one passenger was also sceptical towards the crew's ability to manage emergencies as well.

One of the interviewees explained how she thought about different emergency scenarios the first time she brought her baby on the ferry. She considered herself comfortable only being responsible for managing herself in a crisis. However, she felt much less comfortable being responsible for both herself and her child, worrying about what would happen if she had to swim while carrying the baby.

Another passenger pointed out that there were many signs on certain parts of the ferry, and she felt confused by the number and was unsure where to look. Needing to understand which signs are important as well as figuring out what all the signs mean would take valuable time in an emergency. The passenger suggested cleaning the signs and ensuring the reliability of the remaining ones as a solution.

Conclusions:

- Passengers cannot be expected to feel comfortable handling an emergency themselves.
- Passengers cannot be expected to have considered how they should act during an emergency and therefore need clear guidance and instructions.
- Passengers may have responsibility for others, such as children, which can increase stress and complicate decision-making during emergencies.
- Too much signage can be confusing; it is important to consider the purpose and necessity of each sign.

3.6 Passengers can help

Both the expert and the crew members said not to underestimate passengers' ability to help in emergencies, and many of the interviewed passengers said they wanted to be helpful during an emergency. The passengers expressed a willingness to help others, and some felt confident they could manage an emergency, or at least contribute by performing a smaller task. The actions all passengers would likely need to perform include tasks such as moving to a designated area of the vessel or putting on life vests. Some interviewed passengers mentioned that they could help by using fire extinguishers, throwing a lifebuoy, raising an alarm, and pointing towards a MOB. Pointing to a person in the water is an example of a task suitable for passengers since it allows the crew member to look away from the MOB with minimal risk of losing sight of them.

The expert, as well as the road ferry crew, provided a rough rule of thumb they used to estimate what the passengers would do in an emergency. They expect that about 1% will panic, 10% will help, and the remaining passengers would neither panic nor actively assist. However, the road ferry crew noted that this group often gathered to observe what had happened, which could slow down traffic and create an additional disturbance. The road ferry crew also considered how to choose who amongst the passengers could help but concluded that there was no way for them to know which person would be helpful beforehand.

One of the crew members on the passenger ferry described how he had asked among the passengers if anyone could assist during a medical emergency. According to him, this approach has worked well, particularly since many healthcare professionals and emergency responders commute on the ferry. Although some passengers have proven themselves very helpful, there are tasks they should avoid, such as using the MOB sling and deploying life rafts. The MOB sling would take too long for passengers who do not already know how to use it to figure out, while deploying the life rafts could be dangerous if deployed incorrectly or in poor conditions; more on this in subsection 3.7.4.

One way of understanding these differences is through Rasmussen's Skill, Rule, Knowledge (SRK) model (Rasmussen, 1983). As described by Osvalder and Ulfvengren (2009), the SRK model describes three types of decision-making that require varying levels of consciousness. Skill-based actions are highly automated and require no active consciousness to perform. This does not take up much capacity of the short-term memory, and it is easy to do other things at the same time, such as walking and talking. Rule-based behaviour is used in known situations. Rules, procedures, and old knowledge dictate the behaviour. The rules could be universal or created by the person due to experience. Lastly, knowledge-based behaviour occurs when the situation is unknown or requires more focus and decision-making.

The SRK model can help explain how passengers and crew differed in their views regarding suitable emergency tasks. Whether an action is performed at the skill-, rule-, or knowledge-based level depends on individuals' previous experience. As a result, a task that is routine for trained crew members may instead require knowledge-based reasoning from passengers. This indicates that passenger tasks should be limited to actions that rely on previous experience or simple instructions, rather than requiring passengers to solve unfamiliar problems during an emergency.

Conclusions:

- Many passengers are willing to help during emergencies and should be supported in doing so.
- Passengers can contribute to emergency response by performing simple tasks such as raising alarms, pointing towards a MOB, or assisting others.
- Not all emergency tasks are suitable for passengers; task complexity and associated risks must be considered.
- Panic and stress may lead passengers to make unsafe decisions and should be mitigated when possible.
- It is difficult to predict which passengers will be willing or able to help during an emergency.

3.7 Personnel

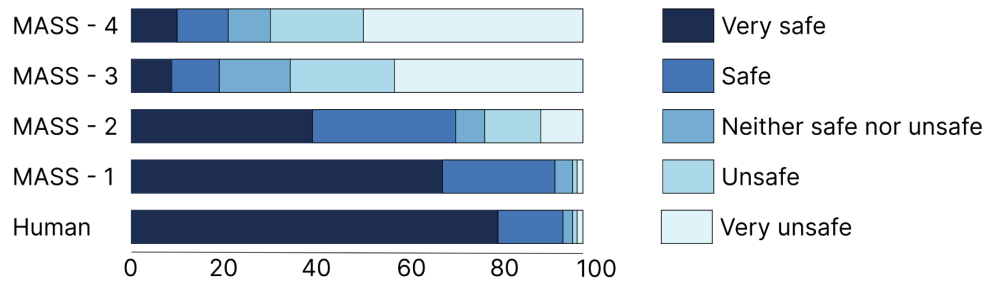
To investigate what passengers felt about ferries being autonomous without any crew on board, two existing papers were examined. The first study by Goerlandt and Pulsifer (2022) involved 97 questionnaire respondents in Canada, divided into age groups spanning from 55 to 75+. The second study by Munim et al. (2022) involved 130 questionnaire respondents in Norway, divided into age groups spanning from 18 to 39+. Both studies used IMO's definition of degrees of autonomy, shown in Table 3.1 below. The respondents rated how safe they would feel on a five-point scale ranging from very unsafe to very safe.

Table 3.1: Definitions of degrees of autonomy for urban passenger ferries, content from IMO (2021)

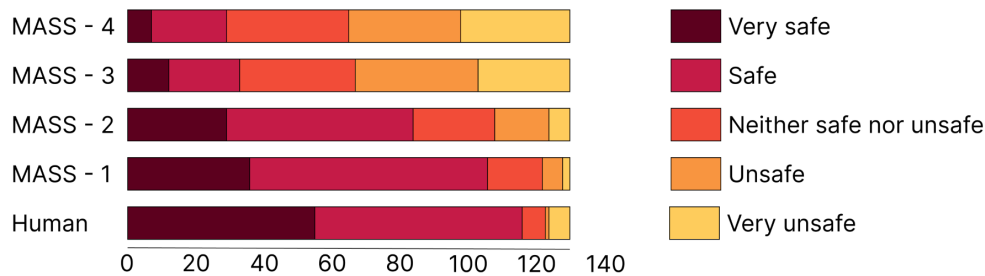
Degree 1	MASS-1	<i>Ship with automated processes and decision support:</i> Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated and at times be unsupervised, but with seafarers on board ready to take control.
Degree 2	MASS-2	<i>Remotely controlled ship with seafarers on board:</i> The ship is controlled and operated from another location. Seafarers are available on board to take control and to operate the shipboard systems and functions.
Degree 3	MASS-3	<i>Remotely controlled ship without seafarers on board:</i> The ship is controlled and operated from another location. There are no seafarers on board.
Degree 4	MASS-4	<i>Fully autonomous ship:</i> The operating system of the ship is able to make decisions and determine actions by itself.

There was an additional category in both papers called MASS-0 (or Human) that represents the current ferries, which are manoeuvred by humans with limited automation and decision support.

The results can be seen in Figure 3.5 below, but were very similar between the two studies. “Human” was perceived as the safest option while MASS-4 was perceived as the least safe option with the highest ratings of “unsafe” and “very unsafe” (Goerlandt & Pulsifer, 2022; Munim et al., 2022). However, the scale is not linear; there is a major shift occurring between MASS-2 and MASS-3 where the only change is that the seafarers are removed in MASS-3. From this, we conclude that the presence of seafarers makes passengers feel safer onboard.



(a) Recreated graph showing the results from Goerlandt and Pulsifer (2022) study.



(b) Recreated graph showing the results from Munim et al. (2022) study.

Figure 3.5: Diagrams show respondents' perceived safety at different autonomous levels from two different studies.

Since studies have already investigated perceived safety at different levels of automation, it was decided not to ask passengers this during the passenger interviews. However, the 4 passengers during the pilot interview were asked directly if they would feel safe without a crew on board. Their answers ranged from thinking the situation would be ridiculous to feeling a bit uneasy about it to fully accepting it as a reasonable change. Even though it was not asked directly during passenger interviews, some of the interviewees expressed a desire for a crew on board when answering other questions. When all 14 interviewees were asked what the most efficient way to get their attention was, 4 of the interviewees said a crew member, and 6 passengers specifically mentioned preferring the ferry to be manned at some point of the interview.

While 2 passengers were worried about the current crew's jobs, the interviewed crew members were more worried about how the tasks they performed would be managed. They felt that they were necessary and thought it would be impossible to replace them with any automation. Following is a list of the tasks the crew performs on a normal day:

- Answer questions, mostly about tickets and payment systems.

- Check the engine room.
- Small repairs.
- Make sure people feel safe.
- Opening and closing the ramp.
- Counting passengers, so the rescue knows how many resources to send in case of an emergency.

3.7.1 Emergency training

The interviewed crew members said that it is common for them to practise and prepare themselves to handle emergencies. According to the SRK model, this training makes emergency tasks increasingly rule-based, reducing the need for knowledge-based reasoning during emergencies. Instead of having to determine what to do, the crew can rely on established procedures and previous training. While training enables the crew to rely on established procedures, the absence of onboard crew changes how emergencies need to be managed. The following sections examine selected emergency scenarios from both the current crew perspective and previous research on autonomous ferry operations.

3.7.2 Emergency case - MOB

The crew interview participants explained that if a MOB situation were to occur, they are trained to use the MOB sling and crane to retrieve the person from the water. This was not something they believed a passenger could learn in time to successfully help the MOB. Some MOB slings are also stored disassembled, which would require a passenger to figure out even more details while trying to save someone. If something were to occur, it is also the deckhand's job to contact the captain, who then is responsible for contacting people on land.

In a study by Bram et al. (2025), onboard a passenger river ferry manned by one crew member, a MOB scenario was evaluated testing two different operational arrangements: (1) the baseline case where the onboard crew member is manouvring the vessel as well as managing the MOB sling while receiving instructions from a land-based safety officer via cellphone, and (2) an experimental scenario involving a simulated ROC operator responsible for remotely manouvring the vessel or monitoring autonomous manouvring while the onboard crew member manages the MOB sling. In this second arrangement, the onboard crew member and the ROC operator kept communication via cellphone as well. The MOB procedure was divided into the following steps:

3. Findings

1. Locate (identify and track MOB)
2. Inform (rescue service, passengers and land-based safety officer)
3. Approach (manoeuvre to MOB, deactivate thrusters and provide a lifebuoy)
4. Retrieve (assemble and deploy MOB sling, Open/close evacuation door & start medical care if needed)
5. Go to shore (update rescue services and external reporting)

Participants rated perceived difficulty, and the results are shown in Figure 3.6. The results show that locating the MOB is challenging for the ROC operator, whereas it is perceived as very easy by the people on board the ship. The other major difference in rating is in the approach; the single crew member found it difficult to keep track of the MOB while also manoeuvring the vessel to the right position. One problem that occurred during the experiments was the placement of the communication device. The phone was placed in a shirt pocket so the crew member could use both hands while working. However, this caused the phone to fall out of the pocket and into the water.

Together, these findings suggest that sharing tasks between onboard crew and a remote operator can ease a MOB situation, but the retrieval is still dependent on crew members on board.

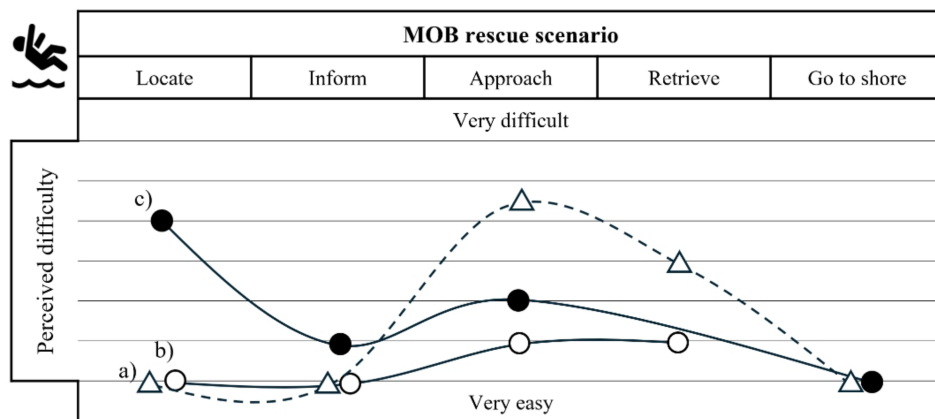


Figure 3.6: Perceived task difficulty among onboard and remote operators during man-overboard drills. Adapted from “*Reframing Procedures and Teamwork for Man Overboard (MOB) Scenarios on Small MASS Passenger Ferries*” by Bram et al. (2025), *Advances in Human Factors of Transportation* (p.539), with permission

3.7.3 Emergency case - Fire

During a fire, the interview crew said that they would prioritise moving passengers away from the smoke and limiting the spread of the fire. Depending on what is burning, they may also try to extinguish the fire. An efficient way to get passengers away from the smoke is for the captain to turn the boat so that the smoke blows away from the boat and all its passengers. Evacuation would likely be necessary, and the preferred approach for the boat visited in the study was to dock at the destination quay and have all passengers disembark there since in this case it is a short-route ferry across the river. If they had to evacuate on the water, the deckhand would deploy the life raft and tell all passengers to put on life vests.

3.7.4 Emergency case - Evacuation

According to a study by Burgén and Bram (2024), it was evident that evacuating a ferry is an involved and potentially dangerous process. It was determined from both their interviews and literary studies that it is preferable to keep passengers on the ferry and later evacuate them to another vessel or directly to land, rather than using a Marine Evacuation System (MES) such as a life raft. Although the rafts used on most ferries in the archipelago were considered easy to deploy by the interviewed crew, deployment was considered unlikely. Partly by being close to shore, but also because the ferry needs to manoeuvre to protect the raft from the wind, in which case they have the capability to go to shore.

Throughout the report by Burgén and Bram (2024), numerous risks and consequences of converting to uncrewed ferries are raised. First, there is a risk that ROC operators have poorer situational awareness (SA) than the onboard crew. It is also unlikely that any of the passengers can accurately assess the situation, which could make it difficult for rescue services to provide the necessary assistance. Without a crew on board, rescue personnel face greater pressure and require more resources, as they cannot rely on anyone on board to help. Another consequence is that the ferry itself cannot assist other vessels, as there is no crew on board. As a result, more resources and thought need to be put into rescue services and infrastructure around the ferry, or it might become overloaded and unable to provide the required assistance.

On another point, passengers are likely to lack knowledge of the procedures and limitations of inflatable life-saving vessels, such as rafts and boats. The crew interview participants explained that the ferries on route 283 are equipped with life rafts that can be deployed by pressing a button. However, both the crew and the expert explained that deploying a life raft requires knowledge of when, where, and how to deploy it, as well as when it is safe and beneficial to do so. If deployed in the wrong place or during certain weather conditions, it can do more harm than good. One example given by the experts is that if deployed close to the dock, the life raft simply won't deploy correctly and will also prevent the ferry from docking. Another example is that in some windy conditions, the life raft can lift and turn over, throwing passengers or trapping them under the raft. So a trained individual should deploy

it as they know when it is reasonable and beneficial to do so. In addition, there are other risks and factors passengers might not consider in an emergency that can, for example, damage the raft, making it unusable.

Conclusions:

- The current “system” used relies on a crew being able to solve/handle any small or big problem/emergency. Having a crewmember onboard would provide someone who can take the lead and knows what to do in an emergency.
- Outside of emergencies, passengers will still rely on staff to ask about non-emergency-related aspects of the trip, such as tickets.
- The emergency procedures may be automated or simplified to help passengers perform the required actions.
- The perceived safety generally declines among passengers when there is no crew on board, and many passengers prefer having a crew member present in emergencies as well as during normal operations.

3.8 Design considerations

This section presents findings and considerations that may affect the design of future passenger communication systems on autonomous ferries. Some relate to technical assumptions, while others concern practical use and passenger behaviour.

3.8.1 Misuse of emergency systems

When adding a communication form, there is always a risk of misuse, such as prank calls or test calls. In New York City (USA), they installed an emergency subway intercom system that was finished in 2018 and is placed on all stations in the city (Campanile et al., 2024). However, when investigating the 140,698 calls between May and October 2023, they found that 28% of the calls were from subway riders in need of assistance, 50% were deemed mischief, and the remaining 22% were labelled test calls. Some of the so-called pranksters made multiple calls in a row on several consecutive days.

Not all non-emergency calls are made with malicious intent. Some may result from callers being uncertain about whether a situation requires emergency assistance. Rashford and Isoardi (2010) reported that the Australian Queensland Ambulance Service received 242 000 non-emergency calls in addition to 493 312 genuine emergency medical calls. In comparison, more than 8 000 cases were identified as either hoax calls or cases where no patient was found at the scene, accounting for less than 2% of the Triple Zero calls. This highlights that not all calls that do not result in an emergency response are necessarily made with the intention of misusing the service. In 2022, the Swedish emergency service SOS Alarm had its highest number of callers to date (SOS Alarm, 2023). This increased the average answering time from 15.4

seconds in 2021 to 25.6 seconds in 2022, pushing the required answering time of 8 seconds even further. A third of the total calls during 2022 were deemed to be false alarms, and the most common type was “quiet calls,” in which no conversation could be established. Based on the medical calls, about 22% were non-emergency cases.

Not only are emergency calls misused, but emergency brakes are misused at times as well. The emergency brakes were used 603 times in Stockholm’s subway (Sweden) between January and October 2017 (Claesson, 2017). Although the amount has decreased by more than half since 2013, there are still only a small number that would count as real emergencies. Even though some of the wrong uses are without malicious intent, others are speculated to be intended to paint graffiti or for other mischief.

3.8.2 Design assumptions

Several assumptions were made during the project to define the scope of the proposed solution. One assumption was that the ferry’s fire suppression systems (both automated and manually operated) would be sufficient to allow the vessel to reach the dock safely before evacuation became necessary. Therefore, it was assumed that evacuation in case of fire would not take place at sea. Another suggestion from the expert was that we should assume communication with shore is reliable, meaning we always have 4G and/or 5G connectivity.

The engine room is a high-risk area regarding fire or malfunction. The ferry used as a case study for this report (line 286 - Stenpiren to Lindholmspiren) has two engines and could likely use the other if something were to happen to the first. The engines have automatic fire detection systems, such as thermal, light, and smoke detectors. All of these send signals to the captain if abnormal values appear, although most of them are false alarms. This could be sent to ROC instead, and if there were still uncertainty, the middle human decision step could be removed, and the automatic distinguishing system could be activated directly. The ferry would still be able to reach the pier because it has another engine.

3.8.3 Practical design considerations

Previous research has also identified several design considerations relevant to passenger interaction on autonomous ferries. In this study, Porathe (2021) examined possible solutions for interfaces on board a small urban passenger ferry in Trondheim, Norway. The ferry carries up to 12 passengers (with bikes) over the harbour canal. The focus was on communication with other boats in the canal, as well as the interface used by passengers. The passenger system allows them to interact with the ferry, where they can start the trip, but also helps in emergencies and provides contact with the ROC. Although emergency scenarios are not the main focus of the study, Porathe discusses some possible approaches for handling specific situations. For example, in the event of a battery fire, it is suggested that the ferry should be able to drop the battery into the canal, where it would sink and be recovered later,

after all energy has been released. However, it is noted that ordinary firefighting systems would also be required. Another interesting suggestion from the report is using a voice interface during the boarding to allow passengers to focus on the ramp visually, since this is an efficient distribution of cognitive resources according to Wickens et al. (2015). Several of these ideas align with recommendations provided by the interviewed expert.

Some specific guidelines that were discussed with the expert included considering sound levels, since they tend to be high with wind and people who may panic. It is important when developing a communication device that passengers can hear and be heard in an emergency. The expert also described the importance of considering how the device can be used while passengers are responding to an emergency, as they may need both hands to perform other tasks. Lastly, it was also discussed whether passengers would feel comfortable using the communication device unless the situation is life-threatening. One reason for this fear was a personal experience of not using the fire escape when a fire alarm went off, even though one should. Because there was no fire or smoke in sight, the situation did not feel urgent enough to use the dedicated emergency tools. This illustrates that providing emergency equipment does not necessarily guarantee that passengers will use it when required. Therefore, the design of the interface may also need to consider how passenger behaviour can be influenced.

One approach to influence such behaviour is nudging, which aims to guide users towards a desired behaviour without explicitly forcing them. Rather than changing the available options, nudging changes how these options are presented to influence decision-making (Schmidt & Engelen, 2020). An example of nudging could be having an option, like donating to charity when purchasing an item, filled in by default. The shopper can easily decide not to donate any money, although they are more likely to choose that option if it is marked as the default. However, nudging can be perceived negatively, as it influences aspects of human decision-making that are often automatic or based on less conscious processes. It is important that nudging does not eliminate a choice; neither should it hide an option or force the user to do something. Another example that may be perceived more positively is putting images of damaged lungs on packets of cigarettes, which does not change the possibility of buying them or smoking them, but the choice is presented differently to the user.

In emergencies, passengers may experience increased stress and have limited attention available for assessing the situation and deciding how to act. Since nudging concerns how choices are presented to users, it may be a relevant consideration when designing communication systems where rapid and appropriate decisions are important.

Conclusions:

- Assumptions:

- Evacuation due to fire will not need to take place at sea.
- There is 4G/5G connectivity to shore.
- Engines have automatic fire detection and extinguishing systems.
- Design considerations:
 - Sound levels are likely to be loud during emergencies, and the volume should be adapted accordingly.
 - Passengers who want to help or assist during emergencies should be able to use both hands.
 - The solution needs to be approachable for passengers.

4

Requirements

Based on our findings, we identified five primary requirements to enhance passenger information, awareness, safety and communication with operational staff in the context of an uncrewed ferry, particularly in the context of onboard emergencies.

R1 – Ensure calmness and safety amongst passengers.

Currently, crewed ferries provide safety and calm among passengers through human connection and intervention, providing a sense of security and support, in addition to guidance. Fulfilling the sub-requirements below aims to guide in promoting calmness and safety amongst passengers when the crew is not present:

Any solution should not rely on passengers being able to handle or resolve an emergency themselves or without intervention.

The solution should provide means of supporting passengers in resolving emergencies and in determining what actions to take to ensure their own safety without compromising others. This will also help calm them and make them better able to handle themselves with minimal or no intervention from others.

Prevent panic and induce confidence amongst passengers, supporting that they remain calm and able to handle themselves.

Preventing panic and instilling confidence in passengers will help them remain calm and able to follow instructions, as well as take actions that could save themselves or even others.

Ensure that passengers remain safe by preventing them from taking actions that could endanger them.

The solution should prevent or discourage passengers from performing tasks they cannot perform safely in addition to making sure that they remain in safe areas, per the situation. Primarily, ensuring that they remain on board for as long as it's safe and preventing them from jumping into the water.

R2 – Make passengers understand what they should do.

For passengers to understand what they should do and act on it, a few requirements must be met.

Facilitating rule-based behaviour.

By facilitating rule-based behaviour, any solution could provide passengers with a means to help ensure their own safety. Additionally, nudging them towards making the right decisions would further ensure they make choices that could help themselves or others.

Prepare passengers.

Passengers should be prepared for emergencies, at least to the extent that there is no need for any prior knowledge of how to resolve emergencies on ferries. Knowing where and how to get the relevant information is, however, pivotal.

Provide passengers with information and/or instructions.

Any subsequent solution should provide passengers with the necessary information and instructions regarding an ongoing emergency. The purpose of which is to ensure that passengers remain safe and that there is a possibility to resolve an emergency successfully. This can be done in various ways. Either by a system that already has the required information or through a mediator such as a ROC operator.

There is additional value in having the means to communicate with both individual passengers and all of them. Providing information to all passengers will facilitate crowd control, while communicating with an individual can help calm them or provide instructions to resolve a specific problem.

R3 – Allow passengers to help during emergencies.

By allowing passengers to help during emergencies, the severity of some scenarios can be reduced. From the literature review and user studies, some requirements were identified that will help facilitate this:

Provide passengers with what they need to help meaningfully in an emergency, without endangering themselves or others.

By providing tools and information to help in an emergency, they can mitigate some of the danger and are more likely to take action that helps rather than one that would endanger them or others. This way, they would also relieve some strain on rescue services.

Retaining passengers' ability to use both hands.

Making sure any solution(s) retain the passenger's ability to use both hands helps ensure they can perform tasks correctly and more efficiently.

Keep the passengers aware of the ongoing emergency.

It's important to keep passengers informed about what is happening to ensure they remain calm and take appropriate action. Any solution(s) should have the means to mediate this information well.

R4 – Allow accessibility and attention.

To allow as many passengers as possible to access information or be provided with the means to help, ensure the system can capture passengers' attention and that the information can be perceived through more than one sense.

Do not limit the system to one language; for example, implement figures to help those who do not understand the local language understand the necessary information.

R5 – The solution needs to be approachable.

The solution needs to be approachable to ensure it is used, primarily by not feeling alien or hard to understand. Through using a common design language from other communication devices, the user is more likely to identify the solution as a communication device.

Ensure the user interface follows current UI and UX practices to make it intuitive to use. Furthermore, ensure there is little room for misinterpretation or for options that could result in user error.

5

Developed concepts & Evaluation

This chapter presents the outcomes of the concept development and evaluation process. It describes how initial ideas were generated, analysed, and prototyped through an iterative process of refinement and evaluation. The following subsections follow a chronological order, reflecting the progression of the concept development process.

5.1 Brainwriting I

The first sessions of brainwriting generated ideas for different portable and stationary communication solutions, as seen in Figure 5.1. Some common ones include the wall-mounted communications station and the portable tablet. Both have a screen that allows the user to see the ROC operator while communicating with them.

The other solutions seen in the first session were portable hands-free solutions like smartwatches, headphones, and a standalone portable communication device with a camera. Those ideas were more aimed at helping ROC personnel guide individual passengers through different tasks.

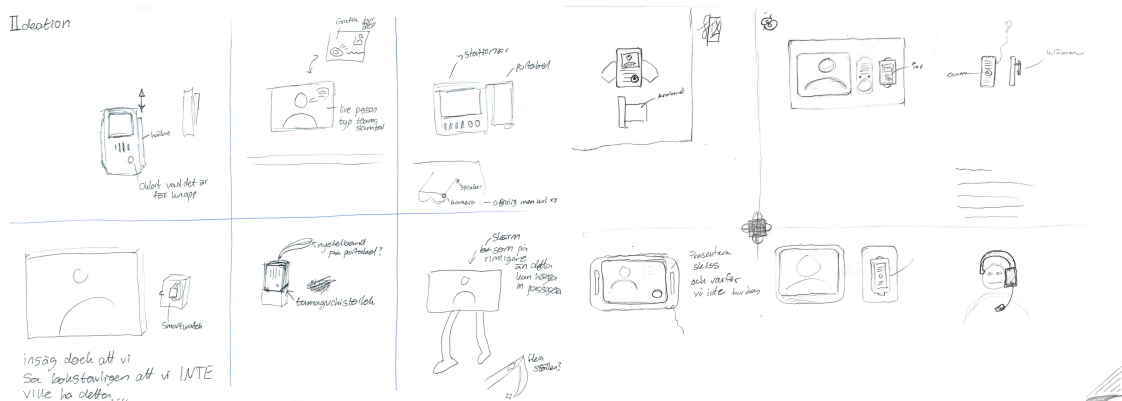


Figure 5.1: Sketches made during the 1st session of Brainwriting 1.

5.2 Analysing Initial Ideas

As some of the sketches from Brainwriting 1 were similar, they were grouped, totalling 12 ideas. To analyse the ideas, the PNI shown in Figure 5.3 was developed to aid in identifying key aspects, benefits, and drawbacks. This chapter explains each idea and its outcome from the PNI.

PNI					
Images	Idé	Positive	Negative	Intressant	Frågor
	Portabelt tablet	• Portabelt • Enkel att känna igen • Skärm → kan se ROC och annan info • Funtar både på väggen och portabelt	• Portabelt är onödigt i de flesta fall • Portabelt → tappa bort • Ötympligt? • Liten skärm om den är på väggen		Kommer det verkligen hjälpa att ta med den? Svårt att se ett scenario som omfattar klara med hjälp av lösningen i portabelt form.
	Portabel device med lista	• Enkelare för passagerare och ROC att hålla kontakt. • Inte bunden till en plats • Kräver inte att passageraren håller i den	• Kan förvirra • Tekniskt komplex, inga existerande lösningar som uppfyller kraven. • Svårt att välja eller se till att en kompetent person får den.	Det finns många olika metoder för att få den → kan utforskas vidare	Hur väljer man vem som ansvarar den? Svårt att välja eller se till att en kompetent person får den.
	Portabel med Kamera	• ROC kan se från passagerares perspektiv • Portabelt	• Kräver att passagerare kan & vill hjälpa • Kan bli svårt att få bra vinklar • Portabelt, kan tappas bort • Sakskaderade med de med hörselvariationer	• Kan hjälpa till att "leda" från ett första persons perspektiv.	Hur mycket hjälper det? (Behövs det en till kameravinkel)
	Headset	• Kan vara enklare för passagerare att höra/ta emot instruktioner • Passagerare kan jobba hands free	• Bara en passagerare kan höra åt gången • Passar kanske inte alla • Sakskaderade med de med hörselvariationer • Portabelt, kan tappas bort • ev bökig		Hur ska dessa förvaras?
	Station med tillhörande portabel lösning.	• Erbjuder en definierad plats att ta kontakt med ROC. • Gör det möjligt att ta med sig till där det behövs.	• Portabelt del kan tappas bort	Bara stationär?	Hur påverkar detta användaren?
	System som förflyttar sig med passagerare	• Passagerare behöver inte själv hålla koll på (konceptet)	• Oskart hur vi ska göra detta		Hur kan vi göra detta möjligt?
Images	Idé	Positivt	Negativt	Intressant	Frågor
	Vägledning	• Kan guida passagerare åt rätt håll • Visar åt inbudsledare för de med synnedsättningar	• Hjälper ej blinda (gör ej situationen värre åt)	De från färderiet vill ha en blinkande lampas som passagerare kan gå mot för att erklara beskriva var på boken de ska ta sig	
	Info "film"	• Repetition kan hjälpa folk att minnas vad det ska göras ifall olycka är framme. • Förtvänder passagerare inför nödsituationer	• Visar resor är för korta för att visa någon meningsfull information.	Redan implementerat	Finns det något vi kan bidra med, utöver det som finns?
	Outdoor lights for fire extinguisher	• Hjälper att visa vad man ska använda • Tydliggör att något är fel?	• Kan visa ledas ifall det inte fungerar som det ska.	Skulle kunna förbättra responsid	Elektronik vid brand
	Högtalare	• Många passagerare förväntar sig högtalarrop • Information går ut till alla	• Kan missa / inte höra	Skulle kunna ha en kungande effekt eller ingen alls. Kan följa standarder med att alltid ropa ut saker 2 gånger så fler kan höra	
	Utse en ansvarig från passagerarna	• Kommer undvika att alla står och tittar på	• Kräver att det finns passagerare ombord • Kräver att en passagerare vill ta ansvar, annars tvivlas en → säligt		Kan vi ens göra så här i projektet?
	Skärm?	• Att det är någon live gör folk lugnare (intervjuer)	• Viktigt stationär	Kan vara mer kungande att också se personen. Möjligt att ROC personal har arbetat för mycket att göra för att kunna vara lugnande i ett videosamtal.	

Figure 5.3: The results of the PNI from the sketches in Brainwriting I.

5.2.1 Portable Tablet

First out is the idea of using a portable tablet, whose primary benefit is that passengers can bring it with them and continue communicating with the ROC anywhere on the ferry. However, this could prove quite cumbersome, as it would require the user to move and reposition the tablet with their hands. It is still possible to use it in stationary mode, although to remain usable in its portable mode, this will also limit the screen size. With the device being portable and most likely unlocked for ease of use in emergencies, it also risks being misplaced or stolen.

5.2.2 Portable device with mounting

A smaller, portable device with a mounting option that keeps it attached to the passenger could provide an easier way to keep in touch with the ROC while keeping the user's hands free. Also, an interesting point here is that the mounting solution could be done in many different ways. With a size comparable to a small phone, it could also be a more practical solution than a portable tablet. Though its smaller size also makes it technically complex, smartphones are the only apparent device that meets the technical demands today. Its significantly smaller size would also make it more prone to being misplaced or stolen than a tablet. However, one hurdle might be choosing and getting it into the hands of a capable passenger who can help manage an emergency.

5.2.3 Portable device with camera

Adding extra functionality to the previous idea with a camera gives the ROC and/or rescue personnel the ability to see directly from the passenger's perspective. An interesting point here, compared to the previous two, is how an operator can guide a person from a first-person perspective. Though it still leaves the question of whether more angles are needed to complement the device's perspective, if the intention is to guide the user in observing them. Note that this idea still retains the problems of the other portable ideas, making it prone to misplacement or theft, as well as getting it to a capable passenger.

5.2.4 Headset

Another portable solution is a headset that enables passengers to be heard and to hear better than they would with other options. Like smaller portable devices, it keeps the user's hands free by attaching to the user's head or ear. Its biggest downsides are that the ROC can communicate with only one passenger at a time and that it is unlikely to accommodate all prospective passengers who are willing and able to help.

5.2.5 Stationary device

Focusing on keeping the device stationary gives passengers one or more dedicated locations where they can contact ROC or rescue services. Even though having a stationary device can be limiting, it avoids many of the drawbacks of portable devices. It could also provide more qualitative communication with better hardware.

Interestingly, some of the sketches are also complemented by portable solutions, as in the other sketches. This provides the benefits of portable devices in scenarios where a stationary device may not provide much help.

5.2.6 A “moving” system

A moving system then takes advantage of existing screens and/or stationary devices, “following” the passenger around by, for example, having the ROC operator switching between different screens or communication stations. The benefit here is that it can “move” with the passenger without any effort on their part. Such a system could work in other ways, but at this stage the “moving system” is more of a sketch rather than a thought out idea.

5.2.7 Guiding system

The second session of the brainwriting focused more on how information could be mediated to the passengers during fire and evacuation scenarios. One idea is a system with lights or arrows to guide passengers towards emergency exits or other safe spaces. It becomes more inclusive as it is easier for people with hearing disabilities to follow directions. Additionally, it becomes clear to passengers that an emergency is ongoing and where they should go. Some ideas could also help in scenarios with reduced visibility. An interesting point here is that later in the project, when visiting a road ferry, the workers explained a similar solution that they had proposed. Their idea was a light that they could use to tell passengers where to gather, as it was sometimes difficult for them to distinguish between the terms “fore” and “aft” of the vessel.

5.2.8 Guide light for fire extinguisher

In addition to guiding passengers to safe spaces, another idea is to install indicator lights that help passengers quickly identify which equipment to use. In this case, this would help choose the correct fire extinguisher for the ongoing fire. The idea is to improve response time and effectiveness.

This does, however, require an operator or a system that can identify the type of fire currently developing and then turn on the relevant light. Then it also risks misguiding passengers if it does not work properly.

5.2.9 Speaker system

Apart from visual means, the speaker system is already in place, but it might have limitations that become apparent once ferries become uncrewed. It is an effective way to inform passengers of ongoing emergencies and give instructions to the crowd. From our user studies and literature review, it is also clear that speaker announcements are expected and preferred when being addressed by the captain or crew. However, there is still a risk that some people may not hear it due to a noisy environment, headphones, or a hearing impairment. Those risks may be reduced by using it in combination with guiding lights or other visual solutions, such as screens.

5.2.10 Screens

On the one hand, screens are an idea that could clearly showcase that an emergency is ongoing, as well as emergency-specific information. Displaying the announcer can also help calm passengers, as it clearly signals that someone is aware of and working on the problem. However, there may be a risk that the operator appears stressed if they have a lot to do. This idea also does not provide any interaction between the passenger and the ROC operator.

5.2.11 Information video

In addition to providing live information, screens could work proactively and provide information about preventative measures through informational videos and thus prepare passengers for emergencies. With repetition, or simply by recognising something they have previously seen, it could significantly help many passengers know what to do during an emergency. However, as with many coastal ferries, such as the one between Lindholmspiren and Stenpiren, the routes are too short to display any meaningful information that could affect the same trip. It also requires passengers to actively watch the information video.

5.2.12 Responsible passenger

Appointing or ensuring a competent passenger takes charge of communication or other tasks is mainly a complementary solution. This is because many of the other ideas have problems ensuring they are actually used and used correctly in an emergency. This is, however, tricky, as it requires a capable passenger to be on board, willing and able to help. This means that in the case of many of the ideas, they need to encourage this specific user to engage, or a ROC operator might need to appoint someone. This could result in a passenger being unable to complete the tasks assigned. One positive outcome could be that it encourages someone, or the appointed person, to act rather than do nothing. Instead for being the sole solution, it is something to consider implementing along other solutions.

5.3 Key Features

When drawing and analysing the various ideas, numerous parts of each idea were identified as features that could be iterated and evaluated separately; these will be called key features. By identifying those features, numerous sub-solutions can be created without needing to make every possible combination of each idea. This allows for a more efficient way to iterate and create various concepts at higher fidelity. For each idea, there are a few key features with numerous variants. These can be seen in Figure 5.4, along with a brief description below:

Displays – On portable devices, the display is a key feature that comes in many variants, such as size and display type/technology. For example, will it have a coloured LED display, a segmented display, or e-ink? Whether to include one at all also needs to be considered.

Attachment method – For a portable device to be brought by the user, the method of attaching or carrying it is a key feature that could be further iterated on. The primary point here is to develop variants that explore different ways to provide passengers with a feature that lets them use a portable device while keeping their hands free. This can be done in numerous ways, creating a lot of variation in what a portable solution might look like. For example, some possible variants are lanyard, wristband, clip, glasses, and headset.

Camera – To help onshore personnel gain insight, it might be beneficial to have one or more cameras on either portable or stationary devices. There are many types of cameras with different capabilities, such as night vision and wide-angle lenses. They could also serve different purposes depending on placement. For example, they can provide a way to observe either the user or their surroundings.

Sound/Audio – When using the device, the user needs to be able to communicate with a remote individual (such as an ROC operator or rescue personnel). The audio in this case can be delivered in a few ways, such as through headphones, the device's speaker, or the ferry's Public Announcement (PA) system.

Screen – A stationary device has slightly different variants compared to portable devices due to fewer constraints in space and power. However, variance in size or whether to have a screen at all remains. There is also the question of whether to include touch capabilities to allow the user to interact with the device to retrieve information when it is not in use for emergencies.

Interaction/User Interface – In addition to touch capabilities, the stationary device could be equipped with a physical user interface. One example here is whether to have one or multiple buttons for certain actions, or to have some with multiple functions.

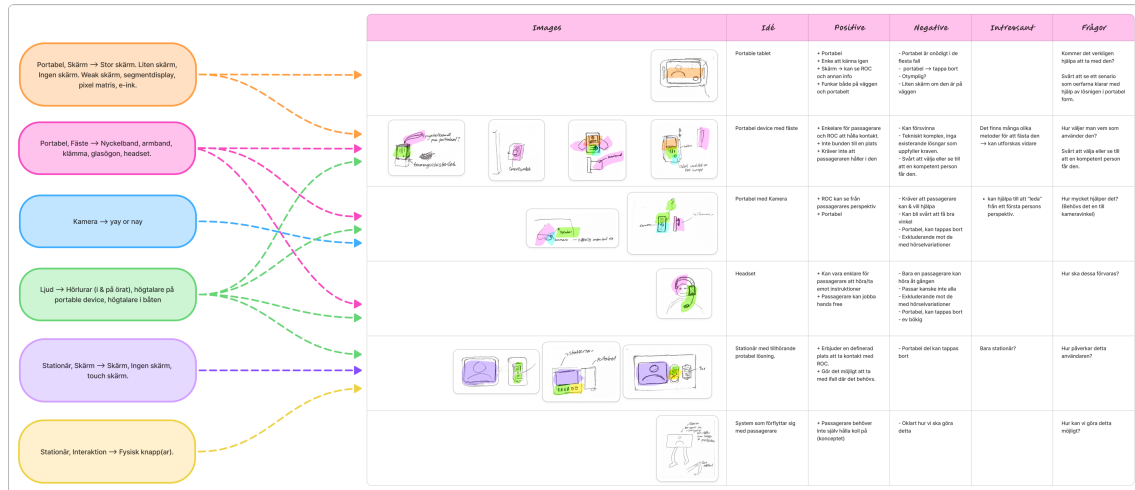


Figure 5.4: Identifying the key features and marking them in the PNI.

5.5.1 Portable communication

This concept allows the user to communicate with onshore personnel, such as an ROC operator, using a built-in microphone and a speaker or headphones. The user would then attach the communication device using a clip. However, as seen in Brainwriting 2, there are many other options, some of which could be combined. At this stage, the clip was deemed sufficient to provide a good camera angle that onshore personnel could use to see passengers' actions from their perspective. Figure 5.6 shows some variants of what a small portable communication device with a camera and clip mount could look like.

This solution does, however, present technical difficulties and might face challenges, as it would require capabilities similar to those of both a phone and an action camera. Meanwhile, it would provide uninterrupted communication with onshore personnel. There are, however, some potential benefits to this solution, as it provides onshore personnel with a camera angle and insight not normally possible with a regular CCTV system.

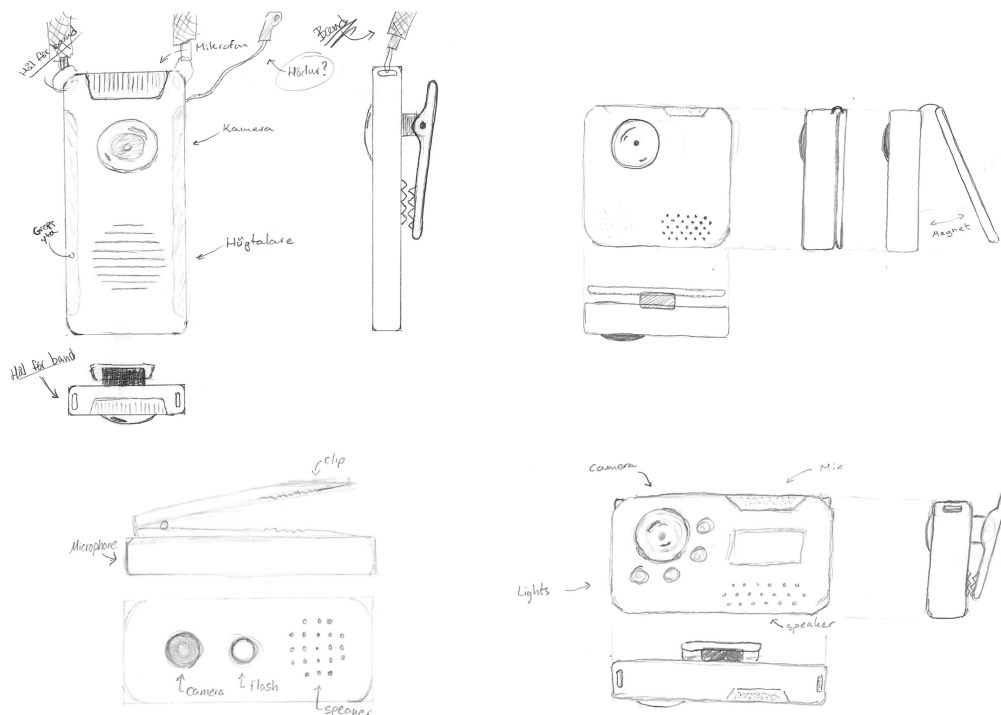


Figure 5.6: Sketches of possible solutions of a portable device with a clip and a camera.

5.5.2 Stationary communication

The main feature of this concept, seen in Figure 5.7, is that it is stationary, facilitating passengers' search for a communication source in an emergency. It is a device installed on the ferry that allows passengers to communicate with the ROC.

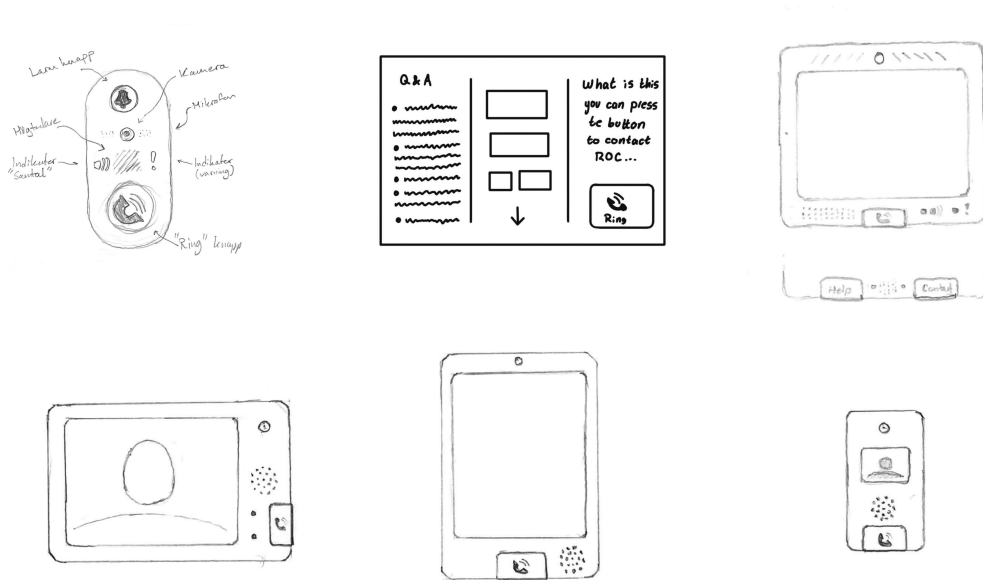


Figure 5.7: Sketches of stationary communication device concepts.

The screen is the most varied part of the ideas within this concept. Most current solutions do not have a screen, but all include a call button and a speaker. However, we suggest adding a larger screen that passengers can use in normal situations, such as checking ticket prices. It may contain information such as FAQs, general information, and a brief description of the device itself. This decision is made to lower the barrier to interacting with the device. By making more passengers feel comfortable using the concept, we believe they may be more inclined to report minor incidents earlier, making it easier to prevent them from escalating. An example could be reporting a kid playing with matches.

There may be some difficulties communicating to passengers that there is a touch on a large TV screen (depending on what size is decided upon). However, with good interface design, it should be apparent that the user can navigate using touch. This could be done by using shadows to replicate “real” buttons, making the options feel clickable. Having a large screen will also allow more than one passenger to receive specific information at a time since it is more visible.

Since the touch function may malfunction, a physical button is also included. Although the call button appears in one of the sketches, this is because passengers may feel more comfortable pressing the digital button than the physical one.

A negative aspect of this concept is that the passenger is bound to the device's location, which could be very problematic if an incident such as a fire were to occur. However, the current solution to avoid this is to place one at the fore and one at the aft of the ferry.

5.5.3 Headset

This concept is based on headphones; by using this method, the passenger may have the opportunity to hear/receive instructions more easily; however, it limits the communication to one specific person. Since the headset limits communication to one passenger, it also becomes necessary to decide whether a passenger is able to help and, if so, which one. This challenge applies to several of the concepts but is particularly evident here. Some of the sketches, as shown in Figure 5.8, include a camera that will allow the ROC operator to see what the passenger is currently doing.

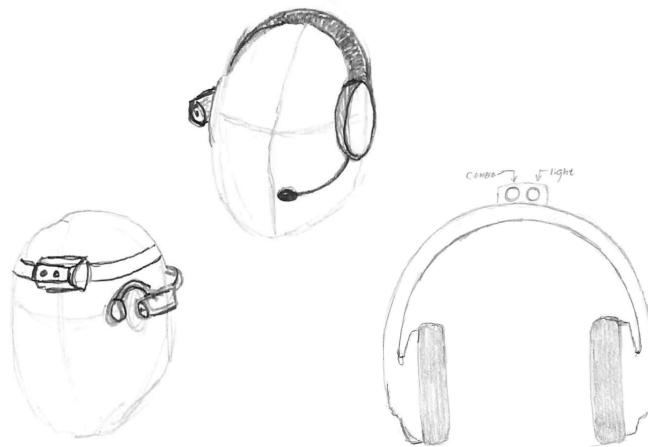


Figure 5.8: Sketches of headset concepts,

5.5.4 Portable tablet

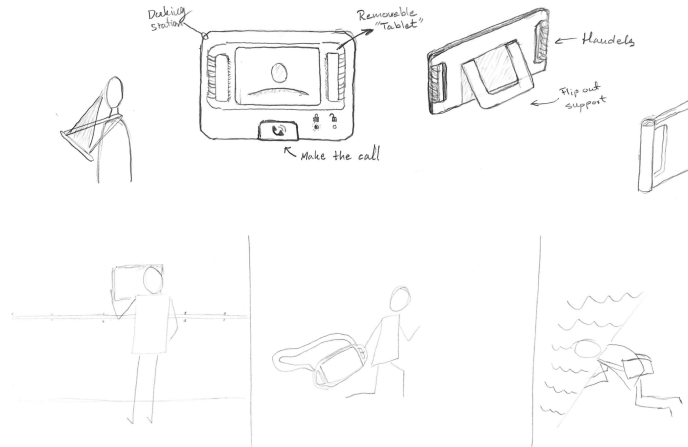


Figure 5.9: Sketches of portable tablet concept and contexts of use.

This is primarily a portable device, but it will spend most of its time docked on a wall, thus allowing it to double as a stationary device. During normal operations, it will remain docked on one or multiple walls inside passenger compartments, protecting it from harsh weather and allowing for easy access by passengers. The tablet will always be “unlocked” to reduce the risk of a locking mechanism failing during an emergency, preventing it from being undocked. However, a message will be sent to the ROC notifying them of an ongoing emergency and that the tablet is in use.

When docked, the tablet will function similarly to the stationary device, displaying information such as FAQs and ticket prices, but with the drawback of supporting a smaller screen. However, due to its tablet appearance and smaller screen size, passengers may be more likely to assume it has touch functionality. As shown in Figure 5.9, the docking station has a physical call button to facilitate easy contact with the ROC.

To facilitate portability, the tablet has two handles, providing the user with an easy way to carry and move it. To further support this, Figure 5.9 also shows additional features, such as a kickstand and straps. The strap allows the user to carry the device while keeping their hands free, and the stand supports the device when placed on a surface. This way, the user can receive instructions while keeping their hands free.

There are, however, some potential problems with this solution, such as the touch-screen not working properly in wet conditions or the screen being difficult to view outdoors. But there are also a few cases where a portable device could be much more helpful than a stationary solution.

5.6 Low Fidelity Prototypes

To aid in the evaluation stage, mockups of the portable tablet, portable communicator, and stationary device were created. This serves as a way for the feedback session to see and handle the concepts in real life.

Figure 5.10 shows two variants of the “portable communication” concepts that are made from clothespins and some HDF (High-Density Fibreboard) squares glued together. This creates a mockup with dimensions and weight close to those of a finished product. However, it’s not functional for the camera, microphone, or speaker. The clip adds a function to evaluate its usefulness and determine its worthiness.

The “portable tablet” concept consists of a laser-cut HDF sheet with 3D-printed half-cylinders attached to it with double-sided tape; see Figure 5.11. Beyond its physical size, this mockup has little in common with any prospective finished product. But it still represents how the concept can be held and handled.

As the stationary device is more about the interface and size, a UI mockup and a simple graphical representation of the wall-mounted device were created and printed on paper, roughly A3-sized, see Figure 5.12.



Figure 5.10: Two mockups of the portable communication concept.



Figure 5.11: Portable tablet mockup.

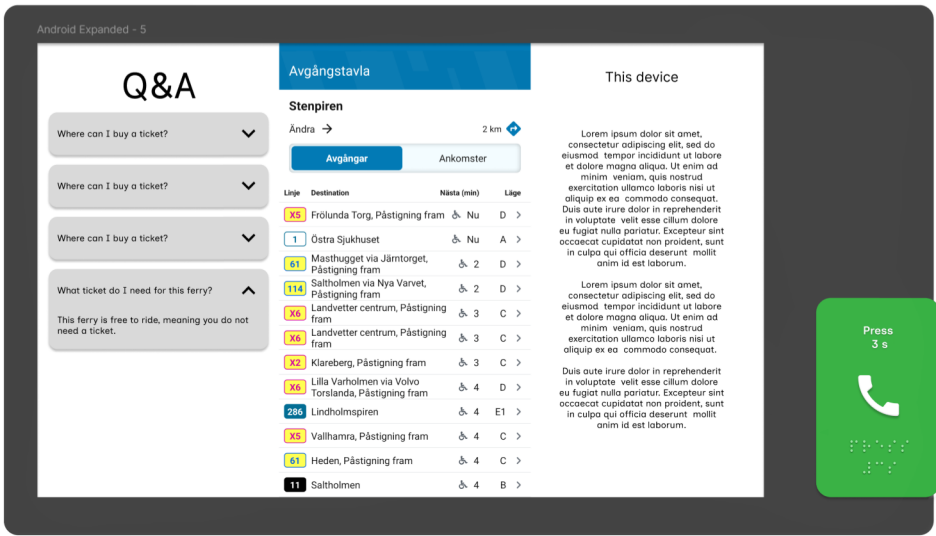


Figure 5.12: Digital representation of what was printed and served as a mockup of the stationery device.

5.7 Evaluating Concepts

Using the low-fidelity prototypes, the first part of the evaluation was conducted as a feedback session where participants, consisting of experts (see Table 2.3 in subsection 2.4.5), could share their thoughts and insights. Using the low-fidelity

prototypes as a reference, they were thus presented with a clearer picture of how they would appear in reality.

Following this feedback session, an evaluation against the requirements list was conducted to determine which requirements were fulfilled, partially fulfilled, or not fulfilled. From this, it was concluded that both the clip and headset concepts met only 2 requirements each, thus neither was worth further development. Furthermore, the feedback session participants pointed out numerous flaws in these ideas; for example, the clip was, in their experience, always coming loose on their radios and is not trustworthy as a mounting method.

Since the tablet and stationary device essentially replace each other, a decision as to which one to move forward with had to be made. Since both of them partially or completely fulfilled 4 out of 5 requirements each, the requirements had to be weighted against each other. The stationary device only partially fulfilled (R3) “Allow passengers to help during emergencies”, due to it not being portable, as it could leave passengers in situations where they cannot act or receive instructions or information at the same time. On the other hand, this also meant that the tablet did not fulfil (R1) “Ensure calmness and safety amongst passengers” as well, due to it being too small to assist more than one person at a time. With the portable tablet also being cumbersome and requiring users to keep track of the device and use their hands, the participants from the feedback session concluded that they liked the idea in some cases but that the stationary device was a better fit. Also, considering that the fire, evacuation, and MOB contexts would rarely benefit from a portable device and R1 being a more important requirement, the choice was made to develop the stationary communications device concept further.

5.8 Mid-fidelity Prototypes

As a result of the evaluation, a mid-fidelity prototype of the stationary concept was developed. It was designed around an Android tablet, as it could be used to interact with the Figma UI. This, in turn, also made it the determining factor of the prototype’s size. Figure 5.13 shows the finished prototype that was developed for the user tests.

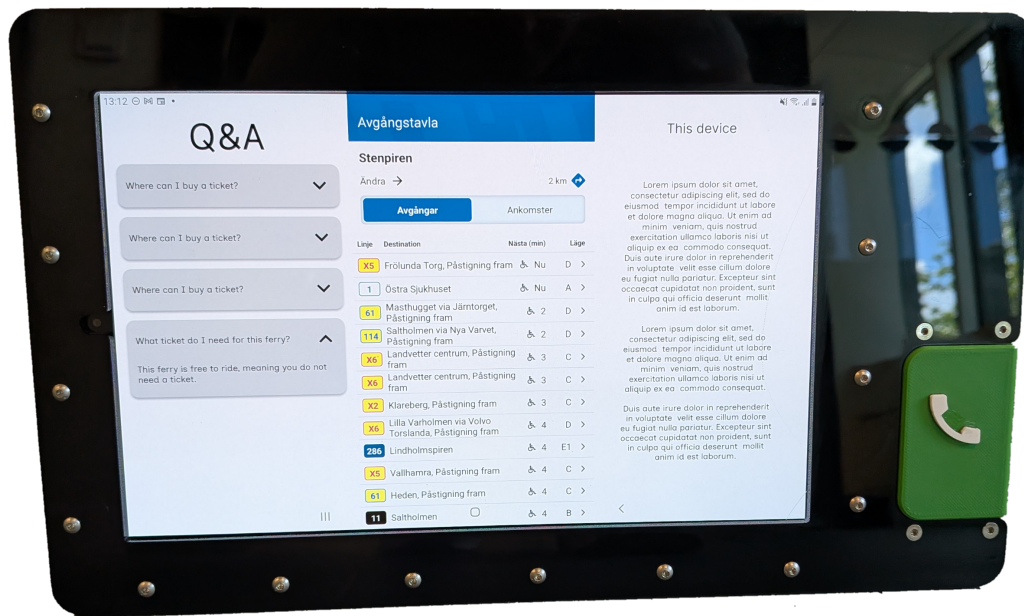


Figure 5.13: A mid-fidelity prototype of the stationary concept.

The front and back plates are made of black acrylic, while the internal parts that hold the tablet are 3D-printed. Screws hold the acrylic together with the 3D-printed pieces sandwiched between. A cutout in the front plate makes the screen visible and allows the camera to see. In addition, a pair of legs was 3D-printed and mounted at the back, allowing the prototype to stand upright rather than lie flat on a table during user testing, since it could not be wall-mounted.

The button is 3D-printed in green PLA filament and has a white phone icon made of acrylic glued onto it. Those features are meant to closely resemble the shape and colour of our digital sketches, mockups, and prototypes. The button is mounted on four screws with springs that allow it to move. Although this movement is uneven and raspy, it still helps indicate that the button is clickable.

Although little time was devoted to the digital user interface's standby mode, the one shown in Figure 5.14 illustrates what could be displayed when the concept is not being used for communications.

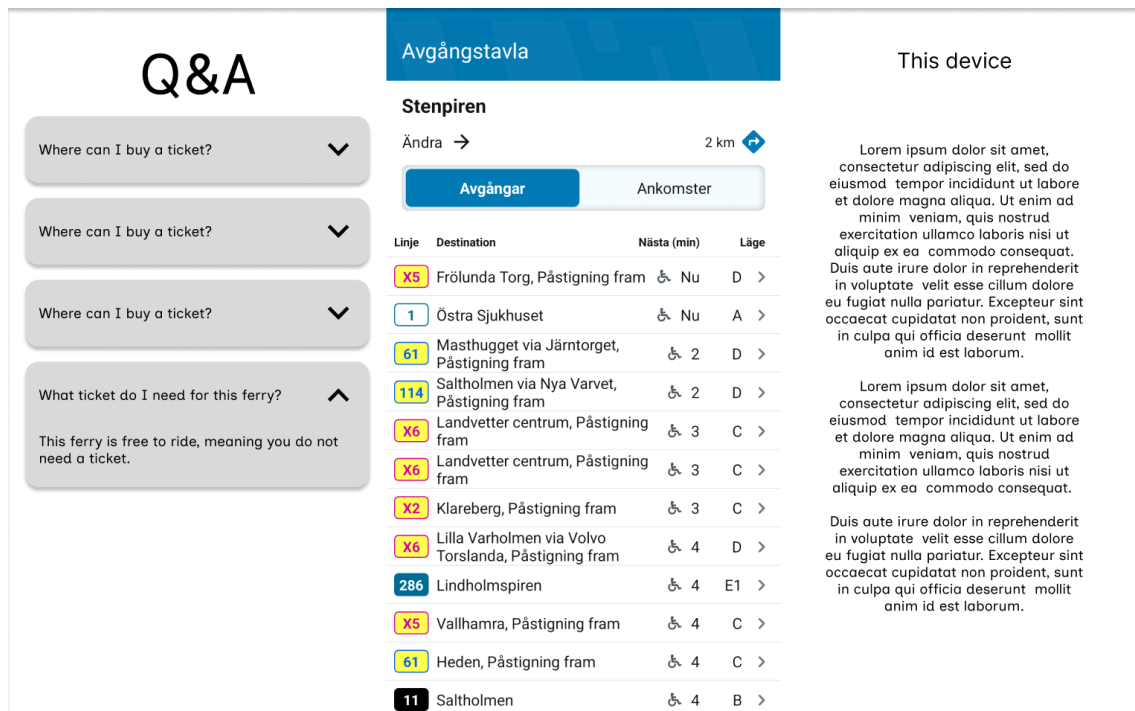


Figure 5.14: A mockup of the user interface displayed on the stationary device. (Note that touch is utilised in this UI)

The left column has a Q&A section that focuses on answering common, brief questions that can be clearly understood in a short text. The centre column shows departures from the stop the ferry will arrive at. To the right is a descriptive text that explains the device's purpose and functions. In addition, a simple Figma application was created to simulate functions such as expanding questions and holding the call button; see Appendix B.

5.9 User Tests and Focus Group

The following section presents the combined results from the user interviews and the focus group regarding the different emergency cases, concepts, and the prototype.

5.9.1 Man Over Board

In the case of an MOB, a member of the focus group said he would throw a lifebuoy, call the Swedish emergency number 112, and look for any emergency break. However, he believed that someone without this knowledge would start to look for signs or instructions on what to do.

The interviewed students thought they would throw a lifebuoy and try to contact help; some of them said they would assign one of these two tasks to someone else to ensure they did not lose track of the MOB. One of them said that they would call

112. They also speculated that their level of stress or panic would be directly linked to the MOB's level of stress or panic. If someone swims calmly in the water, they would feel less stress than an MOB who screams for help while struggling to swim. The students thought they would need good signage, well-marked lifebuoys, a way to contact help, and a way to stop the boat.

5.9.2 Fire

The focus group concluded that since fires can spread very rapidly and explosively on ferries, conveying information rapidly is of great importance. There is also the risk of passengers swarming doors, leading to crushing. There would also be many passengers who seek to abandon ship, either by taking to a life raft or by jumping into the water. The life rafts currently used may not be adequate for autonomous use; alternative versions could be used.

The students expected either a fire alarm or a message from the PA system in case of a fire. The students thought they would try to help by containing the fire with a fire blanket or extinguisher and calling for help. However, the safety of all passengers was the highest priority. One student said that they would prefer an automated system so everything is already taken care of. Also saying, "I feel like I want to call someone who can put out the fire". All students thought that they would try to put out the fire if it were small but felt more unsure if the fire would be more severe. In the event of a more severe fire, two of the students speculated that they would look for the life rafts and instructions on how to use them.

A general theme of considering jumping ship if the situation became too dangerous onboard was present in all students' answers: "I would stay onboard for as long as I feel safe". They also expected the other passengers to be stressed and panic or jump ship, while some others would act more rationally depending on the size of the fire. There is also a pack mentality that one of the students reflected upon. If others do something, you may want to do the same thing. If everyone stays on board, it may encourage others to continue staying on board. Lastly, it was mentioned that instructions can be good since the passenger would not have to figure anything out when they are stressed.

The students expressed liking the blinking light on the fire extinguisher; one of them reacted to the concept with "Oh, that's nice". They generally thought this would be encouraging and easy to see. The focus group was positive towards the sub-concept as well, although they pointed out that the blinking indicator could be blocked by fire. Marking one of them as "the right one" may cause confusion and hesitation among passengers if it is not available for use. However, making the lights on any suitable extinguisher blink would probably be sufficient in the situation. It was also suggested to use some kind of projector to paint the escape route on the floor, although they speculated that this might not be the best solution in a fire.

5.9.3 Evacuation

All the students assumed they should put on a life vest if they had to evacuate. However, the expected evacuation methods differed slightly among the students. One of them expected that they would simply put on the life vest and then jump or climb into the water. Another student thought they would go over a bridge to another boat, while the last thought about evacuating into life rafts.

The students seemed conflicted regarding helping other passengers in an emergency. Some thought they would try to help others as long as they first ensured their own safety. Moreover, the help should not have to be major; it could simply be helping someone walk in the right direction. One of them was unsure about what she could do to help and also wondered how much responsibility she felt comfortable taking upon herself. Pressing a button to start the evacuation process seemed easy, while ensuring that all passengers reached the life rafts seemed like too much responsibility.

Lastly, 2 students discussed lighting: one wanted to have escape-route lights, such as those used in aeroplanes, while the other wanted to have lights on the outside. The important thing with these lights was to be seen, but the student also thought that being able to see would help in the situation.

The conclusion was that in any emergency, someone should call 112 while another person checks for injuries or tries to help. It would be important to have accurate signage and clear instructions.

5.9.4 Concepts

Wearable – The wearable device received some feedback regarding the clip, since clips never work according to the participants. This came from their own experience of how others dropped their phones or radios during work. They felt convinced that the clip would break or someone would drop the device, regardless of the clip being there. When shown the different attachment methods, they preferred the bracelet or the ring, appreciating their tangibility. However, the largest concern was that people might steal it, especially because of the camera. They also pointed out that, in a scenario where every passenger would be required according to ferry instructions to wear something during the trip and then remember to take it off, would not work in a real-life setting

Tablet – The tablet was deemed less usable than the portable device; it would most likely require 2 hands, and they thought the circumstances under which it could be used were too specific.

Stationary – The biggest weakness found in this concept was the need for power, although a small battery that could manage for the time the emergency required was proposed as a solution. They also believed that combining this with speakers would be beneficial.

5.9.5 Prototype

When presenting the concept to the students and the focus group, many thoughts about the buttons were discussed. Three main options were discussed. The first suggestion was to have buttons for each emergency, similar to the example proposed by Porathe (2021). Then each button could automatically start the necessary process for each situation. The MOB button would, for example, start a call, stop the ferry, and release life buoys all around. The second option was to have two buttons: one for information and one for emergencies. This solution was suggested by the students, who told us they preferred two buttons: one red for emergencies and one blue for information. This was similar to an option suggested during the focus group, to use two phones: a red one for emergencies that can be prioritised, and one blue for information. However, this solution would require the passenger to determine whether a situation is an emergency, which may vary in difficulty depending on the person and the circumstances. This leads to the third suggestion of only having one button, just as the mid-fidelity prototype (see Figure 5.13). One of the participants called it a “problem solver”. Whether there is a fire or an intoxicated individual on board, the button would call someone who can help them solve the problem. However, when students were shown the mid-fidelity prototype, 2 out of the 3 students suggested replacing the one button with two instead, one for information and one for emergencies.

For the screen, it would be preferable to have information in several languages. It was also suggested that the device be placed away from ticket machines to avoid unnecessary calls to the ROC. It was also suggested that touch may not be very functional in wet environments, and therefore, the answers to the questions should always be displayed. Also, once a call has started, passengers should not have any control over it, such as hanging up or changing the volume.

During the focus group, it was suggested to add information on the pier or to find another way to communicate necessary safety information to passengers before boarding. It was also suggested to have an automatic release system for the lifebuoys if someone were to fall overboard. Another suggestion was to use passengers’ phones by implementing the emergency communication channel in Västtrafik’s current app, or to utilise the SOS application, since that could be a way to communicate with passengers. If something were to happen, everyone on board could receive a notification from the application. Lastly, it was suggested that a device be placed on the pier.

During the focus group, it was also suggested to add information on the pier or to find another way to communicate necessary safety information to passengers before boarding. In addition, it was suggested to place a communications device there as well. Another suggestion was to use passengers’ phones by implementing the emergency communication channel in Västtrafik’s current app. Or to utilise the SOS application, since that could be a way to communicate with passengers. If something were to happen, everyone on board could receive a notification from the application.

6

Final Concept

Throughout the project's stages, numerous existing and new solutions have been ideated, evaluated, and iterated upon. Since none of the solutions fully replace or substitute for all the tasks and services of a crew in any of the emergency scenarios outlined in the Introduction section of this report, we propose a system comprising five sub-solutions. These sub-solutions will complement each other to form a holistic solution that, in most cases, accommodates passengers' needs.

The first sub-solution (S1) is the stationary communication device that was developed and tested in this project. This sub-solution is intended to fulfil most of the passengers' communication needs. No longer being constrained by tablet size, then further evaluation UX practices and receiving feedback during the user test, this final concept is better adapted to handle the outlined emergency scenarios.

The new design is illustrated in Figure 6.1.

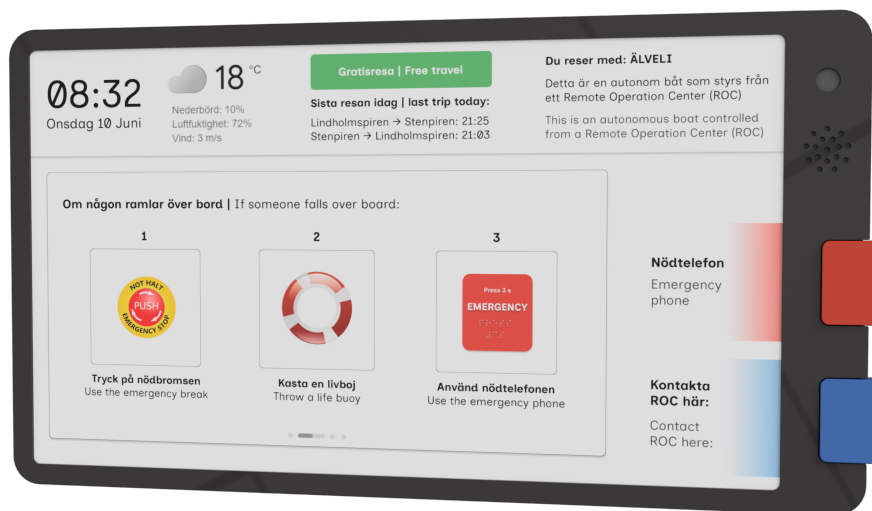


Figure 6.1: Render of Stationary communication device – S1.

The device has a larger 24-inch screen with a 16:9 aspect ratio and no touch capabilities. This is due to the touchscreen not functioning properly when water is on it, as well as to people wearing gloves during the winter. Each device will be

equipped with its own battery and cellular connection, making it self-sufficient if centralised power distribution fails. With this, we concluded that focusing on answering common questions and displaying relevant information continuously would be better. With the larger screen and without the need to expand or select topics, the information can also be read and displayed at greater distances by multiple passengers.

Instead of a single call button, the device now has two separate buttons: one for non-emergency calls and another for emergency calls, see Figure 6.2. The lower call button is for lower-priority calls, such as when the passenger has questions or needs help with something small. This button is Blue with a phone icon to signify that it is easy to press and call someone. This can lower the threshold for calling compared to a combined button. The Upper red button with a siren icon is the emergency call button. This combination signifies a warning and indicates that it is for emergencies. Even though calls would most likely be to the same person/operator, this way the calls will be prioritised. Additionally, through our focus group and interviews, several of the participants suggested two separate buttons to clearly indicate that one would provide information and the other would provide emergency help. To clarify further, the new interface also includes an informational window on how to use the device and what each button does.

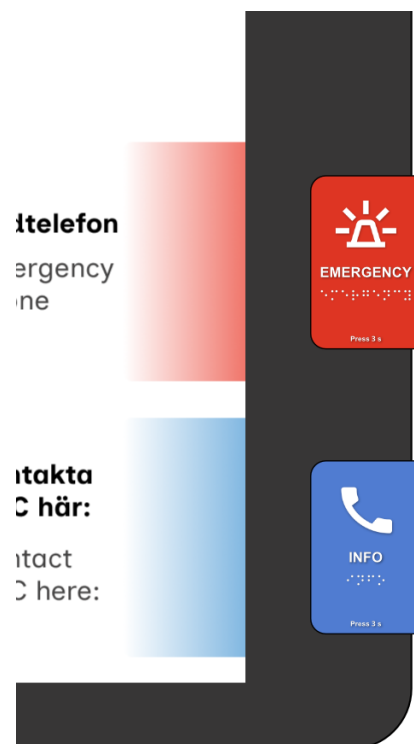


Figure 6.2: Illustration of buttons with icons.

Based on the recommendations and feedback from the experts, the results of our user studies, and user tests, we concluded that placing at least one device at each end of the ferry is necessary. Equipping each device with its own battery and cellular connection, making it self-sufficient, will create just sufficient redundancy and accessibility. However, placing an additional device in the centre would also add redundancy and improve accessibility when there are many passengers on board, which is preferred. The map in Figure 6.3 shows the recommended placement of the communication devices for the ferries in the researched scenario. Also, not placing any right next to a ticket system will avoid confusion. In addition, placing them inside will minimise wear on the device and improve screen visibility by avoiding direct sunlight, preventing rain from running down it, and preventing snow and ice build-up.

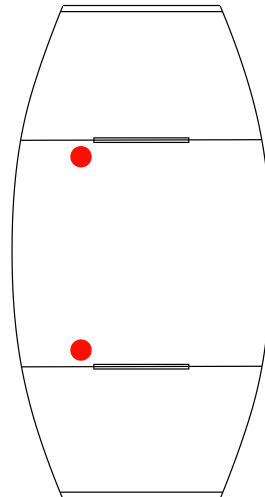


Figure 6.3: Map of the suggested placement of the stationary communication devices.

Further research and evaluation will be necessary on a case-by-case basis for other ferries with a different layout, but overall, one device per passenger compartment and at least two in total, but preferably three or more would be recommended, with a focus on placing them near the boarding/disembarking areas and near locations where passengers would most likely look for information.



Figure 6.4: Example of an emergency stop button.

The second sub-solution (S2) is an emergency stop button that passengers can press when it is appropriate to stop the ferry, such as during a MOB. Figure 6.4 illustrates how such a button would look. These buttons would primarily be placed near locations where someone could fall overboard or spot someone in the water. Figure 6.5 shows the suggested placement for our scenario. Functionally, the emergency stop button would set the Speed Through Water (STW) to zero, meaning the ferry would stay with the current, similar to what an MOB would. In conjunction with this, the ferry will deploy life buoys to mark the MOB's position in case the ferry needs to divert.

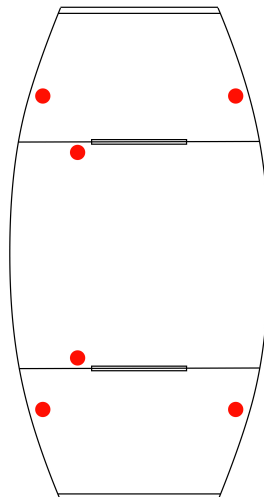


Figure 6.5: Map of the suggested placement of the emergency stop.

Apart from passenger-initiated interactive systems, the third sub-solution (S3) aims to guide passengers using three different types of lights: guide lights, reference lights, and marking lights. Figure 6.6 illustrates all of the light types.



(a) Guide Light.



(b) Reference Light.



(c) Marking Light.

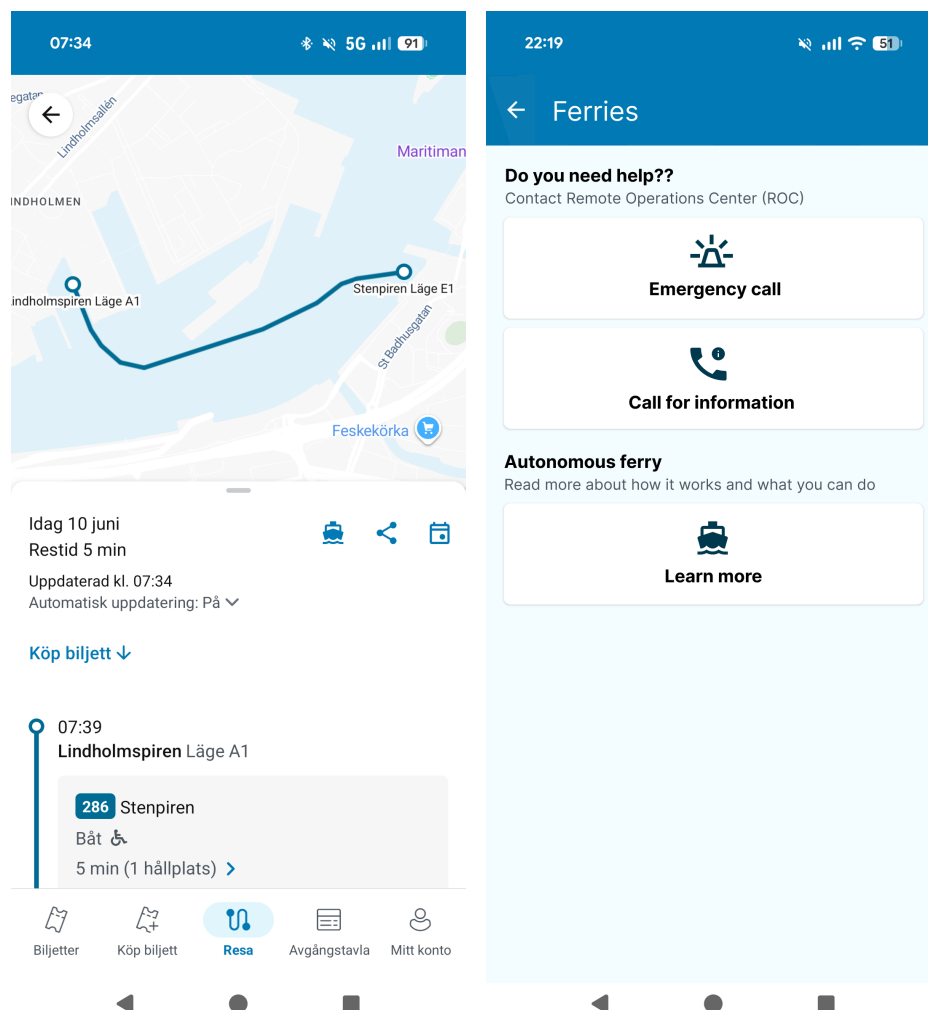
Figure 6.6: Examples of different lights.

The guide lights consist of two white floor strips that guide passengers toward the exits of the ferry, similar to the ones used in passenger aircraft. Their purpose is to indicate evacuation routes, particularly in situations where visibility is limited due to smoke. The reference lights primarily create reference points between the passengers and the ROC. They consist of two yellow lights located on the bow and the stern of the ferry. By referring to these lights, ROC operators can direct passengers towards a specific area of the vessel. For example, passengers can be asked to move towards the yellow light rather than moving towards the stern. Most of the ferries visited in this study were symmetrical in their design, making it very difficult for passengers to determine whether they are moving towards the bow or the stern. The reference lights would solve that problem by providing easily identifiable visual marks.

The last type of lights is called marking lights since they mark the place of necessary equipment. During an emergency, the ROC operators can use these lights to encourage users to act. For example, it can mark the correct type of fire extinguisher to use for that particular fire. This functionality was perceived as encouraging during the user tests and may facilitate action among passengers who feel unsure about how to respond. The marking lights can also be used to mark the storage locations of life vests, helping passengers locate essential safety equipment.

The fourth sub-solution (S4) is a speaker system, already in place on most ferries today but still worth mentioning. As can be seen in the literature and the user studies, passengers expect to be informed through this channel and want short, concise messages with information about the ongoing emergency, as well as instructions on what to do. A reliable, audible speaker system can have a significant impact and provide ROC operators and emergency responders with an important tool that can help immensely during emergencies. How people respond to messages can vary, but it was apparent that a real human voice that strikes a balance between commanding and calming can help keep passengers calm and able to follow instructions.

The fifth and final sub-solution (S5) would be app integration into the existing app infrastructure, in our case, Västtrafik TOGO. Passengers in our user studies mentioned that one of the first places they would look for information is the app they already use for route planning, ticketing, and traffic information. Implementing a dedicated page that serves as a Q&A section with information on ferry safety, as well as options to chat with or call ROC, could make emergency information and communication more accessible. Unlike a stationary device, an app-based solution would allow passengers to access the information and contact ROC from different locations on board, without having to locate a dedicated communication device. It could also provide a more private way of contacting ROC, which may make passengers more comfortable seeking assistance when the situation is not perceived as immediately life-threatening.



(a) Normal route view with ferry button.

(b) Ferry tab.

Figure 6.7: Illustration of app integration into Västrafrak TOGO.

7

Discussion

With our work concluding in a final concept, there are a few aspects to discuss regarding our findings and development that can not be considered results or findings. This begins with a reflection on our final concept and includes discussions of aspects that could have affected our findings, results, and evaluations. Additionally, we discuss further development and research in the area.

7.1 Reflection on final concept

With the final concept, the aim is to fulfil most requirements with the help of multiple sub-solutions. Since there was not ample time or opportunity to test the entire concept or the various sub-systems in practice, we can only evaluate them against the requirements and reflect on how well they fulfil them based on what was learnt. Based on these reflections, Tables 7.1 to 7.5 show to what extent the requirements have been fulfilled, accompanied by a brief explanation of our reasoning, complementing the contents of chapter 6.

Table 7.1: Requirements fulfilled by Stationary Communication Device.

R1	R2	R3	R4	R5
<i>Partially</i>	Fulfilled	Fulfilled	Fulfilled	Fulfilled

First of all, the Stationary communications device (S1) functions as both an information system and a communications device. This is because it can provide passengers with preventive information on how to perform various tasks during emergencies, and also serves as a two-way communication device. This, in turn, enables it to do most things needed to fulfil the requirements. Both functions assist passengers in understanding what to do (R2) and help in emergencies (R3), while making information accessible (R4) and being approachable (R5). However, even though it helps partway, it does not quite fulfil the requirement of ensuring calmness and safety amongst passengers (R1), as it can only address a small group of people who are able to listen. It is also not able to intervene or physically prevent passengers from taking actions that could endanger them.

Table 7.2: Requirements fulfilled by Emergency Stop Buttons.

R1	R2	R3	R4	R5
–	–	Fulfilled	–	–

With the emergency stops (S2), passengers can manually stop the ferry, which is especially useful during MOB scenarios. This way, passengers can contribute to overall safety by noticing someone in the water and acting in cases where the ROC might not notice. This contributes to Requirement 3 (R3) of *allowing passengers to help during emergencies*, by providing them with *a way to help meaningfully, without harming others* and by *retaining their ability to use both their hands*. Both interview and workshop participants mentioned they expected there to be a way to stop the ferry in case something happened. After consulting with our expert, we concluded that such a system would be prudent to implement; thus, we chose to include it in our solution.

Table 7.3: Requirements fulfilled by Guide, Reference & Marking lights.

R1	R2	R3	R4	R5
–	Fulfilled	Fulfilled	Fulfilled	–

§ Guiding lights emerged as both suggestions and examples throughout the project, as a useful system that could help people find exits. The marking lights came up during the ideation process and were presented to people in user tests, workshops, and to the expert. They were well received and became part of the solution. Though we focused on showing how it can be used to mark a fire extinguisher, it could also be used to mark other types of equipment. Reference lights are an idea captured from the interviews with the crew onboard the road ferry that we visited. They wanted to use it as a reference point to indicate which end of the ferry they are referring to, so passengers would have an easier way to gather at the correct end. We adopted these in our final solution and will serve as reference points for the ROC when communicating with passengers. To conclude, these light systems will *inform passengers of what to do* (R2), *allow them to help* (R3), and *grab their attention* (R4).

Table 7.4: Requirements fulfilled by Speaker System.

R1	R2	R3	R4	R5
<i>Partially</i>	Fulfilled	–	<i>Partially</i>	–

Although a speaker system (S4) is already present on ferries, we felt it still needed to be mentioned to explain its use and benefits, as well as how it fits with the other sub-solutions. From our studies, we found that most people expect to receive information through this type of system during ongoing emergencies or for other aspects of their trip. Providing short, clear, and concise messages to passengers can both promote calmness and safety among passengers (R1) and help them understand what they should do (R2). In addition, it helps grab passengers' attention but is still limited in terms of language and passengers' ability to hear the message, thus only partially fulfilling Requirement 4 (R4).

Table 7.5: Requirements fulfilled by App integration.

R1	R2	R3	R4	R5
<i>Partially</i>	Fulfilled	—	Fulfilled	Fulfilled

Finally, Sub-solution 5 (S5) aims to utilise existing app infrastructure by integrating functionality similar to that of the stationary device directly in the passengers' phones. From what was gathered in the user study and interviews, it is one of the first places where people look for information regarding their trip. This partially fulfils (R1) by informing them of ongoing emergencies or allowing them to contact ROC or Rescue Services. It fully fulfils (R2) by preparing passengers through preventative information, also providing information and instructions during emergencies. This, in combination with other features that nudge passengers to behave or act more safely, facilitates rule-based behaviour. Today, being able to notify passengers directly on their phones is the best way to get their attention. Also allowing them to access and approach the same features and information as on the stationary device makes it easily fulfil (R4) and (R5).

7.2 Fulfilling Requirement 1

Though most requirements were fulfilled, with plenty of overlap between the sub-solutions as they complement each other, Requirement 1 – *Ensure calmness and safety amongst passengers* could not be entirely fulfilled by the final concept. Even if the final concept does, to a good extent, promote both calmness and safety, when looking at the sub-requirement, it cannot entirely provide the means for passengers to be completely able to handle or resolve any emergencies themselves; the system also cannot prevent their panic or ensure their safety.

In a way, this is a requirement that is impossible to fulfil, and rather something one would aim to get as close to as possible. An experienced deckhand may be better than the final concepts system in some scenarios, but even they cannot ensure safety in all cases or guarantee that they can prevent panic or support all passengers. Rather, this is a point where you would argue that any system or crew in place is

good enough for the circumstances and provides a reasonable amount of safety for passengers.

As we concluded that some of the more serious emergencies like the ones we investigated are rare, one could argue that the final concepts system could be developed to a point where it is sufficient for smaller passenger ferries travelling in rivers and archipelagos.

7.3 Road Ferries

Although road ferries are outside of our scope, we visited one as it got us the opportunity to learn from experienced captains and deckhands who work with a similar vessel and in a similar context. This visit occurred later in the project, when development and evaluation were already quite far along, but it still gave us useful insight, verified some of our findings and conclusions, and gave us additional ideas.

With a road ferry, our system would have a similar effect for passengers in passenger compartments, but with the higher risk of accidents occurring due to road vehicles, the expectations for the system's effectiveness are higher. But most of all, the system will not be as effective for passengers travelling in their vehicles. This is because the vehicles obstruct passengers' view and can make communication with them difficult due to the physical insulation of the vehicles. Furthermore, communicating with passengers inside vehicles using the ferry's onboard speaker system may be challenging, particularly on the open vehicle deck where outdoor conditions and ambient noise can make announcements difficult to hear. Due to these added factors and all of the challenges that come with it, we chose not to include it as an environment we developed our concepts for or evaluated them against.

7.4 Sampling

As this thesis has involved gathering information and evaluating concepts by observing and interviewing people available to us, mostly through convenience sampling, it is important to reflect on how this could have affected the results. With that in mind, we can still only theorise if there has been an effect.

When visiting the ferry lines on Götaälv for our user study, we approached many people, keeping in mind that we wanted people of different genders and ages; thus, some selection was made deliberately rather than randomly, as we had originally intended. We also tried to approach passengers in different travel situations, for example both indoors and outdoors, with and without bicycles, and with and without headphones, to capture a broader range of perspectives. Despite these efforts, some groups were not represented in the interviews, including passengers travelling during evenings, tourists, and passengers who did not speak Swedish. This may have affected the results, as these passengers could have different information needs

and rely more on visual communication than Swedish-speaking passengers. Furthermore, although participants were asked whether they had any accessibility needs, the resulting sample included very limited representation of people with disabilities. Consequently, the perspectives of passengers with visual, auditory, cognitive, or mobility impairments may not have been adequately represented.

The participants in the user interviews were recruited through convenience sampling and consisted solely of university students. Although they represented potential future passengers, they did not necessarily represent the broader ferry passenger population in terms of age, travel habits, or previous maritime experience. Furthermore, as the participants were acquainted with us, there is a possibility that this influenced the feedback provided. The results from the user tests should therefore primarily be viewed as formative feedback used to identify usability issues and improve the concept, rather than as findings representative of all passengers.

The expert interview, study visit, feedback group and focus group all relied on participants recruited through the project’s collaboration with RISE Research Institutes of Sweden. The purpose of involving experts was not to represent passengers, but to complement the user perspective with professional experience within maritime operations and autonomous shipping. The participants were selected based on their availability and expertise rather than through a systematic sampling process. Although this may have influenced the perspectives gathered, all participants had extensive experience within maritime operations or autonomous shipping, making them highly relevant to the aims of the study.

7.5 Lack of Context and Real World Scenarios

In recent years, numerous smaller ferries have been tested either in closed tests or by operating temporarily for public use. These include but are not limited to vessels like: MF Estelle in Stockholm (“Zeam”, n.d.), Celia ONE in Gothenburg (“Cstride”, n.d.), milliAmpere1 & 2 in Norway (Alsos et al., 2024; Brekke et al., 2022; Haugan, 2022), Falcon in Finland (“Finferries”, n.d.), and Roboat in Amsterdam (“Roboat”, n.d.). In addition, Trafikverkets new road ferry Allvaret is currently in the final stages of testing before being deployed for real-world testing (Trafikverket, n.d.). However, these projects have been primarily focused on developing the vessels’ autonomous capabilities, as well as gauging the public’s perception and experience of using them.

With that, we can also say there are plenty of sources pertaining to evaluating the operations and perception of uncrewed ferries, but much fewer about handling emergencies on them. That said, we did not access resources to do a deep dive within this particular part of the subject to find good and relevant sources that could aid in our process of developing and evaluating devices for emergencies on uncrewed ferries. The papers *Reframing Procedures and Teamwork for Man Overboard (MOB) Scenarios on Small MASS Passenger Ferries* by Bram et al. (2025) and *Safety on automated passenger ships: Exploration of evacuation scenarios for coastal vessels*

by Burgén and Bram (2024) have been the only relevant or helpful ones in our work.

We conclude that this is most likely due to a lack of a real-world environment where emergency systems could be tested, as the functionality of uncrewed ferries is still being developed and evaluated. As a result, companies are just starting to look into these questions since the autonomous shipping market is a quite recent development, with few opportunities for testing new ideas. Therefore, due to the lack of research and real-world cases, creating an accurate context or test environment is difficult and relies heavily on cases similar to current circumstances and theories.

Some of the closest real-world cases are in autonomous trains and metros, for instance, the Copenhagen Metro. Even though the Copenhagen Metro has operated autonomously since 2002 (Metroselskabet, 2022), we could not find any research or information about its passenger communication, presumably in place as seen in Figure 7.1. This is often the case with commercial systems. Hence, apart from knowing about its existence, no actual experiences or insight could be drawn from this particular case, although we could identify some features of the device, such as two separate buttons and colouring.



Figure 7.1: Screenshot from *Scenes from the Copenhagen Metro System* (Andersen, 2022)

Apart from this, there is also the subject of Swedish maritime law (Sjölag, 1994:1009), which currently requires maritime vessels to have a responsible person (often referred to as a captain) onboard, both to ensure passenger and cargo safety and to render aid to other ships if they are in distress. In other countries and international waters,

the story is similar, with strict requirements for having an ample, capable crew who can take responsibility. However, as the IMO has released a new non-mandatory code for MASS cargo vessels (IMO, 2026), some steps are being taken internationally to revise the current rules, though only for vessels without passengers so far.

Summarising, as the aim of the project is to promote safety and situational awareness on autonomous and remotely operated ferries, leaving passengers alone on board a ship without a crew is, at this stage, ill-advised. To note, it would also leave the ship unable to assist other ships that are in distress, which places additional strain on rescue systems. For this thesis we can only assume that laws and technology will adapt and one day permit further research and evaluation, making our work a first step into exploring the challenges of passenger communications systems. Adaptations will probably have to be made in the future as laws are determined and limitations of the technology are set.

7.6 Further Research and Development

With the evaluation of our final concept done in 7.1, we have an estimation of how well a system like that could perform. But there is still a need to develop it further and do proper user testing in a practical setting. For this, the concepts should be further developed into functioning high-fidelity prototypes and implemented into a test environment. This way, the different sub-solutions and their features can be tested better to see how well they work in terms of usability, interaction, reliability and safety. Some aspects that could expectedly be determined through these tests are whether passengers understand, for example, how to follow guide lights, whether they will approach the stationary devices and how they will use them. It could also be helpful when determining if it is preferable to have one or two buttons on the device, as this may influence users' willingness to interact with the system.

Within this thesis, we have worked mostly from the assumption that an uncrewed ferry with autonomous capabilities would appear similar to the ones we researched today, so our ideas and concepts are made in such a way that they could be suited for the ferries we visited. Thus, looking into how the system could be integrated when constructing new ferries could further its effectiveness.

Within this thesis, we have worked mostly from the assumption that an uncrewed ferry with autonomous capabilities would appear similar to the ones we have researched today, thus our ideas and concepts are made in such a way that they could be suited for the ferries we visited. Though it is important to note that future ferries adapted to an autonomous setting may differ in design and features beyond the aspects discussed and explored in this thesis. Thus, looking into how an information and communications system could be integrated is important when constructing new ferries and could further its effectiveness.

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A

Passenger interviews - Questions

Translated from Swedish to English

Questions asked to passengers

Hur ofta åker du färja? - How often do you travel by ferry?

Vad är huvudsyftet med din resa idag? - What is the primary purpose of your trip today?

Om färjan skulle stanna nu under resan, vad hade du väntat dig för information? - If the ferry were to stop, what information would you expect to receive?

Vad tror du är det mest effektiva sättet att få/dra din uppmärksamhet i en nödsituation? - What do you think is the most effective way to attract your attention in an emergency situation?

Har du några tillgänglighetsbehov som är relevanta i en nödsituation? - Do you have any accessibility needs that would be relevant in an emergency situation?

Var skulle du letat efter en informations- eller hjälpknapp? (peka/beskriv) - Where would you look for an information or assistance button? (Please point to or describe the location.)

Finns det några situationer du tror att du hade kunnat lösa utan hjälp från någon annan? - Are there any situations that you believe you could handle without assistance?

Vad förväntar du dig att besättningen ska ge för instruktioner? - What instructions would you expect the crew to provide in an emergency situation?

Är det något annat du har tänkt på gällande nödsituationer ombord? - Is there anything else you have considered regarding emergency situations on board?

Hur gammal är du? - How old are you?

Hur identifierar du dig? - What do you identify as?

Questions asked during staff interviews

Hur länge har du jobbat på båtar? - How long have you been working in this role?

Vad är dina arbetsuppgifter? - What are your main responsibilities?

Vilka färjor/rutter brukar du arbeta på? (ex. ö-trafik eller älv) - Which ferries or routes do you typically work on? (e.g., island services or river services)

Vilka säkerhetsrutiner har ni vid nödsituationer? - What safety procedures do you follow during emergency situations?

Har du varit med om några krissituationer? - Have you experienced any emergency or crisis situations while working?

Vilka uppgifter i nödsituationer kräver att du är fysiskt närvarande? - Which tasks during emergency situations require your physical presence?

Vilka av uppgifterna hade kunnat göras om, bli automatiserade eller hanteras av någon på fastlandet för att avlasta er? - Which of these tasks could be redesigned, automated, or handled remotely from shore to reduce your workload?

Vilka säkerhetsrutiner tycker du är enklast/svårast att förklara för passagerare så de förstår? - Which safety procedures do you find the easiest and most difficult to explain to passengers in a way they understand?

Vad tycker du är bästa sättet att förmedla information till passagerarna i nödsituationer? - What do you consider the most effective way to communicate information to passengers during emergency situations?

Vilken information brukar ni förmedla? - What information do you typically communicate to passengers during emergency situations?

Om båten havererar (motor, styrning) brukar besättningen ha kunskapen och verktygen att laga den? - If the vessel experiences a failure (e.g., engine or steering failure), does the crew typically have the knowledge and tools required to repair it?

B

Figma App Flow

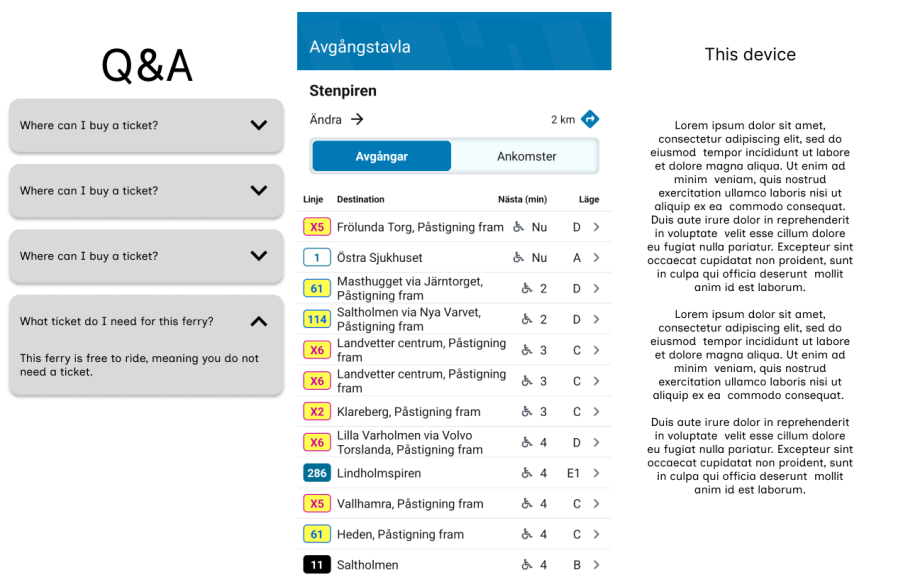


Figure B.1: Before pressing button.

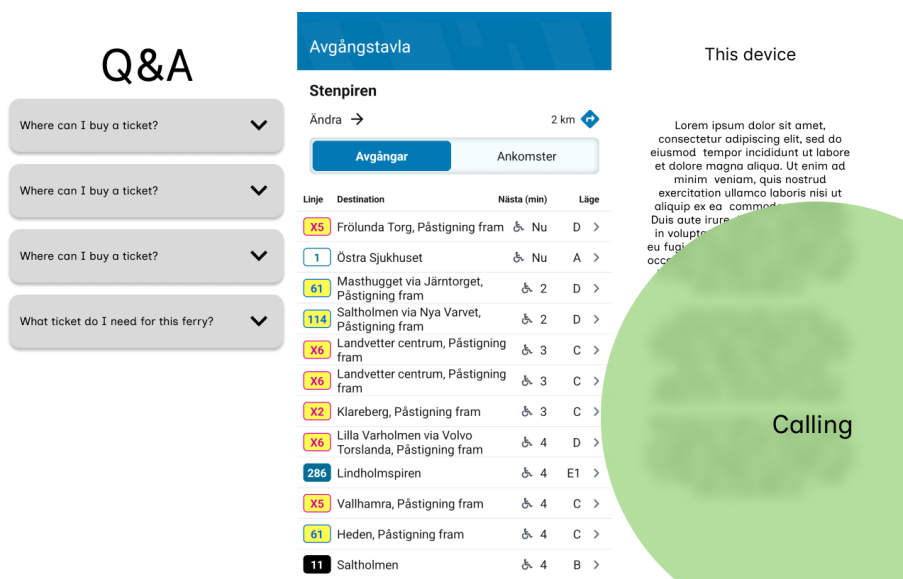


Figure B.2: While holding button.



Figure B.3: After button has been held, Call begins.

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