CHALMERS
UNIVERSITY OF TECHNOLOGY

Designing the Future of Marine Interfaces

A User-Centered Approach to Yacht Display Solutions

Master’s thesis in Industrial Design Engineering

ANNA ENGLUND
IDA OSTERMAN

DEPARTMENT OF INDUSTRIAL AND MATERIALS SCIENCE

CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2025
www.chalmers.se

Master's thesis 2025

Designing the Future of Marine Interfaces
A User-Centered Approach to Yacht Display Solutions

Anna Englund
Ida Osterman

CHALMERS
UNIVERSITY OF TECHNOLOGY

Department of Industrial and Materials Science
Division of Design & Human Factors
Chalmers University of Technology
Gothenburg, Sweden 2025

Master's thesis in Industrial and Materials Science (IMSX30)
Designing the Future of Marine Interfaces: A User-Centered Approach to Yacht Display Solutions
Anna Englund & Ida Osterman

Department of Industrial & Materials Science
Chalmers University of Technology
SE-412 96 Gothenburg
Sweden

Cover: Visualization of the final Human-Machine Interface design, displayed on a multi-functional display aboard a boat.

Chalmers Digitaltryck
Gothenburg, Sweden 2025

GLOSSARY

Abbreviations	Definition
AD	Assisted Docking
AIS	Automatic Identification System
AP	Autopilot
AQ	Aquamatic Sterndrive
DPS	Dynamic Positioning System
EVC	Electronic Vessel Control
GC	Glass Cockpit
GPS	Global Positioning System
MC	Marine Commercial
HMI	Human Machine Interface
IPS	Inboard Performance System
MFD	Multi-Functional Display
ML	Marine Leisure
SOG	Speed Over Ground
STW	Speed Through Water
UI	User Interface

ABSTRACT

This thesis explores the design of a Human Machine Interface for digital displays in yachts, with a focus on enhancing usability, safety, and user experience. Conducted in collaboration with Volvo Penta, the project responds to the increasing digitalization in the boating industry and the associated cognitive demands placed on operators. Grounded in theories about usability and guided by Wicken's model of human information processing, the study combines theoretical research, user interviews, observations, surveys, and benchmarking to understand user needs.

The findings informed the design of a user-centered interface incorporating features such as personalized profiles, system status summaries, context-dependent views, trip summaries, and a tiered warning system. Emphasis was placed on intuitive navigation, visual clarity, and reducing cognitive load during critical tasks. The final outcome is a high-fidelity prototype compatible with multiple platform solutions. This study contributes to Volvo Penta's vision of delivering seamless, safe, and enjoyable marine experiences through innovative digital solutions.

ACKNOWLEDGEMENT

We extend our sincere gratitude to our supervisor and examiner, Lars-Ola Bligård, for his invaluable guidance, support, and constructive feedback throughout the development of this thesis.

A heartfelt thank you to Volvo Penta for the opportunity to collaborate with your team and carry out our master's thesis within your organization. We would also like to express our appreciation to our supervisors, Alice Johansson and Johan Eriksson, whose expertise and support provided us with valuable insight into the company and its products, and helped shape our work.

We are also grateful to everyone who contributed to our study through interviews, observations, and surveys. Your insights were fundamental to the depth and quality of our research.

Finally, we would like to extend our thanks to the academic program, Industrial Design Engineering at Chalmers University of Technology, which has shaped us over the years and enabled us to successfully complete this master's thesis.

EXECUTIVE SUMMARY

The purpose of this report is to present the work conducted in a master's thesis focused on the future design of marine display solutions in yachts. The main research questions explored were:

- What information and functions are most relevant and essential for users from a usability and safety perspective?
- How should a Human Machine Interface be designed to integrate Volvo Penta's EVC system into a multi-functional display?

This project was a collaboration between Chalmers University of Technology and AB Volvo Penta, which aimed to explore how next-generation displays for the leisure marine segment could be designed. Although the initial project brief was broad, several key areas of interest were identified from AB Volvo Penta's perspective. At its core, the project sought to create safe and enjoyable passages at sea while also elevating the overall boating experience.

Digitalization in the boating industry has evolved continuously over the years, significantly transforming the way boats are operated and experienced. Today, the range of digital tools available is extensive, spanning from advanced GPS systems to integrated systems that control engines and overall boat operations. AB Volvo Penta offers several digital solutions, for instance the Glass Cockpit system, which is an all-integrated control and monitoring system that provides essential information for the skipper. It displays data from the engine, driveline, and onboard electronics, alongside navigation data. Fully customizable, the system allows users to tailor layouts to their specific needs, whether that is specific instruments for fishing, water sports, or simply navigating the sea.

To identify areas of improvement in the current Glass Cockpit system and to explore future possibilities for yacht display design, comprehensive research was conducted. Both quantitative and qualitative methods were employed. Data was collected from a wide range of boat operators, varying in experience and professional background. The quantitative study consisted of a survey distributed to Volvo Penta employees with boating experience, as well as to recreational boat operators in Sweden via Facebook groups. The qualitative study involved interviews, some of which were paired with observations. While most interviews were conducted online, a few took place in context - onboard a yacht with the operator actively navigating.

The collected data provided a wealth of insights. A KJ-analysis was used to systematically organize the results, grouping responses into meaningful categories. Approximately half of the findings focused on identifying the most important functions, engine data, and other data that the operators rely on. The other half revealed user pain points and highlighted features that were particularly appreciated in current systems.

When it comes to the most important and commonly used features, the user studies revealed the importance of the nautical chart, which users consistently identified as the most vital feature in a yacht's Human-Machine Interface. It provides real-time positioning, environmental context, and navigational hazard awareness, supporting both active navigation and route planning.

Other essential features frequently cited include radar, engine data, and cameras mounted on the stern. Radar is often used as an overlay on the chart, though some prefer separate views. Engine data is crucial for real-time performance monitoring and safety, while cameras greatly assist with docking and casting off by compensating for limited visibility.

Among engine data, the most consistently prioritized metrics were engine speed, oil temperature, oil pressure, coolant temperature, and fuel level, which are key indicators of engine health. Some additional engine parameters, such as exhaust temperature were considered relevant by some users, while others deemed them unimportant. These differences in preferences varied based on user experience, vessel type, and usage patterns.

Beyond engine-specific metrics, other important data included boat speed, depth, heading, position, and rudder angle. However, the relevance of this information depended on the navigation context. Leisure boat operators also expressed interest in comfort and environmental data, such as fresh water levels, sea and air temperature, and wind speed, which can influence decisions around onboard activities like swimming or showering.

Other interesting areas that arose during the user studies were the significant differences in individual preferences, both in terms of what information users find essential and which features they actively use. This variation highlighted a strong need for customization within the Human-Machine Interface. It also became evident that an excess of information on the display can lead to cognitive overload or, alternatively, users ignoring certain data. What is considered useful in one situation may be irrelevant in another, underscoring the importance of allowing the HMI to adapt to different operational contexts or driving sequences. Additionally, some information elements were found to be unclear or confusing, causing frustration among users. This included the design of gauges, alert systems, and specific symbols, which in some cases failed to effectively communicate their intended message.

These insights informed a subsequent ideation phase, during which a range of new concepts were developed and later evaluated in collaboration with users. The evaluations provided valuable feedback on strengths and weaknesses, which guided iterative improvements and the refinement of final concepts. The final results showcase the design of four new features: *My Profile*, *System Check*, *Trip Summary*, and *Recommended Views*, adapted for different driving sequences. In addition, several existing features were redesigned based on user feedback, including improved banners for *Autopilot* and *Assisted Docking*, as well as more clear and user-friendly alerts, gauges, and symbols.

TABLE OF CONTENTS

1. INTRODUCTION

In the following chapter, a brief background for the project will be presented, followed by the specification of project purpose and objective, as well as an outline of the report.

1.1 Background

The background offers a brief overview of boats and operators, as well as digitalization. This aims to facilitate the reader's understanding of relevant topics for the project.

1.1.1 Boats and Operators

Boats, especially motorboats or powerboats, are engine-propelled watercraft designed for various activities and conditions (Reich, 2025). Most modern boats are made from fiberglass, aluminum, or steel, with construction techniques that improve strength and reduce weight. Propulsion systems vary, including inboard engines, outboards, pod drives, and jet drives. Powerboats come in many forms, from fishing-focused bass boats and center consoles to recreational options like bowriders, deck boats, cabin cruisers, and yachts. Each type is built with specific uses and environments in mind.

The demographic profile of boat operators in the United States (Zippia, 2025) shows that the workforce is predominantly male, comprising approximately 90.4%. Female representation has grown over the past decade, though a gender pay gap persists. The majority of boat operators are aged 40 or older. Regarding education, 44% hold a bachelor's degree, 23% have an associate degree, and 26% have completed high school. Most boat operators are employed in the private sector (64%), with significant representation in government, construction, and hospitality industries.

1.1.2 Digitalization

Digitalization in the boating industry has evolved continuously over the years, significantly transforming the way boats are operated and experienced. Today, the range of digital tools available is extensive, spanning from advanced GPS systems to integrated systems that control engines and overall boat operations. AB Volvo Penta (2025b) offers several digital solutions, for instance the Glass Cockpit system described in chapter 3.1, and Easy Connect, a smartphone application that provides users with real-time data about their boat. This solution also allows users to plan their next route, offering both convenience and enhanced functionality for modern boating enthusiasts.

Digital solutions have the potential to enhance competitiveness and user experience, especially when thoughtfully designed. However, to truly add value, particularly in contexts like boating, they must be carefully aligned with the needs and capabilities of the end user.

One important factor to consider in the boating context is the cognitive workload that the user is exposed to. According to Simonsen (2023), tasks characterized by high cognitive workload often involve large fluctuations in demand, multiple simultaneous tasks, and significant consequences of failure, all of which are prevalent in boating scenarios. While maneuvering a boat, the demands on the driver can fluctuate depending on factors such as the surrounding environment, weather conditions, and passenger interactions. At times, these factors converge, placing immense cognitive demands on the operator, while at other times, the workload may be minimal.

Simultaneously, the driver often must manage multiple tasks, including navigating, monitoring instruments, and interacting with digital screens, all while maintaining control of the vessel. Any lapse or error in this complex environment can result in severe consequences, further amplifying the cognitive load.

A critical contributor to this cognitive workload is, according to Simonsen (2023), the design of the User Interface (UI). Poor design can increase the strain on cognitive resources, making it harder for operators to process information and make effective decisions. This underscores the importance of designing and implementing user-friendly, intuitive digital interfaces for boats, ensuring that they support, rather than hinder, the user in high-pressure situations.

Historically, marine user interfaces have mainly consisted of physical controls, such as knobs, buttons, and levers, which provide both tactile, haptic, and visual feedback for nearly every interaction, such as the actual movement of turning a knob or the feeling and sound when a button "clicks". According to Flanders (2023), haptic feedback is a kind of feedback that creates more intuitive and interactive user experiences, which reinforces the sense of control and satisfaction. Moreover, Flanders states that haptic feedback adds a new layer to the user experience that cannot be achieved through visuals and sound alone.

However, with the emergence of digital interfaces, this tactile feedback is often absent, which can negatively impact the user experience and further increase cognitive workload. In a study made by Nagy et al. (2023), it showed that digital interfaces in cars caused a significantly higher distraction level than physical interfaces. Nagy et al. explained that physical controls, such as knobs and buttons, require less attention from the driver, as they can be operated with muscle memory using their hands and arms. These controls also provide rich haptic and tactile feedback, allowing the driver to focus more on the road rather than the interface.

With this in mind, it can be concluded that digital interfaces are often more complex to navigate than their physical counterparts, making them less intuitive and more time-consuming to operate. As a result, the shift from physical to digital interfaces poses significant challenges for usability and cognitive efficiency in the boating context.

However, digital interfaces offer numerous benefits that must also be considered. They provide opportunities for innovation and are both cost- and resource-efficient, as previously mentioned. Additionally, digital interfaces are often perceived as more visually appealing due to their clean and minimalistic appearance compared to physical interfaces.

To conclude, it is evident that there are both benefits and drawbacks with digital interfaces that have emerged because of the rapid digitalization. Both sides must be taken into consideration, both when investigating the problem, but also when designing a new interface.

1.2 Project Purpose and Objective

The purpose of this project is to explore the future of marine display solutions in yachts and identify needs related to this subject.

The objective is to develop a concept of a digital Human Machine Interface that integrates Volvo Penta's EVC system into a multi-functional display, featuring high fidelity and detailed design. The concept should provide the skipper of a yacht with essential information, features, and functions that ensure an enjoyable and safe passage at sea while also enhancing the overall boating experience. Additionally, the goal is to produce a report outlining the results from the project, including findings from literature studies, benchmark and user studies, and lastly a description of the development of a final concept.

1.3 Outline of the Report

An outline of the report is presented in the following:

1. **Introduction** – This chapter presents a brief background for the project, followed by the specification of project purpose and objective.

2. **Final Result** – This chapter offers a concise presentation of the final result, aiming at providing the reader with a brief overview of the final outcome of the project.

3. **Marine Terminology** – This chapter presents relevant theory for the project's scope, focusing on the marine domain.

4. **Theoretical Frameworks** – This chapter presents relevant theory for the project's scope, focusing on academic theoretical frameworks within cognitive ergonomics and usability.

5. **Methods** – This chapter presents the different methods and tools used during the project. The chapter follows the same structure as the project's execution, beginning with data collection

methods, followed by analysis methods, concept generation methods, and concluding with methods for evaluating the concepts.

6. **General Description of Procedure** – This chapter presents the procedure that was used for the project. The different phases and steps are presented in chronological order.

7. **Project Scope** – This chapter presents the project scope that was defined as a result of theoretical studies and discussions with representatives from Volvo Penta. Furthermore, limitations are presented, explaining the boundaries of the project in terms of areas of focus, to ensure a realistic and feasible process.

8. **Results from Empirical Studies** – This chapter presents the results from the empirical studies that were conducted, which included a benchmark, surveys and interviews.

9. **A Refined Scope and Concept Development** – This chapter presents the results from the point at which a clear direction was established based on the findings from the empirical studies, followed by the subsequent initial ideation and concept development phase.

10. **Final Design** – This chapter presents the final design outcome in detail, providing a thorough explanation of the developed concepts.

11. **Discussion** – This chapter discusses key topics that reflect the overall work, including the applied methods, theoretical frameworks, results, and other relevant aspects of the study.

12. **Conclusions** – The final chapter presents the key conclusions of the study, aiming at answering the research questions for the project.

Appendices – Enclosed are the complementary documents for the report, including project brief, interview templates, surveys, KJ-analysis, and a list of interview participants.

2. FINAL RESULT

The final outcome of this project resulted in a Human Machine Interface for digital displays in yachts, with a strong focus on usability, safety, and user-centered customization, see Figure 1. The solutions stem from user studies which informed a set of key features, including *My Profile*, *System Check*, predefined views for different operating sequences, alerts, *Trip Summary* and additional user interface elements. Following is a short description of the final design.

Figure 1. The final design displayed on a screen in a boat. Used and modified with permission Volvo Group.[1]

The *My Profile* feature allows users to create individual profiles that store preferences such as layout, display settings, and notification preferences. The profile creation process involves three main steps: entering user information, setting display preferences, and customizing the layout of the display. Layout customization includes selecting from recommended templates and assigning specific functions or data views to different sections of the interface. A refined search function and scroll menu help users quickly locate desired data, and completed layouts are stored under "Saved Views" for quick access.

The *System Check* feature provides a quick overview of critical onboard data – fuel level, battery voltage, fresh water, and grey/black water levels – via vertical color-coded bars. Colors range from green

---

[1] Volvo Group. (2022). *Glass cockpit shoot 2022* [photograph]. Retrieved May 8, 2025, from https://media.volvogroup.com/dam/contentitems/726024c64a464e34acbdb0a3015609ce

(normal) to red (critical), making it easy to assess conditions. This visualization supports cognitive processes by reducing reliance on working memory. The feature is configurable in the user profile and appears automatically at engine start, with the aim to enhance both safety and operational efficiency.

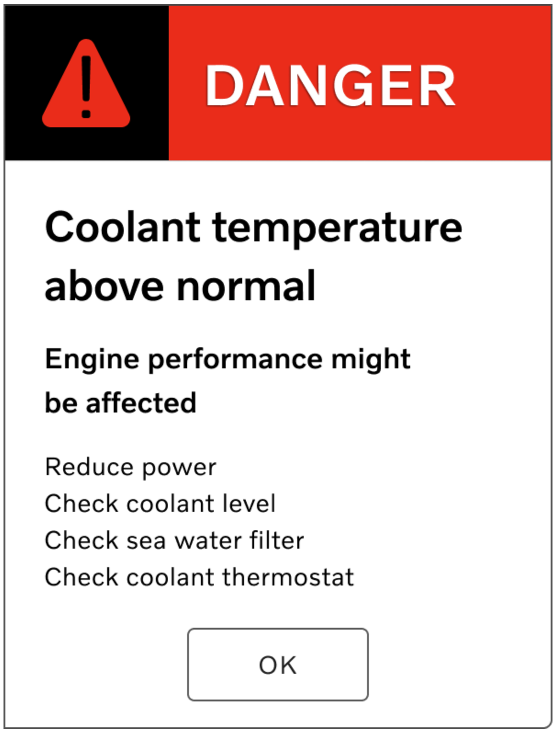
Recognizing different information needs during various driving phases, two recommended views were developed: one for *Cast off/Docking* and one for *Driving*. These pre-set views cater to users who do not wish to create custom layouts.

The *Cast off/Docking* view prioritizes situational awareness features such as depth, rudder angle, and stern camera. Engine data is minimized and combined into dual-needle gauges to save space. The rudder angle indicator uses color-coded dynamic visuals and numerical values to communicate position. Assisted Docking, if available, is shown via a configurable banner, horizontal or vertical, and includes live compass and system feedback.

The *Driving* view emphasizes navigation, with the nautical chart as the primary element, accompanied by key engine and vessel data such as engine speed, oil pressure, vessel speed, and heading. Enhanced visuals for radar overlay, dual engine gauges, heading compass, and a compact Autopilot banner are included. The Autopilot feature shows both current and set headings via directional lines on the chart and changes dynamically depending on selected functions like Heading Hold or Pattern Steering.

The *Trip Summary* feature presents post-trip data with visual and numerical information. Graphical representations of vessel status, such as fresh water and battery voltage, are included to make the information easier to interpret and recall. The feature also displays trip data, such as average fuel flow and distance traveled, aiming to provide the driver with engaging insights into their journey while encouraging more sustainable driving habits.

A new design for alerts has also been developed, featuring a narrow banner that displays an action plan with clear steps to guide user response in critical situations, see Figure 2. Alerts are tiered as 'Caution' (yellow) or 'Danger' (red) and strategically placed on the left side to ensure high visibility without obstructing important navigation information. Icons appear in the top bar to signal active alerts, and a bell icon reveals a compiled list of alerts, allowing drivers to track past issues and prioritize current ones.



DANGER

Coolant temperature above normal

Engine performance might be affected

Reduce power
Check coolant level
Check sea water filter
Check coolant thermostat

Figure 2. The final design of the 'Danger' alert.

Moreover, user interface elements have been designed for the various views, including a visualization of the rudder angle, a compass for heading, and new gauges for engine data, see Figure 3. These designs were based on user input regarding the preferred way to visualize such data, aiming to make them easy and efficient to interpret.

Figure 3. A selection of the user interface elements designed for the different display features, from left: nautical chart function, radar overlay shortcut, rudder angle, heading compass, and combined gauge for oil temperature.

A fixed top bar is added at the top of the display which features essential information, including user profile, system alerts, dark mode, brightness, and quick view switching. It supports intuitive navigation and quick access to high-priority actions. The dark mode is optional and aims to reduce glare during night operations for a more comfortable user experience.

3. MARINE TERMINOLOGY

Modern boats rely on advanced systems and displays, making it important to understand key marine terms. The following chapter presents relevant theory for the project's scope, focusing on the marine domain.

3.1 Volvo Penta

Volvo Penta is a part of Volvo Group. Volvo Penta provides marine and industrial power solutions, made to move people, business, and society (AB Volvo Penta, 2024a). Their marine applications are designed with both planet and people in mind, focusing on two different segments: commercial and leisure (AB Volvo Penta, 2024b). Driven by a commitment to total control, safety, and comfort, Volvo Penta develops advanced marine propulsion solutions, user interfaces, drivelines, and support for a global customer base.

Their marine leisure segment encompasses a wide range of boats, including superyachts, yachts, powerboats, and sailboats (AB Volvo Penta, 2024c). Their motto is that every voyage at sea, whether it is a coastal cruise or an expedition to the great beyond, should make you crave another. They are committed to delivering technology, services, and power solutions that elevate the user's maritime adventures. Their pleasure craft solutions are designed to work as an integrated experience, where every engine, driveline, feature, and accessory is crafted with a focus on ease of use, reliability, and comfort. The marine commercial segment encompasses a wide range of vessels, including passenger vessels, offshore wind transportation, coast guard and patrol vessels, short sea and river transport, workboats, and tugboats (AB Volvo Penta, 2024d).

The Vehicle Interface department at Volvo Penta is committed to creating user-friendly HMIs, focusing on intuitive displays and controls (Volvo Penta, 2024). Their goal is to deliver seamless user experiences tailored to the needs of their marine and industrial customers. Staying ahead in development is essential to challenge the market and anticipate future user demands. They aim to redefine the future of marine display solutions, designing systems that provide skippers with essential information, features, and functions for safe and enjoyable navigation. At the same time, they want to enhance the overall boating experience.

Since 1907, Volvo Penta has been a key player in the boating industry, consistently delivering innovative solutions for boat engines and equipment. Over the years, the company has patented several groundbreaking innovations, such as the three-blade folding propeller introduced in 1996 (AB Volvo Penta, 2025a). A major milestone in the digitalization of the boating industry came in 2013 with the launch of the Glass Cockpit system.

3.2 Marine Products

The following chapter introduces the important concepts and systems that define modern yachts, including propulsion, control, and display technologies. This information is essential for understanding how modern marine leisure vessels are designed and operated.

Yachts

There is no universal definition of what constitutes a 'yacht.' According to D'Ambrosio (2023), a yacht is defined as a recreational vessel either sail- or motor-powered, that includes at least one cabin, allowing the crew to sleep on board. While there is no strict minimum length, yachts are generally considered to be vessels longer than 33 feet (approximately 10 meters). They can be either single- or multi-hulled and may utilize various propulsion systems, including sail, motor, or a combination of both. Larger yachts are commonly classified as superyachts (over 25 meters), mega yachts (over 50 meters), and giga yachts (exceeding 100 meters).

Engine and Propulsion System

The driveline includes all the components on a boat that work together to propel it forward (Sweboat, n.d.). In a motorboat, the driveline connects the engine to the propeller. Inboard Performance System (IPS) is a propulsion system developed by Volvo Penta, featuring twin counter-rotating propellers that face forward instead of the traditional backward orientation (AB Volvo Penta, 2025b). This design allows the propellers to operate in undisturbed water, ensuring that all thrust is directed parallel to the hull for maximum efficiency.

Electronic Vessel Control

Electronic Vessel Control (EVC) is Volvo Penta's marine control system and serves as the brain of the boat, overseeing and coordinating the interaction between engines, transmissions, and controls (AB Volvo Penta, 2025c). The Control system configuration is defined by the type of engine, installation, number of drivelines, and segment (AB Volvo Penta, 2025d). The type of engine can for instance be D4, D6, D8, D13, V6, or GAS, with power outputs ranging from 13 to 1,000 horsepower. The installation type can be IPS, Inboard, or Aquamatic Sterndrive (AQ). Inboard and AQ may either be with mechanical or electrical steering. The number of drivelines can range from a single, to twin, triple or quad. Finally, the segment can be divided into Marine Leisure (ML) or Marine Commercial (MC). The engine type and the number of engines must match the chosen control system, while the segment is independent of the engine.

The standard package for EVC includes throttle control, start/stop panel, steering wheel, a display, and a basic set of features, including Low Speed, Cruise Control, Power Trim etc. (Internal documentation Volvo Penta, January 30, 2025). The displays can range from 2.5" monochrome, for each driveline (engine and gear), up to a 27" Glass Cockpit.

Multi-Functional Display

The Multi-Functional Displays (MFD) combines a chartplotter with various additional features, including radar, echosounder, AIS, instrument data, autopilot control, entertainment, and more. It often serves as the central hub for a boat's marine electronic systems (B&G, 2024). Volvo Penta's MFDs available in various sizes and resolutions, ranging from the B-series with a 7" HD-resolution, to the 9000-series with a 27" 4K resolution (AB Volvo Penta, 2025e). The layout of the displays can be customized, allowing the boat owner to choose how and what information is displayed, for instance, whether it is for docking at a marina or fishing.

Glass Cockpit

The Glass Cockpit (GC) is an example of a multi-functional display. GC is an all-integrated control and monitoring system that provides essential information for the skipper (AB Volvo Penta, 2025e). It displays data from the engine, driveline, and onboard electronics, alongside navigation data. Fully customizable, the system allows users to tailor layouts to their specific needs, whether that is specific instruments for fishing, water sports, or simply navigating the sea. Developed in collaboration with Garmin, the Glass Cockpit combines navigational features with Volvo Penta's EVC system. GC displays information from EVC as well as certain settings, such as language, units, and calibrations (Internal documentation Volvo Penta, February 5, 2025). In turn, EVC receives activation and deactivations of functions from GC, as well as top mount as joystick. The Glass Cockpit requires Volvo Penta's EVC system, either EVC-E4 or EVC2.0, to work (Internal documentation Volvo Penta, January 30, 2025). An overview of the Glass Cockpit system can be seen in Figures 4 to 7.

Figure 4. Glass Cockpit in a boat. Used with permission AB Volvo Penta.[2]

---

[2] AB Volvo Penta. (2021). *Volvo Penta extends its Glass Cockpit offering*. Retrieved January 22, 2025 from https://www.volvopenta.com/about-us/news-page/2021/may/volvo-penta-extends-its-glass-cockpit-offering/

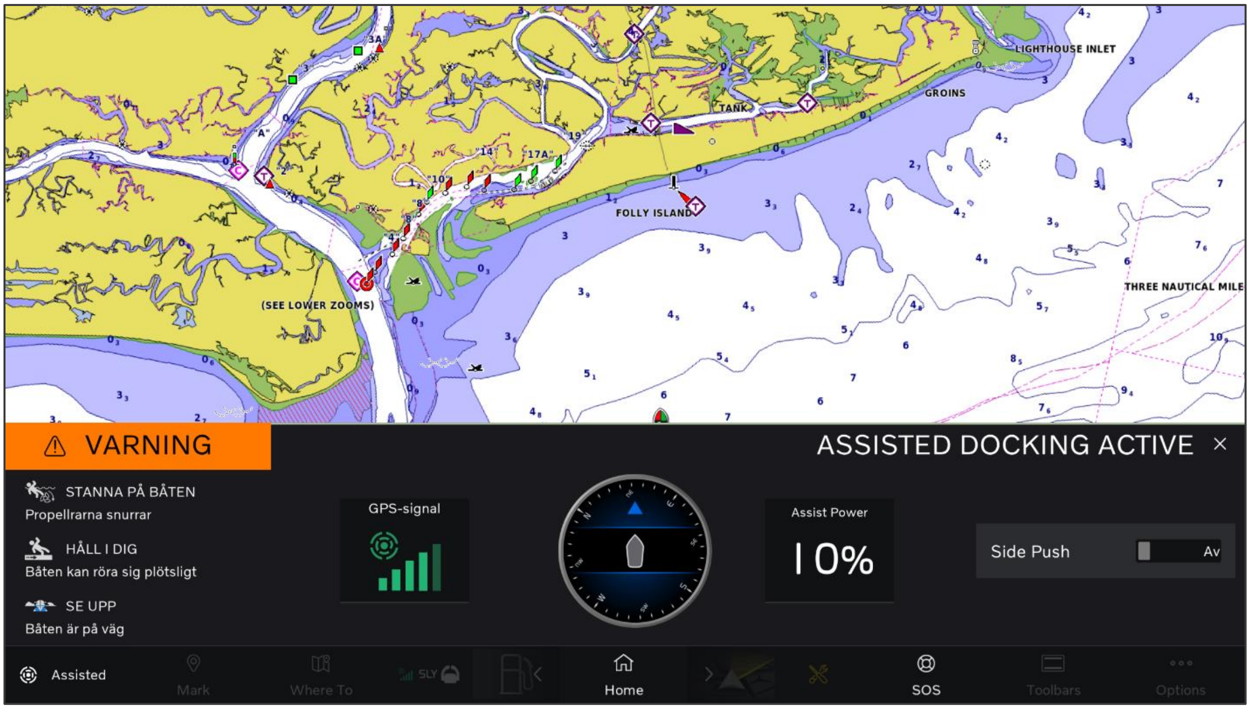
Figure 5. The interface for Glass Cockpit, displaying the nautical chart and engine data for a twin installation.[3]

Figure 6. The interface for Glass Cockpit, displaying the Autopilot.[4]

---

[3] AB Volvo Penta. (2025). [Internal documentation]. Figma.

[4] AB Volvo Penta. (2025). [Internal documentation]. Figma.



VARNING

ASSISTED DOCKING ACTIVE

STANNA PÅ BÅTEN
Propellrarna snurrar

HÅLL I DIG
Båten kan röra sig plötsligt

SE UPP
Båten är på väg

GPS-signal

Assist Power 10%

Side Push Av

Figure 7. The interface for Glass Cockpit, displaying the Assisted Docking banner.[5]

3.3 EVC Features

Depending on the EVC installation, various ‘accessories’, or functions, can be added, see Figure 8 (AB Volvo Penta, 2025f). These include joystick control, throttle control, interceptor system, steering wheel, sailboat control, boat trim system, etc. This enables the system to be customized according to the user’s boat and preferences. These accessories include different types of features, such as assistive docking, which aims to simplify the boating experience. Together with the Glass Cockpit, these functions can be easily accessed and maneuvered. The following is an explanation of three functions that are relevant for this project and are available in Volvo Penta's EVC system: Joystick Control, Assisted Docking, and Autopilot.

---

[5] AB Volvo Penta. (2025). [Internal documentation]. Figma.

Figure 8. A selection of 'accessories' available for the EVC. Used and modified with permission AB Volvo Penta.[6]

Joystick Control

Joystick Control is a steering system developed by Volvo Penta that integrates with the propulsion system to provide responsive, one-handed control (AB Volvo Penta, 2025g). The joystick, see Figure 9, can be described as the link between the skipper and the vessel and can be installed on the helm as well as outdoors. The system allows for adjustments of bow thruster, engine thrust, and steering, reducing the need for complex throttle and wheel movements. The joystick is available for Volvo Penta IPS, Sterndrive, and Inboard Shaft systems and supports twin, triple, and quad installations.

---

[6] AB Volvo Penta. (2025f). *Marine accessories*. Retrieved January 22, 2025, from https://www.volvopenta.com/en-us/marine/accessories/

Figure 9. A skipper interacting with the joystick. Used with permission Volvo Group.[7]

Assisted Docking (AD)

Assisted Docking is Volvo Penta's boat docking system, designed to simplify maneuvering in challenging conditions (AB Volvo Penta, 2025h). It is designed to enhance control by integrating automation with manual operation. Side Push is a feature that comes with Assisted Docking and enables the boat to be moved sideways. The system requires the skipper to always be at the helm and control the vessel using the joystick but helps the user to stay the course by compensating for external forces such as wind and strong currents. Assisted Docking is useful for docking in tight spaces or navigating stressful situations, see Figure 10 for such a scenario. To fully utilize the system, the vessel must be equipped with certain Volvo Penta IPS or DPI drives, Joystick Control, Glass Cockpit, and DPS.

---

[7] Volvo Group. (2024). *Volvo Penta Repowering D6 IPS650 Media Pack* [photograph]. Retrieved January 25, 2025, from https://media.volvogroup.com/dam/contentitems/136829b7e07f4636b502b18500ee40f6

Figure 10. A boat docking at a marina, using Assisted Docking. Used with permission Volvo Group.[8]

Autopilot (AP)

The Autopilot is fully integrated with the Glass Cockpit displays and automatically enters standby mode when the ignition is turned on (Internal documentation Volvo Penta, January 30, 2025). With Shadow Drive, the Autopilot remains engaged, assisting the skipper in maintaining their desired course. To change direction, the skipper simply uses the steering wheel to adjust the heading, and once the boat resumes a straight course, the Autopilot seamlessly takes over again. Joystick Steering and Joystick Driving are software accessories that allow the Autopilot to receive heading inputs, while Auto Guidance enhances navigation by analyzing relevant charts to generate a visual route for the skipper to follow.

3.4 MFD Terminology

Multi-functional displays use various terms that may be challenging for new users to understand. Below is a brief explanation of key terms commonly found in MFDs. The terms are presented in alphabetical order and not ranked by their importance.

---

[8] Volvo Group. (2024). *Beneteau's Prestige 460, equipped with Volvo Penta Assisted Docking* [photograph]. Retrieved February 5, 2025, from https://media.volvogroup.com/dam/contentitems/ab28083bad144617a32eb1320114afb1

AIS (Automatic Identification System) is a vessel tracking technology that enables boats to send and receive information from other vessels and base stations (B&G, 2024). The system provides data such as name, call sign, vessel type, and position.

Boat Speed refers to the speed at which a vessel moves through the water along its current course. Boat speed is typically measured in knots (kt), where one knot equals one nautical mile per hour (Svensk Båtutbildning AB, 2025). Boat speed is often referred to as SOG (*Speed Over Ground*) and STW (*Speed Through Water*) (Simrad, 2024). SOG indicates the boat's actual speed relative to the Earth, using satellite navigation. STW measures the boat's speed relative to the water, typically using a transducer, often called log. The difference between SOG and STW occurs due to factors such as tidal currents, waves, and winds. If the current helps or hinders, SOG will differ from STW, affecting fuel flow and arrival time.

Chartplotter is a device used in ship navigation which shows the boat's real time position on a chart by integration digital charts with GPS positioning data (B&G, 2024). Many chartplotters today are also an MFD. *GPS*, Global Positioning System (U.S.), is a satellite-based navigation system that provides position in longitude, latitude and altitude (National Geographic Education, n.d.).

The *course* is a planned route to a destination, mark or waypoint (B&G, 2024). A *mark* is a designated point in a sailing race that boats must navigate around, often represented by an inflatable buoy. *Waypoints* are precise locations on the Earth's surface, defined by latitude and longitude coordinates. In sailing, they are commonly used to plan routes to a destination or to locate a specific point or mark.

Course over ground (COG) is the actual direction the boat travels in over the Earth's surface, considering external factors such as wind and currents (Unmanned Systems Technology, n.d.). *Heading*, on the other hand, shows the direction the boat's bow is pointing. If there is a difference between COG and heading, it means the boat is drifting off course due to such external factors. *Track* refers to the recorded journey of the vessel over time, displaying the sequence of positions that trace its historical route.

Echo sounders, or *sonar*, use sound waves to determine objects beneath the water's surface and convert echoes from these waves into images of fish, structures, and bottom depth (Garmin, n.d.-a). These sound waves have high power but a short duration, which limits the amount of energy transferred to the water.

Nautical mile is a unit of length used internationally in maritime and aviation context and is equivalent to 1 852 meters (Svensk Båtutbildning AB, 2025). The measurement corresponds to one minute of latitude, which is one-sixtieth of a degree along Earth's meridian.

Radar (Radio Detection and Ranging) is a system used for navigation and surveillance. Radar emits invisible radio waves that travel at the speed of light towards objects (Garmin, n.d.-b). When the waves hit an object, part of the energy reflects back to the radar, where it is received and amplified. The distance to the object is determined by measuring the time it takes for the signal to return. Signal processing also provides information about the object's size, shape, position, and movement.

To conclude, this chapter highlights important boat systems and products that shaped the project, including the Electronic Vessel Control (EVC) and Glass Cockpit, as well as marine terminology relevant for the thesis. This section aims to support a clearer understanding for continued reading of the report as the maritime domain includes many complex concepts and terms that may be challenging to grasp for readers without prior experience. Additionally, this information has been essential in developing an understanding of how boats and their systems operate, as these elements form a significant part of the interface addressed in the project. Finally, a clear understanding of these terms enables the project team to design products that effectively align with the context and user needs.

4. THEORETICAL FRAMEWORKS

This chapter presents relevant theory for the project's scope, focusing on academic theoretical frameworks.

4.1 Wickens' Model and its Application in the Marine Context

As this project revolves around the design of a new interface, it is of high relevance to consider important factors that affect the design and how it is perceived. One of the most important factors is cognitive ergonomics, which acts as a basis for understanding how the human capabilities function in relation to a (technical) system. Novakazi (2023) opine that the human information process is complex and includes several steps. Starting at the stage of perception which includes detecting, receiving information and perceiving, continuing to the actual processing stage, which includes activities such as interpreting, remembering, recalling, reasoning, judging, and deciding. At last is the action stage, which focuses on transferring information and performing actions. Even though this can seem like a linear process, it is affected by several other factors, making it complex and difficult to navigate through. To simplify this, Wickens' model (1992) for human information processing will be used, see Figure 11.

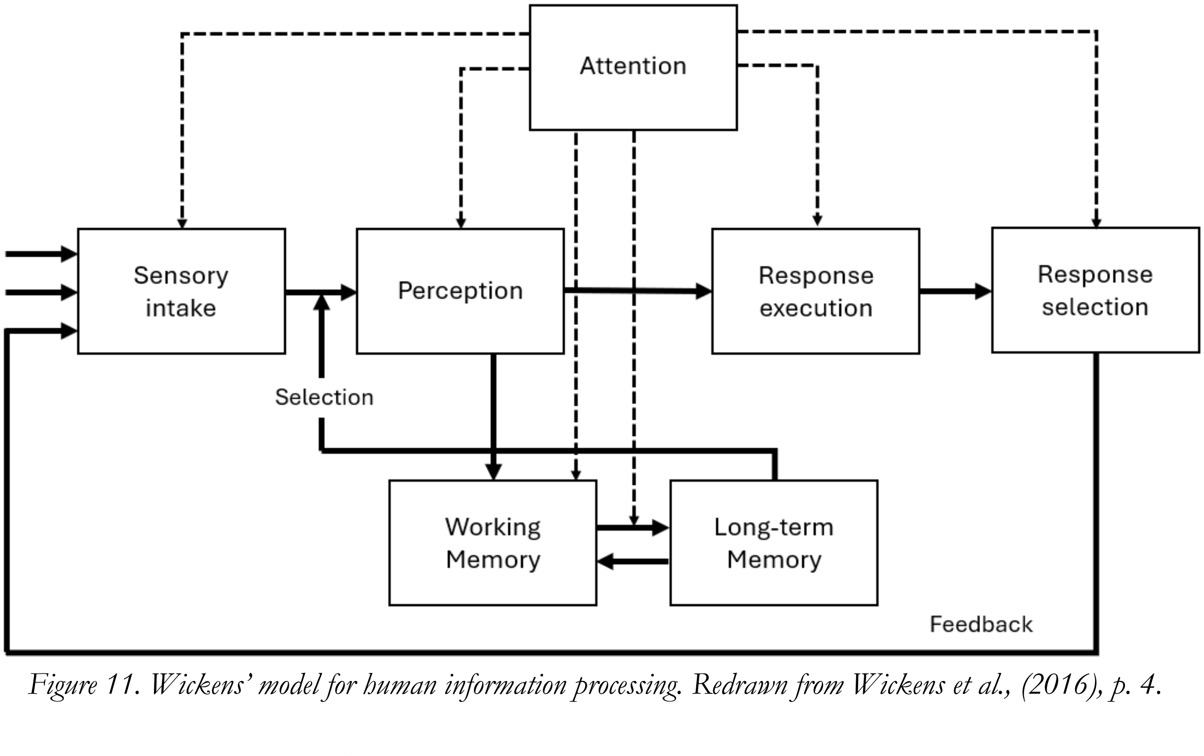


Figure 11. Wickens' model for human information processing. Redrawn from Wickens et al., (2016), p. 4.

Novazaki argues that Wickens' model is a simplification that does not fully capture the complexity of reality. However, it effectively represents the process in a way that is easy to understand from an engineering perspective. In brief, the model describes how humans are constantly exposed to various stimuli that reach our sensory organs. These stimuli can be visual, auditory, haptic, olfactory, or of other types. The incoming information is first sorted through attention in the sensory information buffer before being transferred to working memory, which is limited to what the human can consciously retain at any given moment.

From working memory, information can be transferred into the long-term memory, where it can be stored and retrieved later. The information available in the memory can be used to make decisions, often leading to actions within the system one is engaged with. These actions generate feedback, which is perceived as new stimuli, thus continuing the loop.

In the context of navigating a boat, this model captures several important factors that affect the user's ability to perform the desired tasks. The authors of this report mean that all the stages presented in Wickens' model are equally important to consider when designing an interface for this specific context, meaning that they will all be important to investigate with the user in mind. Having this model as a basis will facilitate understanding the user and their needs, consequently building a better foundation for an upcoming design process.

Sensory Intake

The first stage of Wickens' model is sensory intake, where the sensory organs connect the brain to the external world (Novazaki, 2023). Sensory receptors continuously detect stimuli in various forms, including mechanical, thermal, chemical, and electromagnetic energy. This information is then transmitted to the brain and temporarily stored in the sensory buffer before further processing.

Novazaki states that humans possess approximately 9 to 21 senses for processing stimuli. The most significant and commonly recognized senses include vision (sight), audition (hearing), haptics (touch), olfaction (smell), gustation (taste), kinesthetic (balance), and proprioception (nerve senses). New stimuli often replace older ones, as sensory capacity is limited. Stronger stimuli occupy more space, and different types of stimuli persist for varying durations. For example, visual stimuli last between 0.25 and 2 seconds, auditory stimuli 1 to 5 seconds, and haptic stimuli approximately 0.8 seconds.

Despite the variety of sensory receptors, the visual intake accounts for 80% of all sensory information. Humans rely on visual data more than any other type, with their eyes constantly seeking patterns and structures. Several factors influence visual perception, including contrast, color, depth perception, and movement. Auditory receptors complement vision, allowing humans to detect stimuli from multiple directions. Sound is one of the most effective ways to capture attention. Moreover, haptics also complements other senses and can be used when other senses are occupied.

Applied to the marine context, it becomes evident that navigators on a boat are constantly exposed to a vast amount of stimuli, often of varying nature. They receive sensory input from a distance through their eyes, ears, and nose, for example, noticing movement on a display, hearing a beeping signal, or detecting a particular scent. Additionally, they perceive information both internally and externally through their bodies. Given that a boat is in continuous motion due to the shifting ocean, the balance and muscular senses remain highly active, constantly processing stimuli. External stimuli can include tactile sensations, such as the pressure on a fingertip when pressing a button.

Perception

In the second stage, perception, stimuli are organized and given meaning through a process that is more or less conscious (Novazaki, 2023). The way stimuli are perceived can be influenced by both internal factors, such as a person's feelings, motives, and needs, and external factors, including the characteristics of the stimuli, such as size, intensity, and frequency.

Perception can occur through either a top-down or bottom-up process, each relying on different cognitive mechanisms in the brain. The top-down process interprets sensory information using prior experiences and stored knowledge. It relies on pattern recognition, mental models, ideas, and expectations, making it a more cognitively demanding process since it involves the long-term memory. In contrast, bottom-up processing operates without prior knowledge or expectations. It involves a lower level of cognition, as the brain interprets sensory information solely based on environmental cues and the details present in the stimuli. Because of this, Novazaki describes bottom-up processing as a form of "direct perception". The process of perceiving stimuli is often a combination of these two processes.

When looking at a navigator's perception, it becomes clear that their ability to interpret stimuli is influenced by their level of expertise. An experienced navigator relies more on top-down processing, using their extensive experience and prior knowledge to quickly recognize patterns and interpret information at sea. In contrast, a less experienced navigator is more dependent on bottom-up processing, relying on raw sensory input to make sense of their surroundings. At this stage, the design of the interface and system in which the navigator operates plays a crucial role. Well-designed systems can enhance perception by making information more intuitive and easier to process, ultimately improving efficiency and decision-making.

Attention

Attention is described by Novazaki as the process of focusing and directing mental resources. Since humans are constantly exposed to new information and stimuli but have limited cognitive capacity, attention plays a crucial role in managing these resources effectively. Attention can take different forms, primarily selective or divided. Selective attention allows us to consciously ignore certain stimuli in order to fully concentrate on specific aspects of a scene. In contrast, divided attention means that a person pays attention to more than one thing at a time. It is often difficult to do two tasks at the same time if the tasks use the same modality or require the same kind of response or mental process.

Several factors affect what a person directs their attention towards. Experience and expectancy play a crucial role, one tends to see what one expects and wants to see. Constant stimuli tend to be classified as less important than new and different stimuli, which affects where one directs their attention. Staying alert and maintaining attention is covered in the concept of vigilance, which is highly affected by the characteristics of the stimuli, and important to consider in the marine context. It is important to provide the user with a manageable amount of information and use different kinds of stimuli to support and strengthen the message, for instance in hazardous events.

Working Memory

The memory facilitates the process of interpreting and recognizing information (Novazaki, 2023). The working memory processes the information currently in use and has limited capacity, which can be affected by feeling and fear. It is instantly available and can hold about 7 ±2 units of information at the same time. Chunking information can increase the amount of information that can be active in the working memory and giving it meaning can make it easier to remember.

In the marine context, it is important to consider the capacity of the working memory, so that the navigator can process a manageable amount of information simultaneously. Too many stimuli or information can lead to a high mental workload, affecting the navigator's decision-making.

Long-term Memory

Long-term memory has an unlimited capacity and retains information for long periods of time (Novazaki, 2023). Information is stored in interconnected networks, where different pieces are linked to each other, creating meaning and relationships. However, the way individuals store information varies. For information to move from the working memory to long-term memory, a process known as encoding, training and learning are required. Since forming these links is an effortful process that relies on meaningful associations, learning often takes time. The strength of the connections within the network significantly impacts learning success.

There are two types of information that can be stored in the long-term memory, declarative, and non-declarative knowledge. Declarative knowledge is factual knowledge, things that are possible to verbalize, either episodic or semantic. Episodic is the knowledge of events, when and how certain things happened, and semantic knowledge is general facts, such as "Sweden is a country". Non-declarative knowledge is not possible to verbalize. It can be procedural, which includes physical skills such as biking, or it can be perceptual, which explain how a person recognizes objects and words, or how materials feel towards the skin.

When information stored in long-term memory is needed, it can be retrieved through recognition or recall. Recognition occurs when external cues trigger the brain to search for and interpret stored information, this is referred to as "knowledge in the world." In contrast, recall requires the brain to retrieve information without external cues, relying solely on previously learned knowledge, which is known as "knowledge in the head." A general guideline is to design systems that encourage recognition rather than recall, as recognition is a less cognitively demanding process.

Decision Making and Response Execution

Decisions and actions occur at varying levels of consciousness as a reaction to the environment in which a person is placed (Novazaki, 2023). One may act without active awareness, rely on rules, routines, and past experiences, or engage in active thinking and problem-solving. In many cases, our actions involve multiple levels of decision-making simultaneously.

Rasmussen's SRK framework can be used to describe how decisions are made at three levels: skill-based, rule-based, and knowledge-based. The skill-based level involves highly familiar tasks, often performed automatically and by routine, requiring little to no conscious control. At this level, multitasking is often possible. The rule-based level applies to familiar situations where a person has been trained to respond in a specific way. Encoded rules stored in long-term memory guide actions, for example, "if A happens, then do B." This process is relatively fast and leaves some capacity available in working memory. Finally, the knowledge-based level represents unfamiliar situations, requiring active problem-solving to develop new rules. Because this process demands significant cognitive effort, it leaves little to no extra capacity in working memory. At each different level, stimuli us used in different ways. At the skill-based level, signals are common, while signs are more common at the rule-based level. At the knowledge-based level, symbols are used.

Feedback

The field of cognitive ergonomics examines, and aims to minimize, cognitive load on the users, as well as optimizing human-system interactions. Key factors to consider include simplifying complex tasks, providing clear instructions and feedback (Yadav, 2023). Feedback is according to Norman (2013) "information about the results of actions and the current state of the product or service". Norman further explains that feedback helps the user determine what has happened.

Connecting this theory to Wickens' model for human information processing, it can be concluded that feedback can take various forms. Visual feedback includes elements such as symbols, colors, text, and movement, providing users with immediate visual cues. Auditory feedback refers to sounds that convey information, ranging from simple beeps to full spoken messages. Tactile feedback engages the sense of touch through vibrations, resistance, or the sensation of pressing a button, enhancing user interaction and confirmation.

To conclude, examining Wickens' model of human information processing, it becomes clear that while some steps are influenced by external factors, others are solely determined by human cognitive abilities. For instance, a person's memory and ability to perceive information cannot be directly altered by design. However, design can shape stimuli, attention, decision-making, and feedback, all of which in turn influence how memory is utilized, and information is processed.

4.2 Usability & User Experience

This chapter outlines key theoretical foundations in usability, user experience (UX), and user interface (UI) design that guided the project's user-centered approach. By applying established design principles, the goal was to develop a solution that is intuitive, efficient, and closely aligned with user needs and expectations.

Usability

Usability is an important concept to consider when designing user interfaces. According to ISO 9241-11 (2013) Usability is "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use". *Effectiveness* is to which extent the desired goals can be achieved, while *Efficiency* refers to the time and effort users require to accomplish their goals. *Satisfaction* refers to whether the user's experience with the interface was satisfactory or not.

User Experience and User Interface

UX (User Experience) refers to the complete experience a person has when interacting with a product, service, or company (Norman & Nielsen, 1998). Good UX involves seamlessly meeting the user's needs, ensuring ease of use, and creating a pleasurable, elegant experience. UX goes beyond just providing what customers ask for, it involves the integration of various disciplines including engineering, design, and marketing to create a cohesive and satisfying interaction. *UI (User Interface)* focuses specifically on the design elements that users interact with, such as buttons, screens, and layouts. While UI is a crucial part of the overall UX, it is just one piece of the larger experience. A well-designed UI can enhance UX, but if other aspects do not align, for instance content or functionality, the UX may fall short.

Norman's Psychology of Artifacts

When designing a product's interface, it is important to consider both the product's design and the human factor. The psychology of artifacts includes different aspects, defined by Norman (2013), which can be taken into consideration when developing an interface. These include affordances, signifiers, mapping, conceptual Models, knowledge in the world, knowledge in the head, and constraints.

Affordances refer to the relationships between an object's properties and the capabilities of the person interacting with it. They determine what actions are possible, for example a chair affords sitting for a human.

Signifiers are indicators, such as marks, sounds, or visual cues, that communicate where actions should take place. Unlike affordances, which relates to possibilities, signifiers guide users to understand how to interact with something, for instance a 'PUSH' label on a door.

Mapping refers to the relationships between controls and their effects in the world. Good mapping uses spatial or logical correspondence, making it easier for users to understand how to control a system.

Conceptual models are mental models that users form to understand how something works, often built through experience, instruction, or interaction. A good conceptual model helps predict system behavior and explains what to do when things go wrong.

Knowledge in the w*orld* refers to the external information available to a user, such as signs or the physical layout of an object, that supports memory and guides behavior. *Knowledge in the head* however is the internal knowledge a person has, such as habits, rules, and experiences, that helps them operate systems.

Constraints are limitations that restrict the ways an object can be used and aim to prevent errors by guiding or limiting possible actions.

Jordan's Design Principles

According to Jordan (2002) there are ten design principles that contribute to creating usable designs. These include consistency, compatibility, consideration of user resources, feedback, error prevention and recovery, user control, visual clarity, prioritization of functionality and information, appropriate transfer of technology, and explicitness.

Consistency means that similar tasks should be performed in similar ways, allowing users to transfer knowledge from one function to another, thus reducing errors and minimizing learning time.

Compatibility ensures that a product aligns with users' expectations, based on their experiences with other systems and the real world, including cultural norms and stereotypes.

Consideration of user resources involves minimizing both physical and mental effort, utilizing user resources efficiently and appropriately.

Feedback requires that users receive clear, immediate, and informative responses to their actions, helping them understand the effects and outcomes of their inputs.

Error prevention and recovery emphasize designing interfaces that minimize the risk of errors and support users in detecting and recovering from them effortlessly.

User control gives users the sense of mastery over the system, allowing them to start, stop, and reverse actions without feeling trapped or overridden by the system.

Visual clarity ensures that interfaces are visually well-organized, with legible text, intuitive icons, and clear layouts to reduce confusion and improve navigation.

Prioritization of functionality and information means that the most important and frequently used functions and information should be the most visible and accessible, avoiding unnecessary clutter.

Appropriate transfer of technology indicates that new technologies should be adopted only when they offer clear advantages and should be presented in a way that is intuitive and beneficial for users.

Explicitness demands that the system clearly communicates its current state, available actions, and potential consequences, minimizing ambiguity and the need for guesswork.

Given that this project followed a user-centered design approach, it was important to establish a solid foundation in both usability and UX to ensure that the final design aligns with user expectations and project goals. Recognizing the criteria for good usability allowed the project team to evaluate and improve the interface based on measurable factors. Furthermore, the overall level of usability and user experience can directly influence how well-received and widely used the final design becomes. As such, ensuring a high standard in these areas is critical to the success and adoption of the designed solution.

5. METHODS

This chapter presents the different methods and tools used during the project. The chapter follows the same structure as the project's execution, beginning with data collection methods, followed by analysis methods, concept generation methods, and concluding with methods for evaluating the concepts.

5.1 Data Collection

The project's outcome had an extensive focus on data collection, both theoretical and empirical. The following methods have been used to collect data during the project.

Literature reviews

Literature reviews are used to gather background information for a project or to provide an overview of the current state of knowledge (Bligård, 2015). The data can be collected from both electronic and printed sources, including reports and scientific publications.

User Studies – Interviews

Interviews are question-based method used to gather subject data about user's opinions and experiences (Bligård, 2015). They help develop an understanding of how users think and reason, not just what they do. Interviews can be structured, semi-structured, or unstructured. A structured interview involves asking questions that are fully prepared in advance and is a suitable approach for gathering quantitative data. In contrast, an unstructured interview is more open-ended, focusing on a specific topic, and is best suited for collecting qualitative data. A semi-structured interview lies in between, with a pre-planned outline of topics, but where the conversation remains flexible and open. In an interview, questions can either be open-ended or closed (Denscombe, 2018). Open-ended questions encourage broader responses, while closed questions help confirm or clarify specific details. *Probing* involves asking follow-up questions to gain a deeper understanding of initial answers. The use of mediating objects, such as images or visual aids, can improve communication between the interviewer and interviewee by clarifying questions or allowing the interviewee to explain or elaborate more concretely.

User Studies – Observations

In an observation, the researcher observes events of interests (Bligård, 2015). The primary goal of observation is to understand the user experience without influencing their behavior, uncovering what people actually do rather than what they say they do. There are different types of observations (Patel & Davidson, 2019). They can be either structured or unstructured. Structured observations focus on collecting quantitative data regarding specific variables, whereas unstructured observations are more flexible and aim to provide a broader understanding of the problem areas. Observations can take place in either a controlled or natural environment. A controlled environment involves observing the user under specific conditions, such as performing predefined tasks in a test setting. A natural environment means observing the user in their usual surroundings, without influencing or disrupting their behavior. Additionally, the observer's role can vary depending on what type of observation that is being performed. With a participatory role, the observer can actively engage in the activity and take notes during the process. With a non-participatory role, the observer simply observes without interacting.

User Studies – Surveys

Surveys are a type of structured interview where no interviewer is involved (Bligård, 2015). Participants receive a set of written questions to answer on their own, making it an indirect method with no direct interaction. Surveys are typically used to gather data for a large group, reach individuals who are difficult to contact in person, and validate or challenge findings from previous data collection.

Benchmark

Benchmarking is the process of studying and evaluating competitors' products to assess how your own product performs and identify areas of improvement (Guimaraes, 2021). By analyzing the strengths and weaknesses of other products, designers can gain insights into what works, what does not, and how to refine their own design. A benchmark can help identify market gaps and uncover opportunities for innovation.

5.2 Analysis

The data collected was compiled and structured to facilitate analysis. The analysis was conducted in parallel with the user studies to optimize and adapt subsequent studies, as more specific issues arose and required further investigation. The aim of the analysis was to develop a comprehensive understanding of the various types of challenges, and their magnitudes, associated with digital display solutions in boats. The qualitative data was analyzed using KJ-analysis and HTA-analysis.

KJ-analysis

KJ analysis, named after Jiro Kawakita, is a technique used to organize and gain a comprehensive overview of large volumes of data (Bligård, 2015). The process involves writing down the collected data on individual notes with each note representing a single data point. These notes are then grouped based on common themes, where each group is given a heading that summarizes its contents. KJ analysis follows a *bottom-up* strategy, meaning that the analysis starts with detailed observations and gradually progresses toward a broader understanding. The categorization does not need to be predefined and can instead develop organically throughout the analysis.

5.3 Concept Generation

The analyses, along with the needs and requirements list, served as the foundation for the ideation and concept development phases. Ideas were generated using methods such as brainwriting, brainstorming, or sketching. The purpose of the ideation phase was to explore solutions related to the findings from the user studies. Generated ideas were evaluated, refined, and eventually combined into concepts that aligned with the defined requirements.

Brainstorming

Brainstorming is a method used to generate a large range of ideas (Wikberg Nilsson et al., 2015). The method exists in various forms, but its primary goal is to explore new ideas, emphasizing quantity over quality. It is based on the principle that participants' creative potential is enhanced by seeing and hearing the ideas of others. Therefore, it is important not to criticize other participants and to foster an environment of creativity.

Brainwriting

In brainwriting, each participant writes down their ideas within a set time (Wikberg Nilsson et al., 2015). These ideas are then passed to the next person, who builds upon them. The method is designed to tap into the group's collective creativity, ensuring that everyone contributes and helps refine each idea.

5.4 Concept Evaluation

To assess ideas and concepts, user evaluations were conducted through methods such as user tests, interviews, and semantic scales. For the user tests, the project group planned to develop prototypes of the concepts being evaluated. The level of detail varied across the prototypes. Digital prototypes were visualized using tools such as Figma, featuring high fidelity and detailed designs that are ready for implementation. The purpose of the prototypes was to provide users with a visual representation of their dimensions and design, while allowing for demonstration of realistic interaction. This ensured that users could assess the usability and functionality of the concepts, providing valuable feedback on the overall design and user experience.

Semantic Differential Scale

A semantic differential scale is a tool used to evaluate a user's perception of a product, service, or experience (Wikström, 2002). It features a series of opposite word pairs that describe different aspects of a product, with the user asked to indicate where their impression falls on the scale. It is a suitable method for measuring emotional responses and overall user experience. Additionally, it allows for the comparison of different concepts to understand how design choices impact the user's perception of the product.

6. GENERAL DESCRIPTION OF PROCEDURE

The approach to this project combined investigative and exploratory methods. The investigative approach characterized the first half of the project, where there was a strong focus on extensive research, both theoretical and practical, to establish a solid foundation for designing an effective, intuitive and reliable interface. Building on theoretical studies, the project explored how these concepts could be applied in practice through user studies, assessing their relevance and adaptability to the specific context. Given that the project aimed to develop a user-centered solution, and that there was limited existing insight into what boat operators want in their displays, a strong emphasis was placed on user studies. This focus aimed to generate valuable insights for both the project team and Volvo Penta as an organization.

The explorative approach characterized the second half of the project, with the aim to design an interface that prioritizes usability and the user's safety, thereby optimizing the maneuvering. By exploring different possibilities for how an interface should be designed in the future, different aspects were considered, aiming at creating innovative solutions for how to integrate Volvo Penta's EVC system into a multi-functional display. There was a strong focus on creativity while at the same time incorporating old and established concepts and guidelines within the fields of Usability and UX, as the ones presented in chapter 4.2, that can help enhance the user experience.

6.1 Choice of Process

The project's duration was approximately five months. The project followed an iterative process, where several steps were revisited multiple times throughout its duration, with the aim to create a strong focus on user-centered design. A visualization of the process can be viewed in Figure 12, showcasing a model illustrated by the project team.

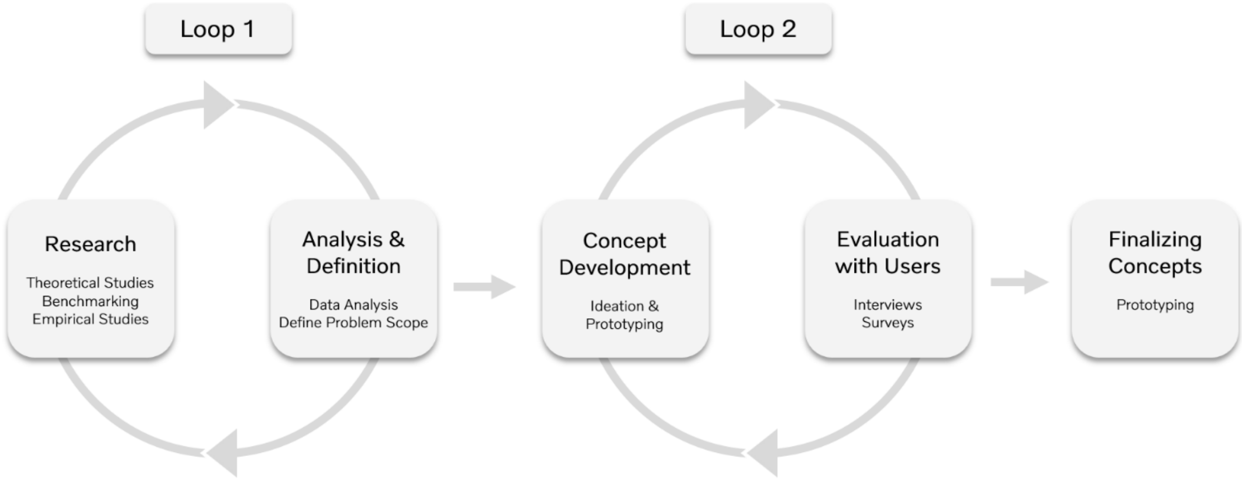


Figure 12. Overview of the process.

This model outlines the iterative phases that shaped the project. Initially, the first loop featured ongoing research and data collection, aiming to define the actual problem scope. As data was analyzed, new gaps and areas for further research emerged, continuing the iterative cycle. A key challenge in this phase was identifying the right users, and determining what aspects are most relevant to explore and ultimately design. However, the iterative approach, integrating research and analysis simultaneously, facilitated deeper insights and a more comprehensive understanding.

The second loop consisted of two steps: concept development and evaluation with users. Incorporating this iterative process ensured that the designs aligned with user needs and reality. By continuously engaging with users and assessing ideas, the likelihood of creating effective designs increased. This approach also strengthened the rationale behind design decisions. The main challenges at this stage were developing innovative solutions to address the operators' problems and finding users to evaluate the design concepts.

Ultimately, the design was finalized, showcasing high fidelity prototypes and concepts of a future marine display solution.

This iterative, three-part process enabled a deeper understanding of the problem area and a continuous improvement of the design. By repeatedly researching, exploring, developing and evaluating, it was ensured that the project stayed updated, and that the solution was relevant. Moreover, it entailed flexibility and adaptation, allowing the team to make improvements along the way, as well as a focus on user-centered design, which led to well-founded design decisions.

Continuing, this chapter presents the different steps that were conducted in the project and how they were implemented.

6.2 Loop 1

The project was initiated by Volvo Penta who provided a project brief, see appendix A, of their interest in exploring the future of marine display solutions. As the project brief was relatively broad, the aim with the first loop was to define a more concrete project scope that benefits both Volvo Penta as an organization and provides meaningful value to the project team. To achieve this, joint discussions were conducted in parallel with the theoretical and empirical studies, which guided the project in a possible direction. An initial project scope was formulated, see result in chapter 7.1. However, the scope was redetermined several times as new interesting areas arose during the theoretical and empirical studies.

Moreover, the aim with the first loop was to gather knowledge about the area, including the current market, how Volvo Penta's products function, and different users and their needs and behaviors.

6.2.1 Research

The research was conducted using three methods: theoretical studies, benchmarking, and empirical studies, including interviews and observations, and surveys.

Theoretical studies

To understand what is essential in developing a digital solution for boating, a thorough understanding of the subject was required. Therefore, theoretical data collection was conducted through literature studies, utilizing database and library searches. Relevant topics included boats, users, challenges and situations that may arise at sea, as well as human information processing. The aim of the literature study was to develop a deeper understanding and knowledge of relevant areas. Additionally, there was an interest in consulting various experts in the boating industry for further research. The results from the literature studies can be viewed in chapters 1, 3 and 4.

Benchmarking

To examine the boats and display solutions currently available on the market, a benchmark analysis was conducted in parallel with the literature studies. The objective was to gain a detailed understanding of competitors' existing systems and identify their strengths and weaknesses. The annual boat fair [*sv. Båtmässan*] in Gothenburg was visited, where different boats and their user interfaces could be examined, resulting in an understanding of the market. The results from the benchmark can be viewed in chapter 8.1.

Empirical Studies – Interviews & Observations

Qualitative data was collected through user studies in the form of interviews and observations of leisure boat operators. The interviews were designed with open-ended questions, with a semi-structure format, enabling the interviews to be shaped according to each respondent's experience and preferences. During the interviews, probing was used to encourage respondents to provide more detailed answers and to minimize potential misunderstandings between the project team and the users. The combination of observations and interviews aimed to generate both implicit and explicit knowledge. Prior to conducting user studies, boat operators were contacted through various online forums, Volvo Penta connections, and relevant boating professions. The target users included active boat operators with any relevant experience - from novices to experts - whether operating professionally or for leisure, and whether using yachts or smaller powerboats. The goal was to capture a broad and nuanced range of respondents.

Two different kinds of interviews were conducted, one context dependent and one context independent. The context dependent was conducted in a boat, either moving or stationary in a harbor, leaving opportunities to observe the respondent interacting with the user interface, while at the same time answering questions, enabling more in-depth reflections and answers. The context independent interviews were held online, without access to a boat and possibilities to interact with the user interface.

For the different interviews and observations, different interview templates were used, see Appendix B and C. For the context dependent observations, the questions were generally more detailed, focusing on specific use scenarios, with the aim to encourage the respondents to actively interact with the interface and guide the interviewees through a defined sequence. In contrast, the questions for the context independent interviews were broader, emphasizing overall user experience and identifying strengths and weaknesses of the interface. Before finalizing the interview templates, a pilot interview was conducted, revealing weaknesses in the interview template that could be improved before the actual interviews began.

As more interviews were conducted, the context-independent interview template was replaced with the context-dependent one. This shift aimed to create a more unified and comprehensive understanding of digital displays in yachts. The context-dependent template, being more detailed, generated deeper and more valuable responses. Even though it was first considered to only be applicable for an interview in the specific context, it turned out to be applicable in an online interview as well.

The distribution of the interview respondents covered a relatively small range of users, see appendix D. Twelve boat operators were interviewed, of which four were test drivers from Volvo Penta, four were Volvo Penta employees with relevant experience of operating their private boats, and four were completely external users. Test drivers are drivers who, on behalf of Volvo Penta, operate various boats to evaluate the company's products such as the EVC system and Glass Cockpit. Out of twelve respondents, only one woman was interviewed, reflecting the male dominance in the area. The age among the respondents varied more, four of the operators were under the age of 30, while the rest of the respondents were older, about 30-60 years old.

Their experience of operating boats varied somewhat more, both in terms of the number of years but also the purpose for which the boat was used. The test drivers had a relatively unique experience, as they operate boats daily all year around, and with clear and definite schedules of what to test each day. The others had different experiences of different kinds of boats, ranging from small day cruisers to big yachts in the Mediterranean Sea. Some respondents used their boats for leisure activities only, while others, one particularly, used them for water sports. The majority had over 15 years of experience and were familiar with a wide range of boats.

Empirical Studies – Surveys

To complement the qualitative data, quantitative data was collected through a brief survey consisting of nine questions, see appendix E. The survey included both multiple-choice and open-ended questions, designed to identify the most important and relevant functions and data for the operator. To avoid discouraging users from participating in the survey, the questions were limited to only gathering the necessary data. As a result, no personal information regarding the participants' age, gender, or experience was collected. However, they were asked to specify the type of boat they had experience with, in order to exclude responses from users who, for example, only sailed and could not relate to the project's thesis.

In total, the survey collected 41 responses, of which 26 were motorboat operators. To assess whether the results differed between Volvo Penta employees and independent users, the survey was split into two. Of the 26 respondents, 17 were external participants recruited through various boating forums, while the remaining 9 were contacts from Volvo Penta's reference group. The result was compared and later analyzed together with the material from the interviews and observations.

6.2.2 Analysis & Definition

The data from the empirical studies were analyzed to identify key insights and outcomes. Survey and interview responses were analyzed using a KJ-analysis. The data was then organized and visualized in graphs to provide an overview of the most common responses, see chapter 8.2 and 8.3. Graphs were used to offer a quick and intuitive understanding of how values were distributed among the respondents. The visual elements made it easy to identify dominant responses. The results informed the problem definition and helped establish the project's direction. Further details are presented below.

Data Analysis

The data from the interviews was analyzed using a modified KJ-analysis. The analysis was divided into two parts due to the different types of questions asked during the interviews. All respondents answered the same three questions, in which they ranked the most important functions, engine data, and other data. These responses were not analyzed using a traditional KJ-analysis, as a separate analysis provided more meaningful numerical insights. Instead, the answers were compiled using color coding and citations to create a comprehensive overview of the most critical functions and data for boat operators, see appendix F.

The remaining interview questions varied between respondents, following a semi-structured format. These responses, consisting of qualitative answers and citations, were analyzed using a traditional KJ-analysis, which helped identify key themes, see appendix F. As a result, sixteen categories were established, covering both general and specific topics. The outcome of the analysis from the interviews and observations can be viewed in chapter 8.3.

The survey results were compiled and analyzed using a modified KJ analysis, similar to the approach used in the interviews. The data was organized into categories: preferred features, engine data, other data, and the information drivers wish to see in a standard view. The outcome of the analysis from the survey can be viewed in chapter 8.2.

Defining Problem Scope

The results from empirical studies and KJ-analysis were discussed in collaboration with supervisors from both Volvo Penta and Chalmers to define the problem scope and agree on a clear path forward.

Given the large volume of data generated by empirical studies, the project had the potential to branch in several directions. As a result, it was crucial to reach a unified decision on the key focus areas for continued work. The result can be seen in chapter 9.1.

6.3 Loop 2

One iteration of the second loop was performed. It started with an initial ideation stage, that later transitioned into a prototyping stage as the ideas gradually developed. The concepts were then evaluated by users, resulting in insights into what could be improved further. Based on this feedback, the concepts were refined and improved, successfully completing one full iteration of the loop. Further description of the phases is presented below.

6.3.1 Concept Development

To explore the solution space, an iterative process of idea generation and prototyping was carried out.

Ideation & Prototyping

An initial ideation phase was conducted, exploring the key topics decided to continue with in the previous stage. Physical models were created using cardboard to visualize the size and dimensions of the screens, providing an overview of how large the components should be to ensure clear readability for the operators. Through brainstorming and brainwriting sessions, a variety of ideas were generated using both traditional sketching (pen and paper) and digital tools such as Figma. Some ideas were developed further, turning them into concepts. The concepts varied in fidelity, level of detail, and scope, ranging from simple sketches to more polished prototypes. The result can be viewed in chapter 9.2.

6.3.2 Evaluation with Users

The design proposals were evaluated using two complementary methods: structured interviews and an online questionnaire.

Interviews

During the interviews, each respondent was presented with the design proposals one at a time, along with an explanation of the underlying ideas. This was followed by a series of structured questions, and in some cases, the use of semantic differential scales to assess perceived usefulness and design appropriateness. The same procedure was repeated for each design. A total of four respondents took part in the interviews, all of whom had previously participated in the initial user study, see appendix G for complete overview of evaluation respondents. The interviews lasted between 40 and 60 minutes and followed a consistent format, based on a predefined template presenting the design proposals one at a time.

Survey

The evaluation survey was distributed to Volvo Penta employees and received 14 anonymous responses. Unlike the in-depth interviews, the survey was more concise and did not address all aspects of the proposals, see appendix H. Instead, it focused on a few designs that could be easily translated into clear and accessible questions. Most items included images of alternative design options, asking participants to select their preferred version and explain their choice. Semantic scales were also used where appropriate.

After data collection, responses from both methods were initially analyzed separately and then compared to identify patterns and insights, with the aim to get an understanding of what to improve further. The results from the evaluation can be viewed under each sub concept in chapter 9.2.

6.4 Finalizing Concepts

The results of the user evaluation were compiled into different categories and analyzed. Quantitative data from the survey and the semantic scales were presented in pie charts and graphs to provide an overview of user preferences. Based on the insights gained, certain design proposals were eliminated, while others were selected for further development and refinement. This process resulted in a final outcome, a high-fidelity prototype. All design proposals were created in Figma and consist of both interactive sequences and static frames. The result can be viewed in chapter 10.

7. PROJECT SCOPE

This chapter presents the project scope that was defined as a result of theoretical studies and discussions with representatives from Volvo Penta. Furthermore, limitations are presented, explaining the boundaries of the project in terms of areas of focus, in order to ensure a realistic and manageable process.

7.1 Project Definition and Scope

Given the background and theoretical data collected, it could be concluded that there was a strong interest for Volvo Penta in exploring the next generation of displays in the marine segment. This new generation should enhance functionality, safety, usability, and operational efficiency while also meeting the demands for aesthetics and modern technology, without designing for a specific supplier brand interface. This makes it relevant to examine what these displays must include to successfully achieve these objectives. With this in mind, the following research questions were formulated.

- What information and functions in marine display solutions are most relevant and essential for users from a usability and safety perspective?
- How should a Human Machine Interface be designed to integrate Volvo Penta's EVC system into a multi-functional display?

These questions served as a guiding framework for the project, shaping its direction. By combining one concise and straightforward question with a more open-ended and broad one, the group was able to balance investigation with exploration. This approach provided a strong foundation for the project while also allowing creativity and flexibility in the design process.

7.2 Limitations

An important part of defining the scope was also determining specific limitations for the project. For starters, the project was limited to one of Volvo Penta's two marine segments, namely Marine Leisure. Within this segment, the scope was further narrowed to a specific type of boat, yachts, ranging from 40 to 65 feet. See Figure 13 for an example of a yacht.

Figure 13. Azimut Atlantis 45 yacht. Used with permission Volvo Group.[9]

Another limitation concerned the type of engine and propulsion system used, as this influences which EVC system can be installed. In this project, the focus was on yachts equipped with D8 to D16 engines, paired with Volvo Penta's IPS propulsion system. Many EVC functions come as standard in these boats and are included in the installation, providing the project team with a wide range of functions to integrate into the interface and evaluate. These functions include:

- Cruise Control
- Single Lever
- Trip Computer
- Low Speed
- Joystick Docking
- Joystick Steering with Autopilot
- Joystick Driving
- Dynamic Positioning System
- Assisted Docking

---

[9] Volvo Group. (2024). *Azimut Atlantis 45* [photograph]. Retrieved February 12, 2025, from https://media.volvogroup.com/dam/contentitems/d52f904c980b4bf69cddb0a301191fb2

- Side Push
- Autopilot
- Thruster Integration

However, not all these functions were included in the design process. The relevant functions, which are presented and described in Chapter 3.2, include Joystick Control, Assisted Docking, and Autopilot.

Another limitation was the number of drivelines the yacht was equipped with. This factor significantly impacts the number of display adaptations required, which risked making the project too extensive given the limited timeline. To streamline development, the project was focused on a twin installation, as it is, according to statistics, the most popular configuration at Volvo Penta and appeals to the largest number of customers (Internal documentation Volvo Penta, February 5, 2025).

Furthermore, since the concept being developed was supposed to be compatible with different types of multi-functional displays, the project was not restricted to a specific display supplier. However, display size was limited. A 22” display was chosen based on guidance from Volvo Penta supervisors, who identified this as a relevant size for this class of yachts (Internal documentation Volvo Penta, February 5, 2025). A smaller display was considered unsuitable for displaying navigation while also supporting overlay functionality, where multiple functions can be displayed simultaneously. Moreover, since yachts are typically larger, more expensive, and more luxurious, they offer more possibilities to incorporate larger screens, compared to smaller boats where space may be limited. However, scalability was important to consider during the design of the interface, as future developments may need to support a range of display sizes within the leisure segment, from 7” to 27”.

The project was further limited to the design of a digital interface and would therefore not take the physical appearance of the display into consideration. However, if the study indicates that certain functions or buttons should not be controlled via a digital display but instead through physical buttons or controls, this would be clearly stated in the recommendations. That said, no specific design proposals for these physical buttons were developed, as they fall outside the project’s scope. Furthermore, technical aspects of displays, such as screen resolution or brightness, will not be considered in the design process, as the project focuses solely on the digital interface rather than the physical characteristics of the display.

While the project team had considerable freedom in designing the interface, it still had to adhere to Volvo Penta’s design language and visual identity, namely their Volvo Experience System (AB Volvo, 2025). This system provides several guidelines on how digital interfaces should and may be designed, incorporating various UX and design principles to create a strong brand experience. It includes, for instance, instructions on which fonts are allowed and how they should be used. It also features a symbol library with rules on how symbols may or may not be designed, see Figure 14.

Figure 14. Guidelines for how symbols are allowed to be designed according to the Volvo Experience System. Used with permission AB Volvo.[10]

The project also had a defined user scope. Since the project team had access to boats for evaluation at Volvo Penta's facility in Krossholmen, where experienced boat operators could provide their insights and preferences, the project was slightly tailored toward expert users. However, it was important to ensure that the interface remains accessible to all users, as some customers may purchase these boats with little prior experience and must still be able to interact with the displays safely and user-friendly. The aim was therefore to conduct interviews with skippers regardless of expertise, the display they used or the boat model they operated, to gain a broad understanding of the usage context.

Finally, economic and production considerations were not factored into the development of the final concept. This approach allowed the project to remain visionary and forward-thinking, without being limited by immediate feasibility, in line with the project aim.

---

[10] AB Volvo. (2025). *Volvo icons*. Retrieved May 13, 2025, from https://www.volvogroup.com/experiencesystem/en/#/brand/615bfcc428c818001105b4e3/61652f5f8ea937001135220e/616678c8f371b400117b6bf1

8. RESULTS FROM EMPIRICAL STUDIES

This chapter presents the results from the empirical studies that were conducted, which included a benchmark, surveys and interviews.

8.1 Benchmark

A benchmark study was conducted to gain deeper insight into the current market offerings. The goal was to develop a more clear understanding of the types of functions, features and data provided by the leading brands, the available sizes and dimensions, whether touch interfaces are exclusively used or if physical buttons are still common, and the overall visual design in the digital space, such as colors, buttons, and sizing. The study also aimed to identify any common design standards followed by most brands. A selection of the brands and products analyzed in the benchmark can be viewed in Table 1.

Table 1. List of different brands and display solutions that were examined in the benchmark.

Simrad	Garmin	B&G	Raymarine
NSX ULTRAWIDE	GPSMAP 9019	Zeus S	AXIOM +
NSO evo3S	GPSMAP 1022	Zeus 3S	AXIOM 2 PRO RVM
NSS evo3S	GPSMAP 8417 MDF	Zeus 3S Glass Helm	AXIOM XL
NSX 3007			ELEMENT S
			Marine Instruments

Most displays are primarily touch-based. If physical buttons are present, they are usually combined with touch functionality. When buttons do exist, they are typically few and small in size, often just a dial or arrow keys for screen navigation, along with an "OK" or "Select" button.

Brands such as Simrad and Raymarine feature backgrounds in their menus with dynamic elements, for instance bubbles or wavy patterns, see Figure 15, which could affect the user's ability to clearly view and interpret the on-screen information. Some text, for example, blends into the background, making it difficult to decipher. Furthermore, in their menus, the different functions are color-coded – blue, red, or green for charts, sonar, and radar – to clearly differentiate between them. This is intended to make it easier to navigate the screen and identify the functions.

Figure 15. Photo of a Simrad display showing the menu of different functions, captured at the Gothenburg boat fair.

It is common for screens to be divided into multiple sections, and many systems allow users to customize their layouts. However, the level of customization varies, some allow full control over both functions and appearance, while others offer predefined grids where users can assign functions. Menus are often located on the right-hand side, and engine data is frequently displayed in a dedicated column. Finally, a top bar typically displays essential information such as time, while a bottom bar is often used for key functions or navigation menus.

Gauges for engine data are a standard feature and are commonly found in both digital formats as well as in analog gauges with needles. Recognizable symbols, such as those for menus, sound, and power, are widely used. Additionally, many interfaces overlay numerical data on background elements, such as nautical charts, to display speed, position or depth.

Most of these displays have a proportion ratio of 16:9, and the same proportion ratio will be used for the display in this project as well. Landscape-oriented screens are more common than portrait ones. When it comes to common screen sizes, those ranging from 9" to 16" are the most typical. For larger screens, 19", 22", and 24" are the most common. As a result, it was decided to limit the screen size in this study to 22”.

The benchmark reveals certain patterns and common features, which will either be followed or deviated from depending on the insights gathered from the interviews. This approach enables a balance between staying consistent with the current market, while also adapting the design to the specific needs and preferences identified in the target group.

8.2 Survey

Two separate surveys, see appendix E, containing the same questions but in different languages, were distributed, one to Volvo Penta employees and another to external users who were reached through various Facebook groups. This division aimed to identify differences between users familiar with Volvo Penta and the EVC system and those with no connection to the company or its products.

The results from the first segment, consisting of independent users, showed that the most important functions in digital boat displays are nautical chart, engine data, sonar, autopilot, radar, and media, see Figure 16. One respondent stated, "The absolute most important things are the plotter and engine data. I also consider VHF a necessity at sea. The rest is nice to have." Many respondents emphasized that nautical charts and engine data were crucial for safety reasons. As one explained, "Charts are always a requirement. Basic engine data can be critical in case of any issues." Another respondent noted that engine data helps optimize efficiency and simply drive more "economically". Radar was considered particularly important in low-visibility conditions, such as heavy fog or darkness. Functions like bow and stern cameras, as well as a windlass, were seen as semi-important. However, one respondent argued that cameras, media, and others become irrelevant with frequent boat use and introduce additional risks related to operational reliability.

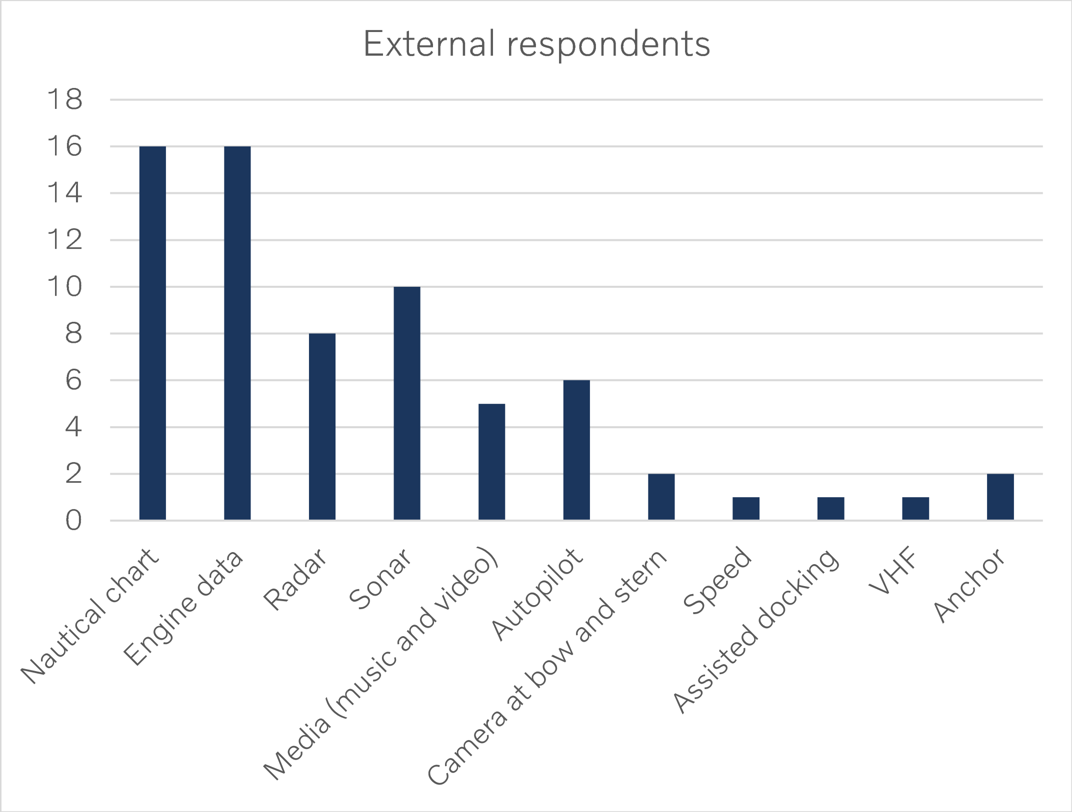


Figure 16. Results from the survey with external respondents regarding the most important functions in a boat display.

Regarding which engine data respondents prioritized, the most frequently mentioned parameters were engine speed, fuel level, engine oil pressure, battery voltage, and coolant temperature, see Figure 17. Engine hours, engine oil temperature, fuel economy, and fuel flow were also highlighted as important. Engine temperature and pressure were considered crucial to monitor because if they are not within their limits, there is a risk of engine failure. Monitoring fuel flow was important not only to avoid running out of fuel but also for economic reasons. As one respondent explained, "Temperature and pressure for the engine's well-being, and fuel economy for the owner's well-being". Another respondent mentioned that exhaust temperature was important to monitor: "It is the very first sign that the engine is about to fail".

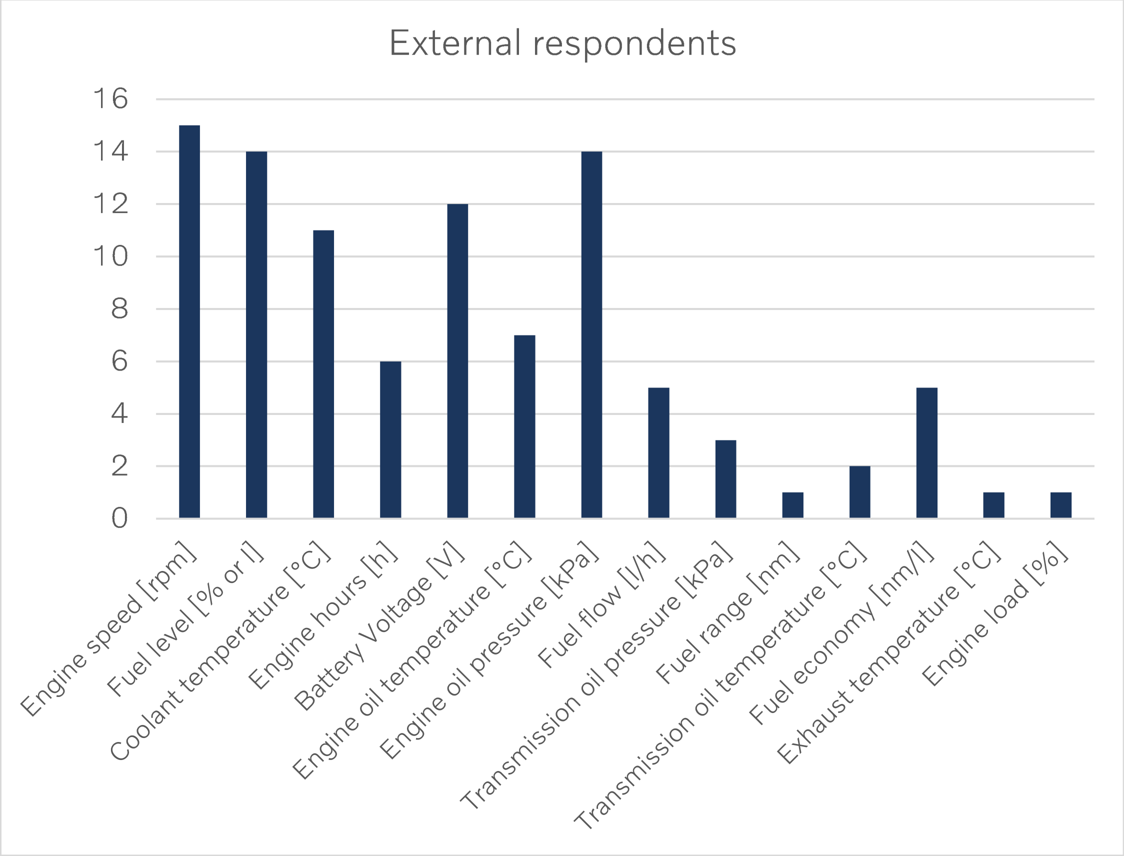


Figure 17. Results from the survey with external respondents regarding the most important engine data in a boat display.

Other data that respondents considered important in a display varied among users, see Figure 18. The most frequently mentioned were boat speed, depth, and position. One respondent only selected boat speed and sea water temperature, explaining that boat speed is important in case of encountering potential speed limits, while sea water temperature is interesting to know when considering going for a swim. Trim level, heading, sea water temperature*, and rudder angle were also highlighted as

---

* Referring to the ocean's temperature, not to be confused with the sea water temperature used in the engine cooling system.

important. Another explained that position and speed were important to see in order to determine where you are and how far you have come. Trim level was seen as valuable for understanding how the boat moves through the water. Some data were more or less important in specific operation contexts. For example, two respondents explained that depth and rudder angle are most important when maneuvering in narrow areas "The rudder angle is very helpful when navigating in a harbor to see how the boat responds when reversing or making small adjustments with the controls".

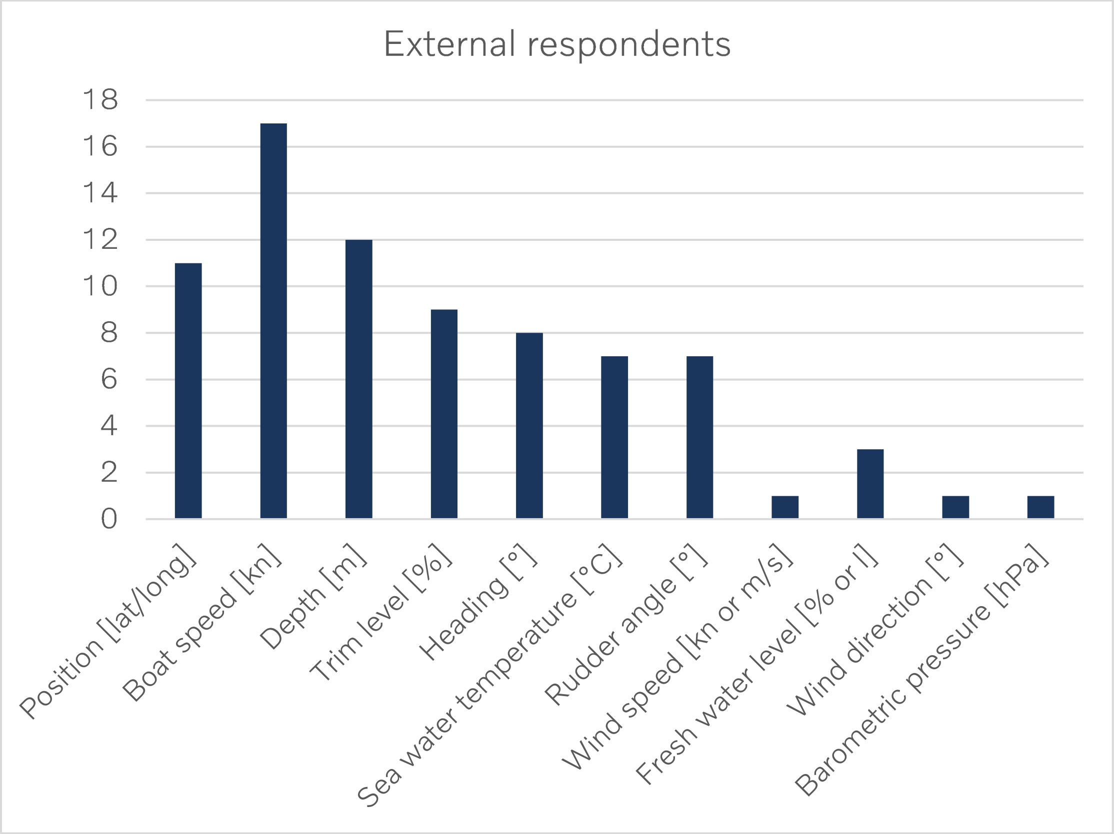


Figure 18. Results from the survey with external respondents regarding the most important other data in a boat display.

When asked which functions or data they primarily wanted to see in a standard view on a boat display, the most common answers were nautical chart, boat speed, depth, and engine data. However, one respondent suggested: "It would be a plus if you could easily switch between two layouts, one for traveling on open water and one for maneuvering in the harbor," due to the different needs for the display depending on the boat's context and the operator's situation.

When surveying Volvo Penta employees, it was found that nautical chart, engine data, and autopilot were the most important functions in a display, see Figure 19. Other commonly mentioned functions included radar, sonar, and Assisted Docking. Many respondents justified their choices by emphasizing that knowing one's location at sea is crucial for safe and efficient navigation. Engine data was also valued for monitoring overall engine health. However, one respondent noted that, similarly to cars, they were not interested in engine data unless a failure or alarm occurred.

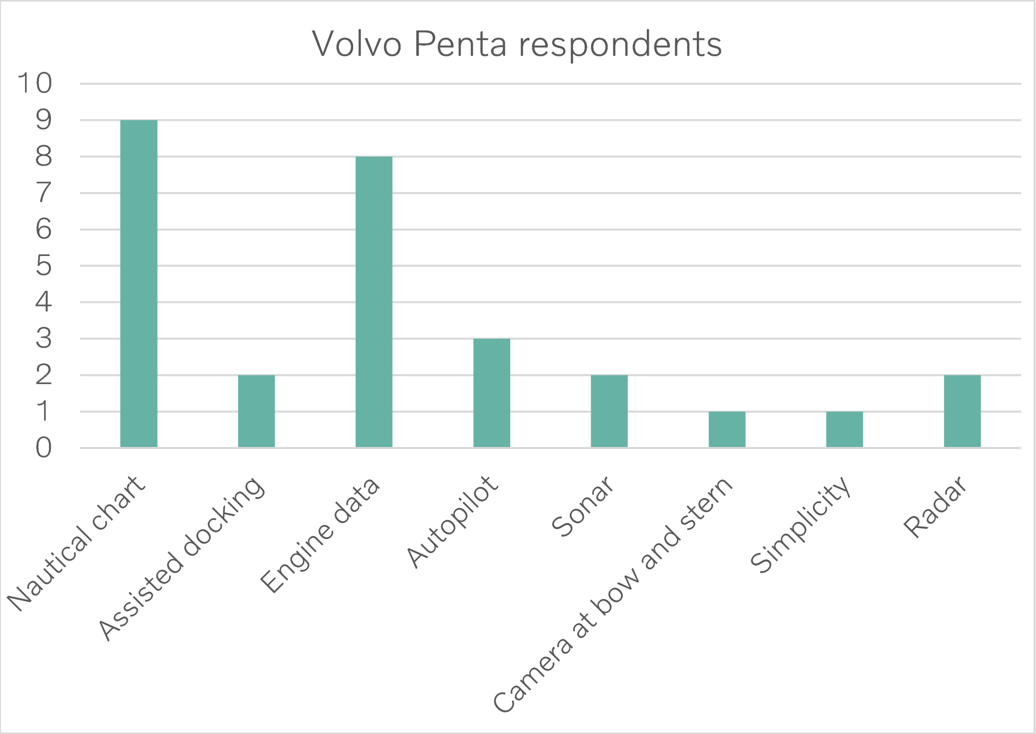


Figure 19. Results from the survey with Volvo Penta respondents regarding the most important functions in a boat display.

Regarding which type of engine data was most important, the most frequently mentioned were fuel level, engine speed, and coolant temperature, see Figure 20. Fuel level was highlighted as crucial to ensure that the boat would reach the destination. Engine speed and coolant temperature, along with other data such as engine oil temperature and engine oil pressure, were important for monitoring the engine and driveline and to ensure everything was functioning correctly. Battery voltage, fuel economy, fuel flow, and fuel range were also mentioned as necessary by some respondents.

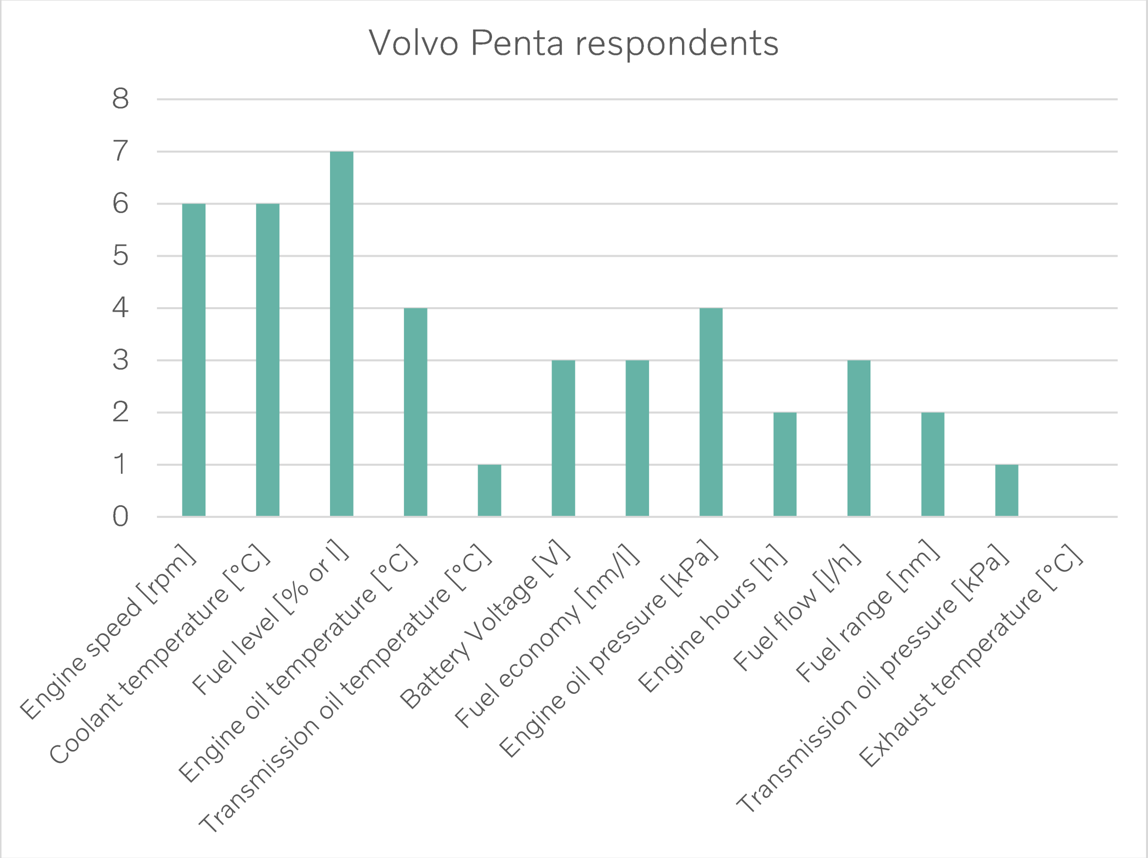


Figure 20. Results from the survey with Volvo Penta respondents regarding the most important engine data in a boat display.

Other data that Volvo Penta respondents considered important included boat speed, depth, position, and heading, see Figure 21. "Speed is important, e.g., for areas with reduced speed limits," one respondent explained. Many stated that this type of data simplifies navigation and is also important for safety reasons. Depth was crucial to avoid running aground, while heading was necessary to ensure the boat stayed on course. Trim level and weather-related data such as wind speed, wind direction, and sea water temperature were also mentioned by some respondents.

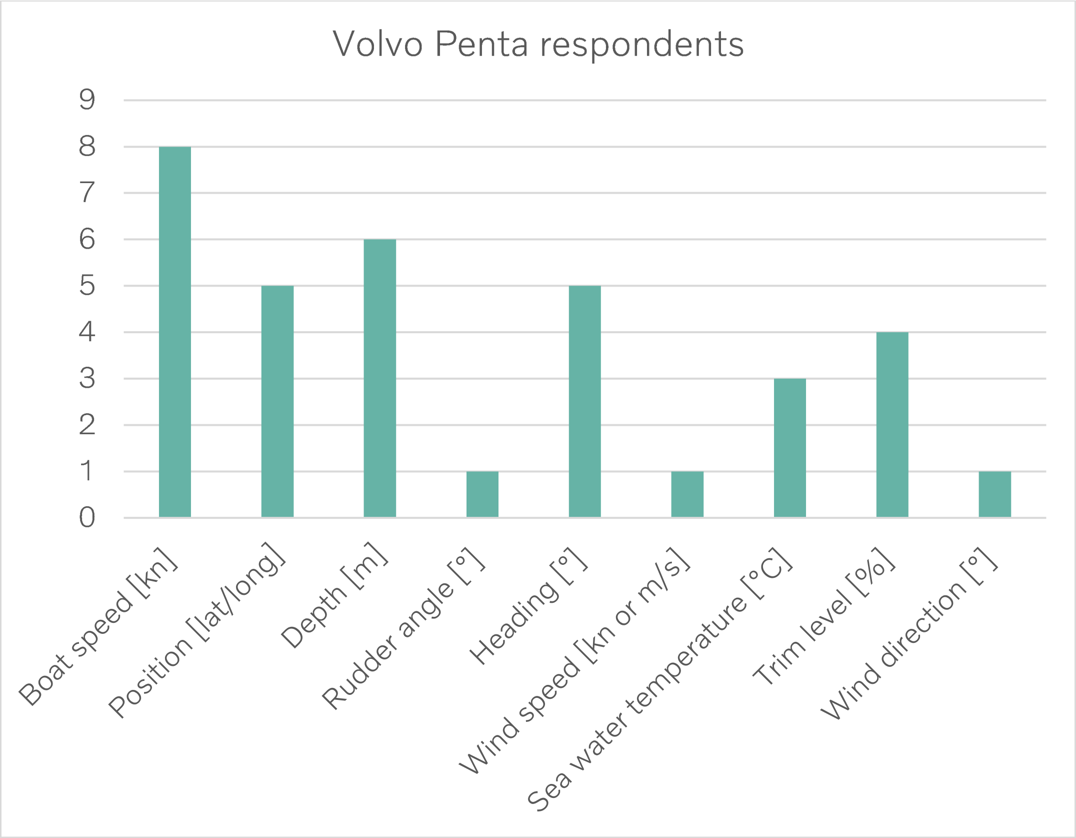


Figure 21. Results from the survey with Volvo Penta respondents regarding the most important other data in a boat display.

Finally, when asked which functions or data they primarily wanted to see in a standard view on a boat display, the most common answers were nautical chart, boat speed, heading, and depth. However, one respondent explained, "It is more important that I can customize the displays as I want" rather than having a predefined standard view.

To summarize, the survey results from both external users and Volvo Penta employees show areas of both alignment and divergence, highlighting the variety of user needs and the importance of flexible, user-centered design solutions.

8.3 Interviews & Observations

Qualitative data was gathered through both context-dependent and context-independent interviews, as well as observations of leisure boat operators with varying backgrounds and experience levels, as presented in chapter 6.2.3.

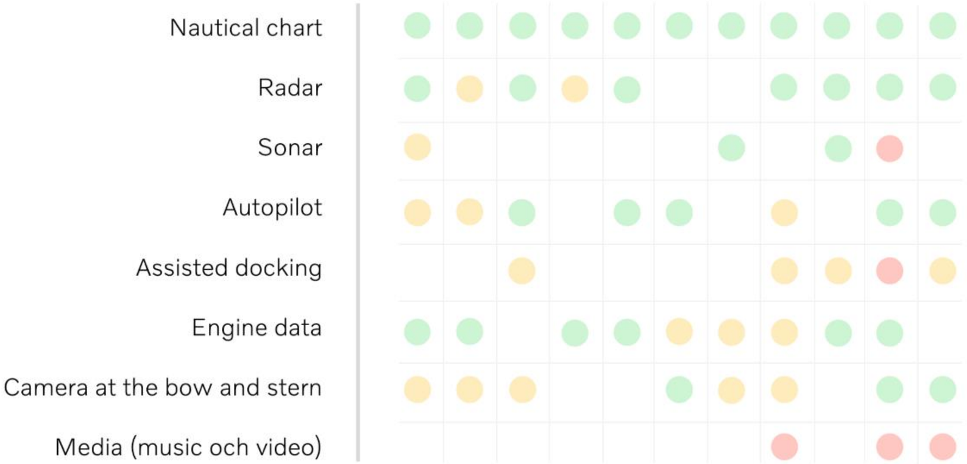
The interview data was compiled in three parts, following the structure of the KJ-analysis. One focused on identifying the most critical functions, engine data, and other essential information for yacht operators during navigation. The second part consisted of various quotes from respondents, categorized to highlight potential areas of development. The third and final part focused on three different driving scenarios and the types of information, functions and features that drivers want to see and interact with during these. The following sections present the results of the KJ-analysis and the insights derived from it.

8.3.1 Assessment of Functions and Data

The following sections will present critical functions, engine data, and other essential information for yacht operators. The figures illustrate the prioritization of functions and data based on respondent rankings. Each column represents an individual respondent's answers, while each row corresponds to a specific function or data point. The color coding indicates the perceived importance: green signifies a highly important function, yellow represents moderate importance, and red denotes low importance.

Essential Functions for Users

When examining the most important and frequently used functions, it was evident that the nautical chart is the most crucial tool for operators, see Figure 22. Many respondents described it as "a given" and "always the top priority" in boat displays. One respondent said, “Nautical chart is definitely a priority, it’s the whole point of boat navigation, knowing where you’re going”. However, there was room for improvement in the design of the chart, which will be discussed later.



Nautical chart	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Radar	🟩	🟨	🟩	🟨	🟩			🟩	🟩	🟩	🟩
Sonar	🟨						🟩		🟩	🟥	
Autopilot	🟨	🟨	🟩		🟩	🟩		🟨		🟩	🟩
Assisted docking			🟨					🟨	🟨	🟥	🟨
Engine data	🟩	🟩		🟩	🟩	🟨	🟨	🟨	🟩	🟩	
Camera at the bow and stern	🟨	🟨	🟨			🟩	🟨	🟨		🟩	🟩
Media (music och video)								🟥		🟥	🟥

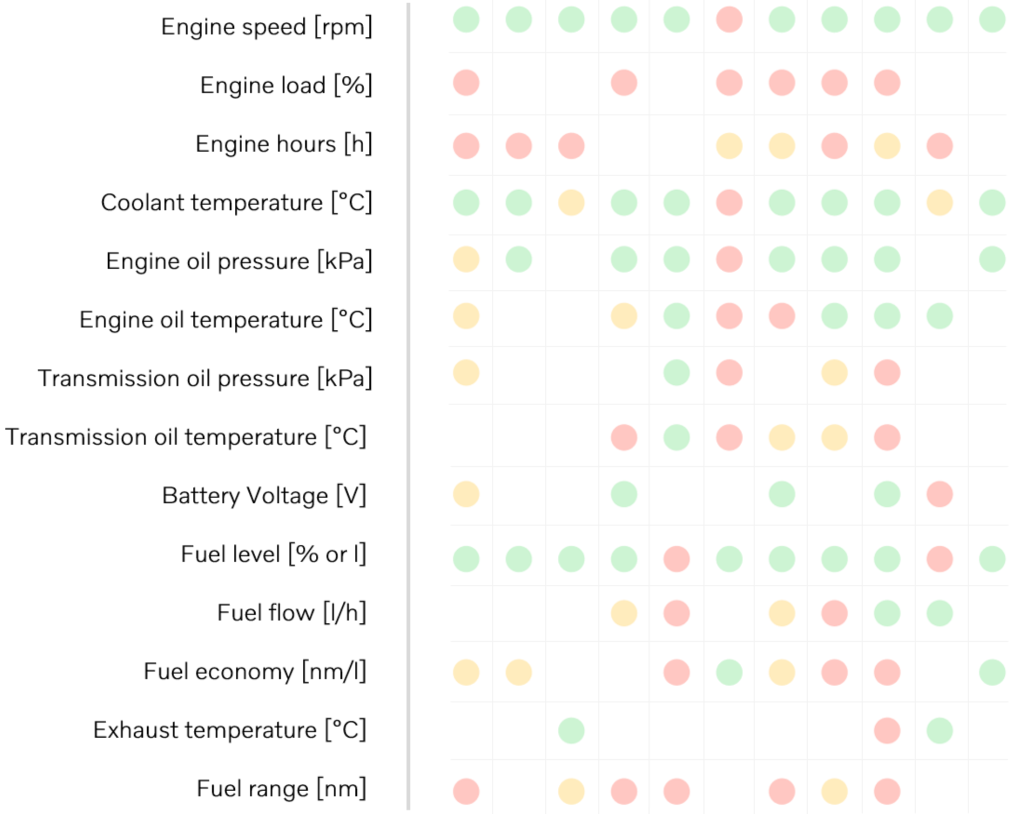
Figure 22. Results from the interviews regarding the most important functions.

Following the nautical chart, radar and engine data were the next most important functions, though their priority varied among users. Some stated that they always kept the radar on, while others only used it in foggy or low-visibility conditions. The necessity of having engine data readily available also varied among operators. However, most agreed that some form of engine data should always be accessible. “I usually have engine data displayed along on side of the edge, where I want to see things such as engine speed and temperatures”, one respondent explained.

Beyond these, the autopilot function ranked next in importance, followed by cameras at the bow and stern, though these were not used by all users nor needed to be displayed at all times. As on respondent described it, “If I am reversing when docking I would like the camera in rear, but that it shows up, like in a car, not that it is visible all the time”.

Key Engine Data

As mentioned, opinions on which engine data was essential varied significantly, see Figure 23. While some considered certain engine data crucial, others found it unnecessary. The two most commonly prioritized engine metrics were engine speed and remaining fuel. Engine speed was widely regarded as a key indicator of engine health and vessel performance. Operators noted that it could be compared with other metrics, such as boat speed and fuel economy, to better understand the yacht’s behavior. Fuel level was also a critical metric to monitor, ensuring that the vessel did not run out of fuel. However, there was disagreement over the preferred unit of measurement: some preferred percentage [%] for its proportional accuracy across different tank sizes, while others favored liters [l] for its clarity and ease of calculation.



Engine speed [rpm]	🟩	🟩	🟩	🟩	🟩	🟥	🟩	🟩	🟩	🟩	🟩
Engine load [%]	🟥			🟥		🟥	🟥	🟥	🟥		
Engine hours [h]	🟥	🟥	🟥			🟨	🟨	🟥	🟨	🟥	
Coolant temperature [°C]	🟩	🟩	🟨	🟩	🟩	🟥	🟩	🟩	🟩	🟨	🟩
Engine oil pressure [kPa]	🟨	🟩		🟩	🟩	🟥	🟩	🟩	🟩		🟩
Engine oil temperature [°C]	🟨			🟨	🟩	🟥	🟥	🟩	🟩	🟩	
Transmission oil pressure [kPa]	🟨				🟩	🟥		🟨	🟥		
Transmission oil temperature [°C]				🟥	🟩	🟥	🟨	🟨	🟥		
Battery Voltage [V]	🟨			🟩			🟩		🟩	🟥	
Fuel level [% or l]	🟩	🟩	🟩	🟩	🟥	🟩	🟩	🟩	🟩	🟥	🟩
Fuel flow [l/h]				🟨	🟥		🟨	🟥	🟩	🟩	
Fuel economy [nm/l]	🟨	🟨			🟥	🟩	🟨	🟥	🟥		🟩
Exhaust temperature [°C]			🟩						🟥	🟩	
Fuel range [nm]	🟥		🟨	🟥	🟥		🟥	🟨	🟥		

Figure 23. Results from the interviews regarding the most important engine data.

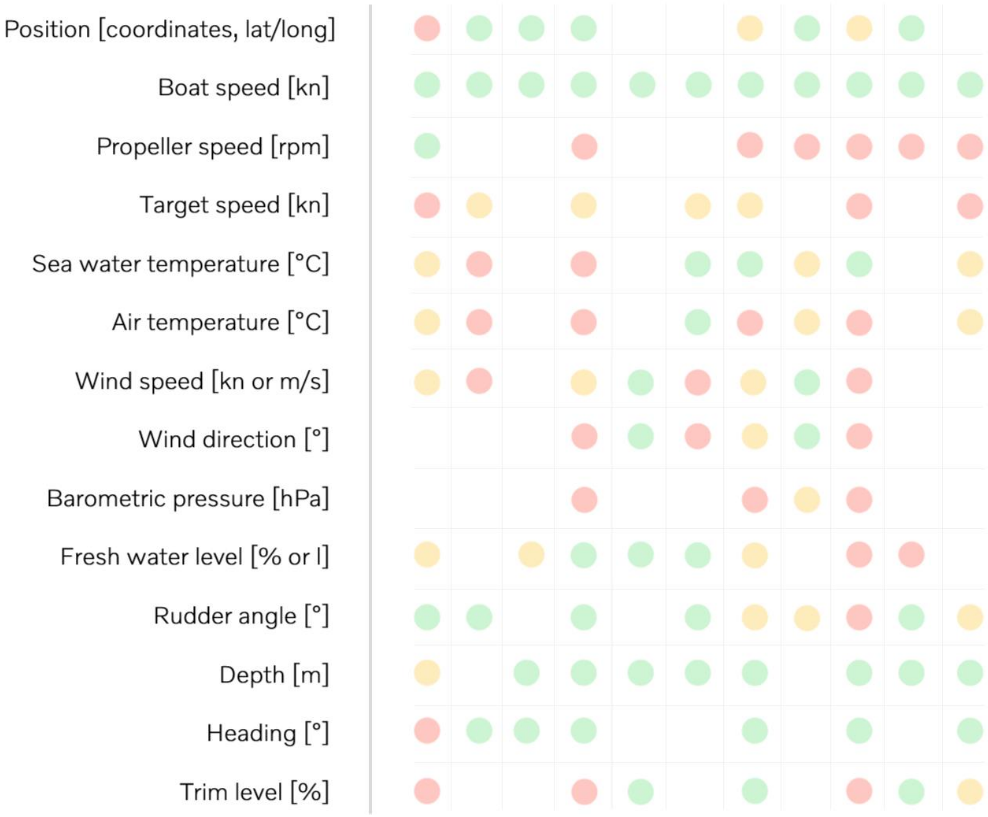
Next in importance was coolant temperature, another key indicator of potential engine issues. One respondent, however, pointed out that exhaust temperature could serve as an even earlier warning of problems with the cooling intake system (typically seawater-cooled). The fact that only one person mentioned this could suggest a general lack of knowledge on the subject, possibly due to not all vessels being equipped with exhaust temperature sensors, or that it is considered an advanced metric beyond what is typically necessary.

Following coolant temperature, the most frequently mentioned data points were engine oil pressure, oil temperature, and battery voltage. Some operators emphasized that improper oil conditions could have catastrophic consequences, making oil monitoring essential. Battery voltage, similar to fuel levels, was crucial to track, as running out of battery power could be highly problematic. However, some users argued that it is unnecessary for this type of data to be displayed at all times since there are alarms for many of them if they approach critical values. As one respondent explained, ”Engine oil pressure is important, but for this, there are often well-functioning alarms, so I don’t need to see it continuously”.

Finally, some data, such as engine load and engine hours, was considered irrelevant by many respondents, as it does not provide any crucial information for the driver during actual driving. However, this type of data may be useful in other situations, such as at the end of the season or when the boat is brought in for service. As stated by one respondent, “Engine hours are not relevant while driving, but are useful for maintenance purposes”. Fuel range was also considered less relevant by some drivers, mainly because it was not always perceived as fully reliable. “I have a hard time trusting the fuel range feature. It's supposed to work so that if I drive at exactly this speed, I'll go a certain distance, but if I encounter headwind, currents, or anything else that affects the boat’s movement, this number will change a lot. So, I never have that displayed on the screen”, one respondent explained.

Additional Data of Interest for Operators

Looking beyond the core functions, other types of data that operators found valuable included boat speed and depth, with speed ranking as the most important, see Figure 24. Regarding boat speed, the majority preferred Speed Over Ground (SOG) as the primary unit, as it provides a more accurate reading than Speed Through Water (STW), which is influenced by factors such as water currents.



Position [coordinates, lat/long]	🔴	🟢	🟢	🟢			🟡	🟢	🟡	🟢	
Boat speed [kn]	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
Propeller speed [rpm]	🟢			🔴			🔴	🔴	🔴	🔴	🔴
Target speed [kn]	🔴	🟡		🟡		🟡	🟡		🔴		🔴
Sea water temperature [°C]	🟡	🔴		🔴		🟢	🟢	🟡	🟢		🟡
Air temperature [°C]	🟡	🔴		🔴		🟢	🔴	🟡	🔴		🟡
Wind speed [kn or m/s]	🟡	🔴		🟡	🟢	🔴	🟡	🟢	🔴		
Wind direction [°]				🔴	🟢	🔴	🟡	🟢	🔴		
Barometric pressure [hPa]				🔴			🔴	🟡	🔴		
Fresh water level [% or l]	🟡		🟡	🟢	🟢	🟢	🟡		🔴	🔴	
Rudder angle [°]	🟢	🟢		🟢		🟢	🟡	🟡	🔴	🟢	🟡
Depth [m]	🟡		🟢	🟢	🟢	🟢	🟢		🟢	🟢	🟢
Heading [°]	🔴	🟢	🟢	🟢			🟢		🟢		🟢
Trim level [%]	🔴			🔴	🟢		🟢		🔴	🟢	🟡

Figure 24. Results from the interviews regarding the most important additional data.

Following speed and depth, key data points included heading, rudder angle, and position. Many operators found it useful to have a heading indicator or some form of compass. One respondent noted that if all systems failed, having a sense of the last known direction could help with continued navigation. Rudder angle was particularly valued during docking maneuvers, as it provided clear information on how the boat would respond when shifting gears. One operator mentioned that it added an extra sense of control. Opinions on position data varied, some preferred to have it displayed at all times, while others were content with easy access when needed. Displaying precise coordinates was considered especially important in emergency situations, such as a man overboard. If the coordinates were readily available, it would be much easier for the operator to relay the exact location to rescue services. Additionally, if someone made a VHF radio call requesting contact at specific coordinates, the operator could quickly determine whether the request was directed at them.

Furthermore, fresh water level was also considered an important metric to have access to while driving, particularly for leisure boaters. Monitoring the water supply allowed operators to plan accordingly, for example, knowing whether there was enough water for showers or how long they could stay at sea before needing to refill the tank.

Finally, weather-related data, such as air pressure, air temperature, wind direction, and wind speed, was given little priority by most. This largely depended on the type of boat they were referring to, as one respondent explained, “For a motorboat, I don’t see the need for wind data”. There was also a varied interest in viewing the water temperature. Those who used the boat more for recreation and water sports showed greater interest, compared to the test drivers who were primarily focused on evaluating the engines and functions of the boat. One respondent stated, “I’d also like to see water temperature easily on the display since we swim a lot, it’s fun to know”.

The responses to these three questions clearly highlight which functions and data are most important to boat operators and will serve as a foundation for several design decisions. Among other things, the results provide a solid basis for enhancing effectiveness, efficiency, and satisfaction, key factors in achieving good usability.

Particularly interesting is the comparison between these responses and those from the surveys, which turned out to be largely consistent. This indicates a high level of reliability in the study, which in turn strengthens the overall credibility of the work.

8.3.2 Key Findings from the KJ-Analysis

The second part of the KJ-analysis highlighted areas that were important in the interaction between the navigator and the displays. Citations were categorized into sixteen different areas, which possessed possibilities for improvements or had qualities that were wished to be kept according to the respondents. The sixteen areas were: physical buttons, alerts, profiles, desired feeling of interface, technical aspects, screen size, menu, gauges, never used, notifications, brand identity, nautical chart, departure, driving, docking, and other, as seen in appendix F.

Physical buttons

Regarding physical buttons and usability of touch screens in marine environments, the respondents had diverse opinions. Many operators found touchscreens problematic when the boat is in motion, especially in rough waters, as it becomes difficult to accurately press buttons, zoom in or out in the nautical chart, and navigate menus. “I don’t like touchscreens at all. As soon as the boat moves, it becomes difficult to, for example, zoom in and out on the screen”, one respondent explained. Some also highlighted ergonomic issues, such as having to stretch forward to interact with the screen, which increases the likelihood of mistakes. One respondent explained, “You want something physical, so you get tactile feedback when interacting with the screen”.

While some users were content with digital buttons, others argued that having physical buttons could improve usability, particularly for critical functions like windshield wipers, navigation lights, and bow thrusters. Several users emphasized that the placement of physical buttons is crucial as well. Buttons positioned too far forward, near the screen, do not provide much benefit. Instead, having physical buttons near the armrest or within easy reach would improve accessibility and control. Some brands already implement this, and users find it helpful, although there are concerns that interacting with a keypad might initially take attention away from the ocean. However, one operator explained that this could be mitigated by potentially developing muscle memory over time.

Another suggestion was to integrate a few physical buttons for only the most relevant and frequently used functions, ensuring they serve a real purpose rather than cluttering the interface. This could, for example, include shortcuts for different views and driving modes or buttons for zooming in on the nautical chart. One respondent stated, "I probably don't need buttons to navigate around the screen with arrows or anything like that, but more for switching views, turning on the stern camera, or activating the autopilot, basically, some shortcuts". Some users mention that external remotes, such as Garmin's grid 20 joystick-based controller, work well by providing tactile feedback without the need to reach for the screen. Furthermore, some buttons on the boats were expected by drivers to be physical. "The horn, for example, should be physical, it would be strange to have it in a touchscreen, just like with the navigation lights", one user stated. "If you want something easily accessible, you'd want a physical button, like for starting the screen, the boat, the windshield wipers, the horn, those basic functions", he continued.

At the same time, a few respondents believed that physical buttons are unnecessary, arguing that touchscreen navigation is often quicker and more intuitive than using a physical keypad. There was also a general agreement that not all functions require physical buttons, essential navigation tools like nautical charts and radar, for example, can remain touchscreen-based. As one respondent explained, "I don't think it's necessary to have buttons to navigate the screen, it's often easier and faster to just tap the screen rather than using a keypad like the Garmin grid".

One user suggested that interacting with touchscreens would be easier if the buttons were larger. However, this could risk covering important information on the screen. The respondent stated, "It would be easier if the buttons on the screen were unrealistically large, but that's difficult because they must not obscure important information like the chart or engine data".

Although there was a strong preference among some users for physical buttons, this project did not address this aspect of the interface in the design process. The existing number and design of physical buttons remained unchanged. The focus was on designing a fully digital interface without physical buttons. This direction followed guidance and decisions from Volvo Penta representatives, who are aiming for a more digitalized user experience. However, the area was included in Chapter 10.7 as a set of recommendations for future boat display design.

Alerts

Operators had mixed opinions of the effectiveness of alerts/warnings on boat displays. While they recognized the importance of receiving critical alerts for safety and system monitoring, they also found that the current implementation could be overwhelming and, at times, intrusive. Many users feel that pop-up messages, while useful for urgent information, often disrupt their navigation experience, especially when they obscure important data like the nautical chart. Some alerts, such as alerts about slight course deviations or obstacles that are no longer relevant, become more of a nuisance than a help. As one respondent explained, “Sometimes it can be annoying when a large, bold alert pops up in the middle of the screen while navigating in a tight spot, especially if it’s not critical, such as low coolant level”.

Another concern was the lack of clarity in error messages. One respondent uttered that when something goes wrong, he often receives cryptic codes without any guidance on what they mean or how serious the issue is. Instead of clear instructions, they are left to troubleshoot by restarting the system or searching for answers online. Some believed that error messages should provide immediate, comprehensible information on the display, eliminating the need for external research.

Despite these concerns, users generally appreciated the alert system when it functioned well. Many wanted alerts for critical issues such as low battery voltage, low oil pressure, high oil temperature, and the presence of water in the propulsion system. Collision alerts, particularly those based on AIS data that predict vessel courses, were seen as extremely valuable, especially in busy waterways like the Gothenburg harbor entrance. As one respondent stated, “If I'm accidentally heading toward shallow water, I would like to receive a warning”. Some users also wanted alerts for potential breakdowns or critical failures before they occur, rather than just when the issue has already developed.

To improve the system, users suggested a more refined approach to alerts. Instead of full-screen pop-ups, they prefer alerts to appear in a corner where they do not obscure essential navigation data. “I want warnings to appear in a corner, so they do not cover anything”, on user explained. Some respondents said that they would like a combination of visual and auditory alerts, to draw attention without being overly disruptive. As one user mentioned, “It is nice if the alerts come with a little beep, even if it is distracting for the ear, or that the screen flashes”.

Some users suggested that alerts should be customizable so that the operator could prioritize the alerts based on their level of severity or relevance. As one respondent explained, “You need to present warnings in relation to how serious they are. You can’t miss warnings, but they shouldn’t ruin the rest of my experience to the point where it makes things more dangerous”. An example of a less critical warning would be alerts such as 'time for service.' A user mentioned that such alerts do not need to appear while driving. However, more critical alerts, such as extremely high engine oil temperature, coolant temperature, or low engine oil pressure, issues that could pose a direct risk, should ideally appear on the screen as soon as they are triggered.

Some aspects of this area were decided to be further explored during the design process. Since alert systems are governed by laws and regulations, certain issues such as prioritization, relevance, and the number of alerts is challenging to address. However, other concerns, such as the lack of clarity in error messages, guidance on how to resolve issues, placement, and overall visual design, were identified as areas with potential for improvement. These opportunities made it relevant to investigate new design solutions further.

Profiles

Another feature that some of the respondents commented on was customization or creating profiles for different drivers. Since different drivers want different things displayed on the digital screens, the composition of the display can vary greatly. If another driver has used the boat and created an interface that suits their preferences, it can take a while to change the screen layout back according to your preferences. The possibility of having different profiles with predetermined and personalized display layouts was presented by two different respondents. They explained that it would increase the usability of the interface since the operator will have their own layout that corresponds to their interests and needs, and thereby make it easier to understand and use. Moreover, it will save time and leave more attention to the sea, consequently increasing the safety on board. “It would be really nice to be able to set up your screens at home and then just plug in your own profile when you get to the boat”, one respondent explained.

This area was further explored in the subsequent design process. It was considered to be a relevant area of improvement that both increases the usability of the interface and thereby the overall user experience, as well as something that is a current topic and a common feature in several different applications, whether that is a smartphone, car, or an e-commerce website.

Desired feeling of the interface

The respondents generally preferred a minimalistic and well-structured interface that balances simplicity with functionality. “More towards a minimalist approach, if anything. I’ve often started up a Garmin and found the preset views overwhelming, there’s so much information that it makes you dizzy. I remove as much as possible”, one user explained. Aesthetics were also important, but not at the cost of usability. One respondent uttered that he wants an interface that is both visually appealing and highly functional and emphasized that these do not need to be contradictory.

Moreover, many highlighted the importance of clarity and ease of use, even in direct sunlight and when there is a risk of water splashing on the screen. Some express a desire for the HMI to feel luxurious and well thought out, while others focus more on ensuring that the interface is intuitive and structured rather than simply reducing the number of interactions required. Overall, based on the responses from the interviews, it can be concluded that the ideal interface should be clean, organized, and adaptable to different user needs, ensuring both efficiency and premium experience.

This area was further addressed to some extent. While achieving a specific desired feeling in the interface was not a primary focus, it remained a consideration throughout the entire design process, from initial sketches to high-fidelity prototyping. Typical hardware demands, like ease of use in direct sunlight and with water splashing on the screen, were not addressed further, as issues regarding hardware were out of the project’s scope.

Technical aspects

The operators expressed some concerns regarding technical aspects that were considered important for the usability of the displays. First and foremost, several operators talked about the importance of a display with high resolution and that it should be readable in strong sunlight. Having a fast zoom function was also important for one operator. One other operator suggested that he would like the possibility to switch views for different sequences of the drive, one for casting off, one for driving and one for docking, each with necessary functions for that specific sequence. The possibility to see previously searched locations, similarly to the function in a car's GPS, was also a desired function. One respondent uttered "Why isn't that available in an easy way? It is those kinds of conveniences that are missing".

Some parts of this area were not explored further, as they fall outside the scope of the project, for instance, the need for high screen resolution and display brightness. For these parts, recommendations were formulated to address the concerns raised by the operators. However, some issues were addressed, such as the opportunity to switch views for different sequences, as it could improve efficiency and satisfaction.

Menu

Several opinions about the menus were brought up during the interviews, both regarding the placement of the menu, as well as its structure. The ideal placement of the menu was a topic with diverse opinions, while some preferred it placed at the bottom of the display, others preferred it to be placed on the right side, creating a possibility to support the hand on the side of the display, consequently increasing the chance to hit the right button. Having it on the right side also makes it convenient to move the right hand between the joystick, speed lever, steering wheel and the display.

Regarding the structure of the current menus, several operators expressed dissatisfaction. They meant that the current menu structure is unclear, with too many dropdowns under each heading, making navigation in the HMI difficult. One operator wanted to have functions that are connected to each other gathered in the same place to improve the usability. Another stated that it would be beneficial with a search function instead and explained, "It can be difficult to know where to look because it is difficult to categorize things, sometimes they [the functions] belong to several categories". Since the current system [Glass Cockpit interface] has a big tree-structure with many sub-menus, respondents explained that it could be challenging to navigate the interface and find what you were looking for. One respondent, who is a boat dealer, explained it further, "The small Volvo Penta display is very difficult to navigate. It's hard to find the menus, and hard to get to what you want to do. It's a confusing system. It's a Garmin screen that they've reprogrammed with their own software. Many people in the industry say the same thing. Whenever you try to do something, it always feels far away and difficult to find what you're looking for, because you're buried five, six, seven steps deep into the menus, which isn't entirely logical".

This area was chosen to address further in the design process, as large and unclear menu structures proved to decrease both efficiency, effectiveness and satisfaction, the three measurements of good usability.

Gauges

Regarding the visualization of information, and more specifically information like engine data, the operators had different opinions about different types of gauges' effectiveness. Right now, gauges can be either analog, digital, or bar-type, each with different advantages and drawbacks. For some operators, numbers are enough to visualize information, as the analog gauges can make it difficult to read an exact value, especially if there are several small ones placed next to each other. For others the analog gauges make it easier to interpret the information as it shows a scale along with the pin. One operator said "With analog gauges, you can have a reasonable scale showing that everything between X and Y is okay. This means I don't need to read the value; I can just quickly see if it's okay or normal", which captures the effectiveness of traditional analog gauges. Another user stated, "I like the old and round gauges, especially when you want to look quickly and get an overview. If you only see numbers, you have no reference". However, several operators agreed that some data is more effectively presented as numbers, for instance speed and depth. As one respondent explained, "For me, just the text '10 m', for example, is enough – get rid of the fluff and make it clear". One operator even preferred digital numbers over analog gauges for displaying other engine data but emphasized the importance of knowing the limit values to interpret the information accurately. "I like the digital numbers; gauges can sometimes be a bit misleading as it can be difficult to tell if the needle is exactly in the middle or not. However, if you don't know the lower and upper limits, numbers can also be difficult to interpret", the operator explained.

Moreover, there were opinions about symbol-heavy interfaces as well. Some operators preferred to have clear text labels instead of symbols to present what kind of data is visualized, as many symbols looked similar to each other, possibly creating confusion, see examples in Figure 25.

Figure 25. Examples of similar symbols for engine related data.

The area of gauges and visualization of data was further explored in the design process. It is a central and crucial part of operating a yacht, meaning that readability and clarity are crucial components to consider. A standard gauge was explored, utilizing the data gathered from the interviews.

Notifications/Feedback

Some functions, when activated, trigger a popup notification informing the driver that the feature is enabled. While some operators appreciated this feedback, others found it distracting. One respondent noted that the popup prevents any further interaction with the screen until it is manually dismissed or disappears on its own after a delay. As explained by one respondent, referring to Glass Cockpit, "When a popup appears, you can't do anything else on the screen until you dismiss it. It does disappear after a while, but you still must actively press 'OK' or close it”. Some operators felt that certain functions, such as Assisted Docking, sometimes take up too much space on the screen. However, since that is the information they are focused on at that moment, it might not be a significant issue.

Additionally, two respondents suggested implementing a summary of the system's current state. One envisioned a post-drive summary of the drive, displaying key metrics such as fuel flow, battery level, and freshwater level. The other proposed a welcome page when starting the engine(s), providing an overview of the system’s status with messages such as ‘Battery OK’, ‘Oil Level OK’, and ‘Fuel Level 70%’. This would offer the operator immediate clarity on the vessel’s condition before setting off. This area was chosen to further explore in the design process, as it opened up possibilities to increase a feeling of control, calmness and consequently satisfaction.

Brand

There was a unanimous response from all respondents that the brand of the display does not matter, it is more a question about the technical qualities they hold, what the boat is equipped with and what you as a user is used to. “For me, the brand of the screen matters less as long as it works well”, one respondent explained. One person stated that you unintentionally become committed to a brand because many things are tied together, for instance if you have a Garmin display, you are more likely to buy a Garmin radar, camera etc., which makes you get used to a brand and therefore stick to it. However, one respondent expressed that brand does in fact matter and that he wants one of the five biggest brands on the market, because their financial assets mean they have money to develop software in a good way, and that he would be skeptical about a new brand if it were to appear.

As this topic revealed a general perception that brand is not important in the interaction with the display, it was decided that the area would not be explored further.

Nautical chart

The nautical chart and its design were topics with many opinions, and several operators wished for new features and functions to improve the usability of the nautical chart and make it even more useful. To start with, the nautical chart was described as the single most critical and most used function in the display, as it provides essential information when navigating and prevents groundings, making its reliability an important factor. However, what information is essential differed from driver to driver, which led to several operators expressing a wish to be able to filter what the chart is showing. While some only want to have depths shallower than three meters displayed, others wanted depths up to six meters displayed. One user explained that this could depend on how deep their boat sits in the water, which is why he wanted the ability to set it himself based on which depths are critical for his boat.

One respondent expressed that there is sometimes too much information in the chart, and for instance in the day, he wants to remove lighthouse characteristics because he can see them by himself. The operator explained, “If there is too much information, it takes away attention from what is absolutely most important”.

Another feature that was brought up by several operators was the zoom function, which can cause frustration if not working smoothly. One operator said that the chart can stop following the boat if they do not hit the zoom buttons and instead touch somewhere else on the chart. The respondent explained, “If you look closely, you can notice this, but sometimes it’s tricky to spot. There’s a small 'Cancel Panning' button, but if you don’t notice it, you can end up completely off course”.

Another common request from operators was an automatic zoom functionality, one that zooms in if you are approaching a shallow area or narrow passage. Many mentioned that they either use two chart views, one zoomed in, and one zoomed out, or manually adjust the zoom. One respondent suggested an automatic zoom function for this, “I would really like an automatic zoom function in the nautical chart, for example, when entering a narrow strait”. Another operator stated that as well, “I’d also like it if, when I'm out driving with the large, zoomed-out view, and I approach something, it could automatically pop up a close-up view that shows what is around me. Then, it could zoom back out once I’m no longer near anything”.

Finally, one respondent uttered the importance of being able to see what is ahead of the boat to be able to plan the driving, which is often negatively affected when other functions are activated and cover parts of the display. It is also affected by the screen size and proportions; a lower but wider proportion will show a shorter distance ahead than a taller but narrow screen.

As the nautical chart is not the responsibility of Volvo Penta, but their cooperation partner Garmin, the design of the chart is out of Volvo Penta’s hands to influence. This area was therefore not further explored. However, design recommendations were formulated based on the operators’ opinions expressed during the interviews, and can be viewed in chapter 10.7.

8.3.3 Operating Sequences

The third part of the user studies was more context-driven and aimed at identifying the features and information operators wanted to see on their boat display during three different driving sequences: departure, navigation toward a destination, and docking. The result of this part was further explored in the design process as it unveiled interesting areas of improvement that were considered to improve the usability and user experience.

Departure

The results from the interviews showed somewhat different responses among the drivers regarding what they wanted to see on their displays during the departure sequence. Many agreed that depth was particularly important to ensure that they did not run aground, as one operator explained, "To know that it's deep enough where I am and where I’m navigating". Another function mentioned by several users was the camera at the stern. One driver stated, "The rear camera is probably the most important camera on the boat from a navigation perspective". One respondent explained that he always checked the fuel level and engine data before leaving the marina, while still moored at the dock. This was to determine if he needed to refuel before heading out and to ensure that the engines were in good condition. One operator even wanted to see a camera in the engine room to ensure that everything was okay and that no leaks or similar issues had occurred.

Assisted Docking was also considered valuable in this sequence, provided it was available on the boat, especially if there were strong winds or waves affecting the boat. One driver explained that Assisted Docking can be useful if you are alone on board or have many tasks to perform during the departure, "Sometimes I use DPS or Assisted Docking, for example, if I have a lot of people on board or if I'm alone and need to stow fenders, ropes, or similar items... It's convenient to be able to activate AD and know the boat will stay stationary". Rudder angle was also mentioned by several as an important feature to monitor. One respondent explained, "The rudder angle is useful for understanding what happens when I shift to forward or reverse, helping to determine the direction the boat will take, especially in windy conditions".

Some operators also mentioned that they checked the nautical chart during this sequence, partly to stay aware of their surroundings but also to plan their route and determine where to go. However, this could vary depending on whether they were navigating in familiar areas or not. As one respondent explained, "The chart is most relevant if it's a place you're not familiar with. If you're going somewhere new, you'll often check the chart to make sure you're on the right course and avoid running aground".

Navigate toward a destination

When it came to the navigation sequence towards a destination, everyone agreed that the nautical chart is the most important and the primary display they wanted to see. In this sequence, some drivers also explained that they used waypoints and routes to determine where they should go. As one respondent explained, "You can get information about the distance and direction to the waypoint on the chart. I usually use that; it helps me with the navigation process". Once again, it was mentioned that both a zoomed-in and zoomed-out view were desired, or that this could be handled automatically as they approached land.

Autopilot was also a commonly mentioned function in this sequence. "Autopilot works really well, especially when it's properly set up," explained one respondent. "I like being able to drive with the joystick, let go of it, and the boat will continue to hold its course. It's a really great function". Additionally, boat speed, fuel flow, and some engine data were also mentioned as relevant information to have on display. Another automated feature mentioned was the Autotrim, however, it did not need to be visible at all times, only to indicate if it was activated. The trim level was highlighted as important because it impacts economic factors, such as fuel flow, but also indicates how the boat behaves. Not having to manually adjust the trim tabs allowed the boat operator to focus on other things instead. For instance, many respondents expressed an interest in seeing vessel speed, along with engine and coolant temperatures. Engine speed and oil pressure were also highlighted as important for gaining a clear overview of the engine's health. Remaining fuel, current depth, and heading were also mentioned as relevant information to display in this context.

Docking

What boat operators wanted to see when docking varies, especially depending on the type of harbor they are docking in, whether it is a natural harbor or a pier. “In a natural harbor, you might need a zoomed-in chart to see depth, shallow areas, etc. But when docking at a pier, you usually need the camera more than the chart, you already know where you are, and if it's a harbor, it’s almost certainly deep enough to dock”, one respondent explained. Another driver mentioned that he would like to see the nautical chart combined with depth and sonar when docking, especially in a natural harbor. “If I have multiple screens, I keep the sonar on one screen, the nautical chart on another, etc.”, the user explained.

Similar to departure, the camera was also an important function in this sequence, as one driver explained, “The camera is important, especially on larger boats, as it can be very difficult to see where the stern is”. This was something multiple boat operators agreed with.

Assisted Docking was also mentioned by several, but two of them felt that it takes up too much space on the screen if, for example, you want to see the rear camera or nautical chart at the same time. “It would be nice to be able to customize the Assisted Docking view”, one respondent added. Another operator expressed some skepticism about relying solely on Assisted Docking if, against all expectations, the system was to malfunction. “There’s a risk that if you’ve never docked manually and always rely on assisted docking, you might struggle to do it the traditional way,” the user explained. “Assisted Docking provides a kind of false sense of security. When it works, it’s great, but I’m not sure if I completely trust it”.

8.3.4 Summary

To summarize, this chapter has presented findings from the interviews and observations. The most important functions, features, and data have been assessed, and additional areas with potential for improvement have been identified. The core functions included nautical charts, engine data, radar, sonar, and autopilot. Key engine data included engine speed, fuel level, coolant temperature, engine oil pressure, and engine oil temperature. Battery voltage was also mentioned by some operators. Other essential data included boat speed, depth, position, heading, and rudder angle. However, the importance of this information varied considerably depending on the context and operating sequence, for example, during docking versus navigating in open waters. One of the most important take aways is the deviation in answers, which highlights how the operators’ needs differ depending on usage, knowledge and experience, and personal preferences.

9. A REFINED SCOPE AND CONCEPT DEVELOPMENT

This chapter presents the results from the point at which a clear direction was established based on the findings from the empirical studies, followed by the subsequent initial ideation and concept development phase.

9.1 Refined Project Scope

The result from the empirical studies was extensive, leaving endless possibilities for different directions to continue with. A set direction therefore had to be decided on. Through discussions with supervisors from Volvo Penta and Chalmers, a direction forward was decided, which includes exploration of the topics explained below.

The topics were carefully selected for their potential to bring added value to Volvo Penta, either by offering something futuristic, such as the introduction of innovative and original ideas, or by meeting strong user demand. Priority was given to areas with the greatest opportunity for innovative development. Conversely, features within the Glass Cockpit system that are already functioning effectively were considered lower priority and not pursued further.

Customization and Creating Profiles

From both the interviews and from representatives from Volvo Penta, there was an interest in customization and creating profiles, with the aim of improving both usability and overall user experience. Even though it is currently possible to customize some things in the interface, it was decided to explore this further, including a new feature which is creating your own user profile.

System Check

To create a feeling of both safety and control it was decided to explore the concept of a start page featuring a *System Check*, showing important data before embarking on a trip. An equivalent at the end of a trip was also of interest.

Search Function

A search function was highly desired by the users, which would enable them to find and navigate in the complex network of functions more easily. This was decided to explore further: how it could look, function and help the users when using the displays.

Recommended Views for Different Driving Sequences

Even though the drivers wanted to use different functions and see different data while driving, it was considered useful by both the project team and Volvo Penta representatives to make use of the extensive data that was gathered on which functions, engine data and other data that are most important to the operators. It was consequently decided to explore how a standard view could be designed, showcasing an optimal view for a twin installation based on the data from the interview.

Day Mode VS Dark Mode

The main focus would be to create design proposals for a day mode, following the design guidelines from the Volvo Experience System. However, dark mode would also be interesting to explore, but to a smaller extent. The decision to base the design on Volvo Experience System was based on directions from Volvo Group Design, which uttered that they wanted the products onboard boats to be consistent with other digital products in the Volvo Group portfolio.

The refined project scope places strong emphasis on developing new and innovative solutions to the problems identified during the empirical studies. While the scope has been narrowed and made more specific, it remains aligned with the initial research questions presented in chapter 7.1, now with greater detail and a clearer direction. The refined scope focuses on areas that will improve usability and safety, ultimately enhancing the overall boating experience

9.2 Ideation, Concept Development and Evaluation

This chapter presents the results from the initial ideation and concept development, as well as the evaluation of the proposed designs.

The design concepts were evaluated by users through both in-depth interviews and a survey. During the interviews, participants were presented with various proposals, followed by targeted questions and open discussions. The survey, designed to be brief, featured a smaller selection of design proposals and was structured around multiple-choice and short-answer questions. The goal of the evaluation was to identify strengths, weaknesses, and potential improvements that could enhance overall usability

9.2.1 Creating a Profile

The first part that was ideated was a sequence for creating a profile and customizing a display layout that corresponds to one's own preferences. The sequence is a three-step procedure, consisting of the steps "Create a profile", "Settings", and "Create Layout". At first, the user gets welcomed by a start page where the different users are presented, see Figure 26, and if the user chooses to "Add user", it will be directed to the three-step procedure.

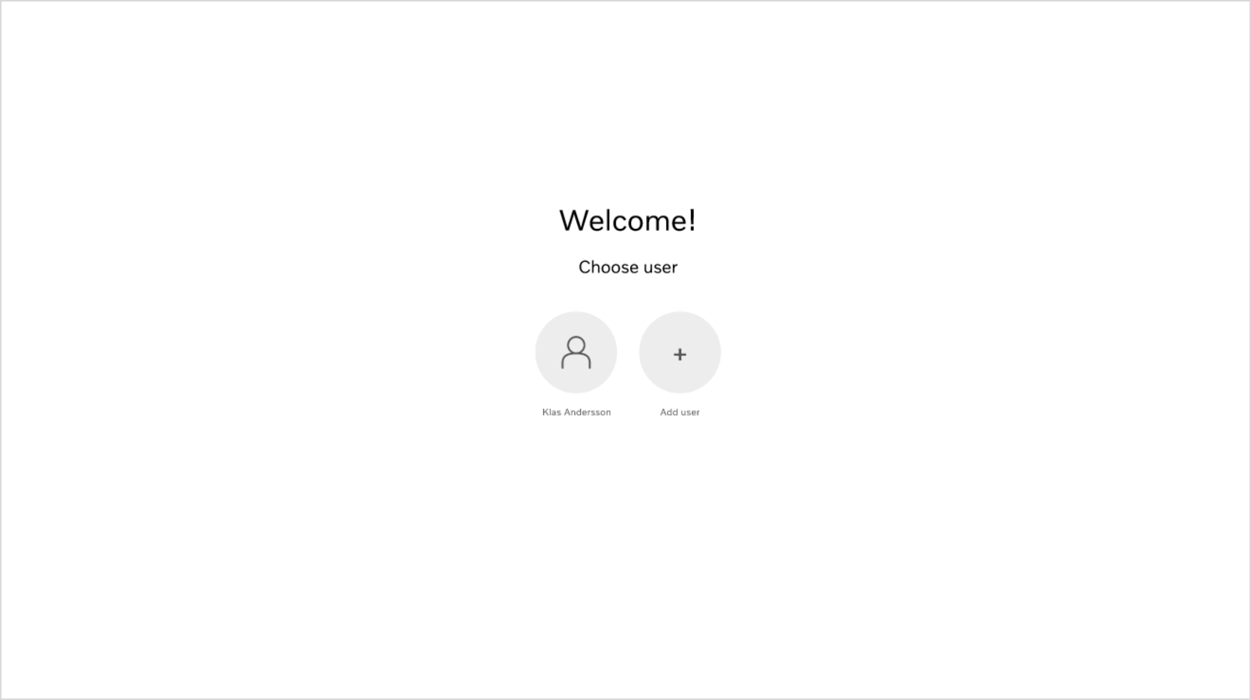


Figure 26. The welcome page where the operator can select or create a new profile.

The first step is to create a profile, which is made by filling in some information about themselves, their name, telephone number, email address, and their preferred language, see Figure 27.

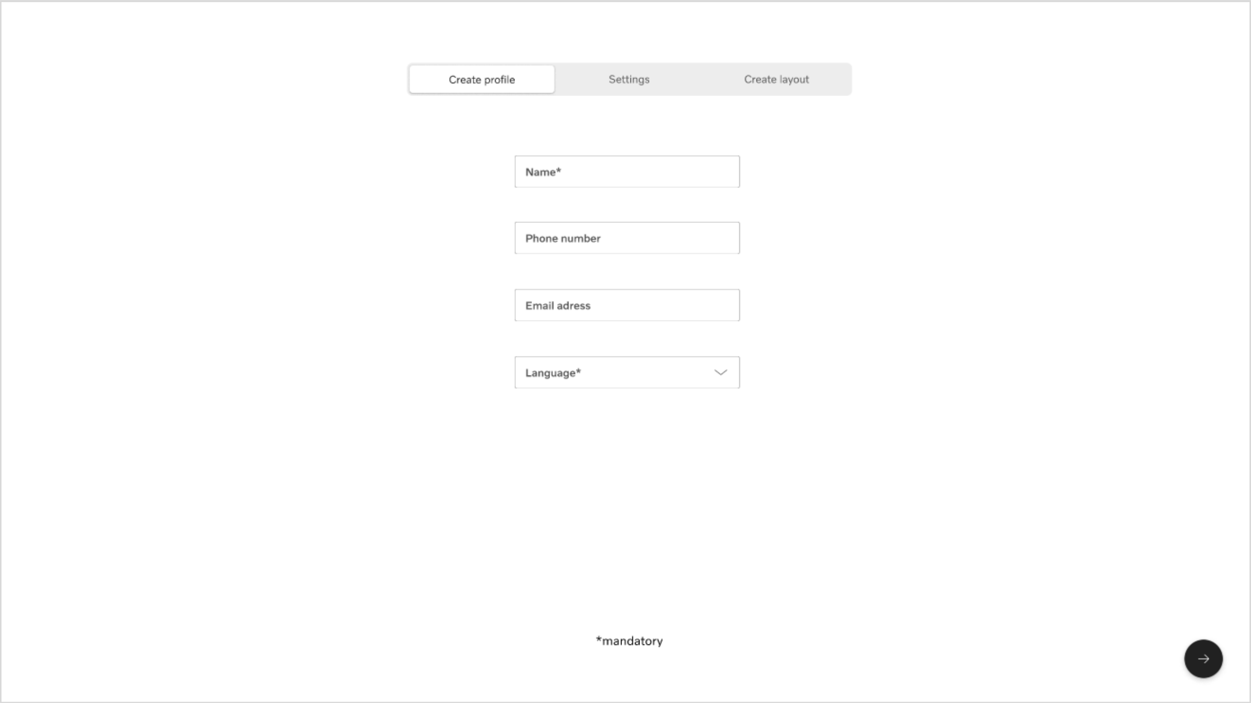
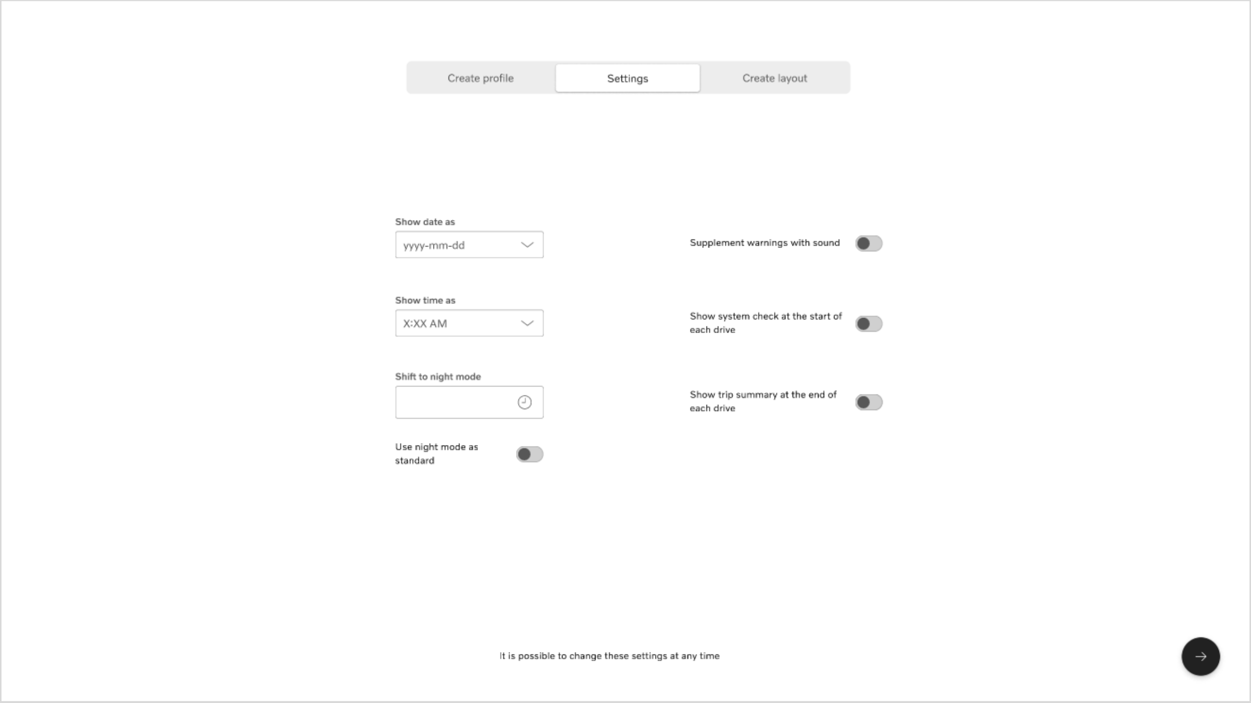


Figure 27. The first step, creating a profile.

Afterwards, when pressing the arrow in the bottom right corner, the user is directed to the next step, settings, see Figure 28. In this step they fill in information on how they want the date and time presented, when the display should shift to dark mode, or if the standard should be dark mode, whether alerts should be complemented by sound or not, and lastly if a *System Check* and *Trip Summary* should be displayed at the start and end of every trip.



Show date as: yyyy-mm-dd

Show time as: X:XX AM

Shift to night mode:

Use night mode as standard

Supplement warnings with sound

Show system check at the start of each drive

Show trip summary at the end of each drive

It is possible to change these settings at any time

Figure 28. The second step, settings for the profile.

In the last step, the user can create their own personal view for their display, see Figure 29. This function – allowing users to create their own views – already exists in the current Glass Cockpit displays, and will remain similar, only modified for the new graphical profile. A new addition to this function, however, is the possibility to search for functions and data, see Figure 30, aiming at simplifying the process of finding the desired function or data. Alternatively, the operator can use the scrollable menu on the right to select various functions and data to display in their layout. This list contains visualizations of the different functions, such as radar, sonar, and autopilot, to help the user better understand what the layout will contain, see Figure 31.

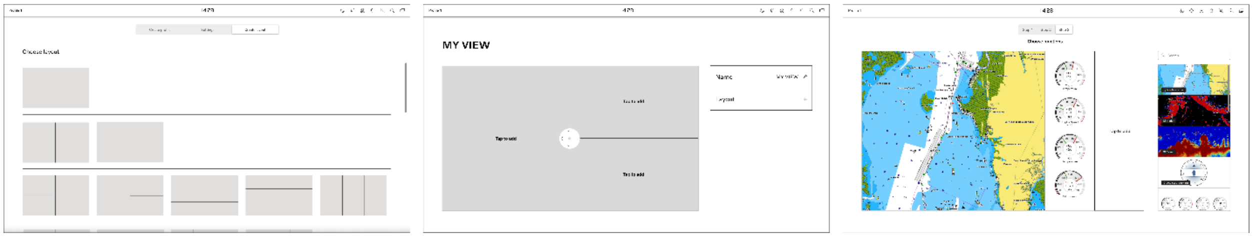


Figure 29. The third step, creation of the boat operator's personal view for the display. From left: choose a layout, enter a name for the layout and possibility to modify the different sections, and choose data for the layout.

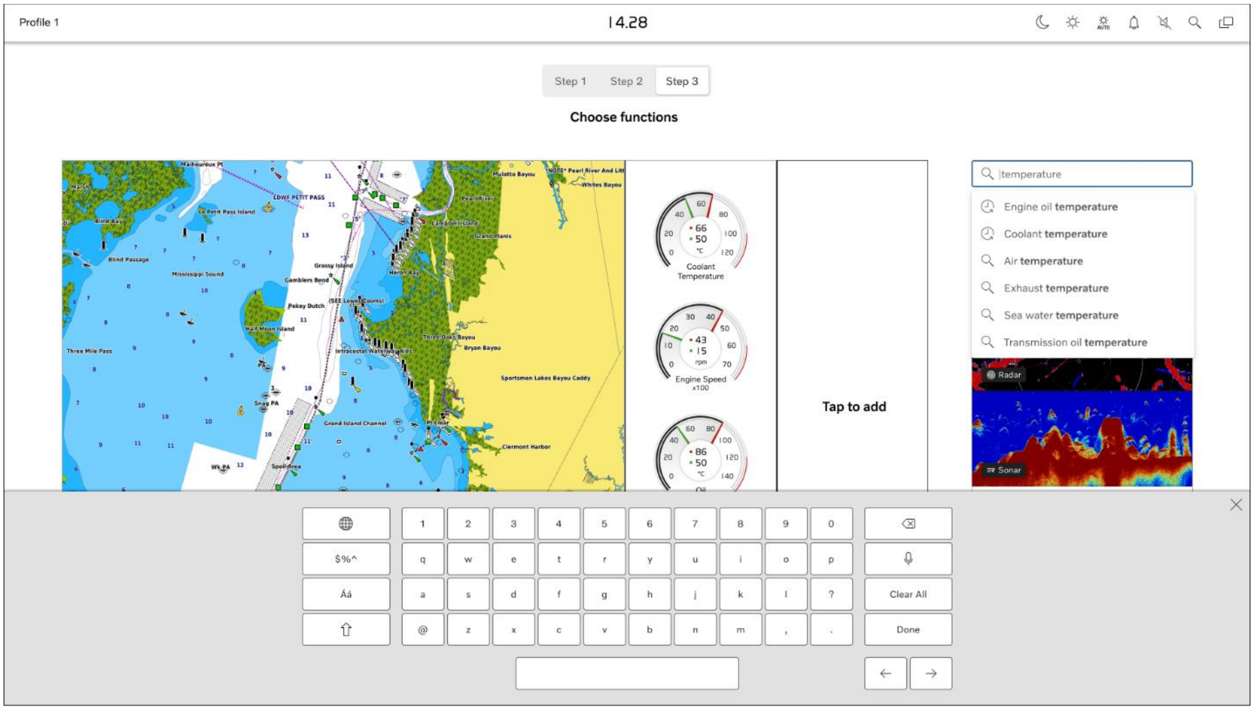


Figure 30. A search bar feature for the layout customization.

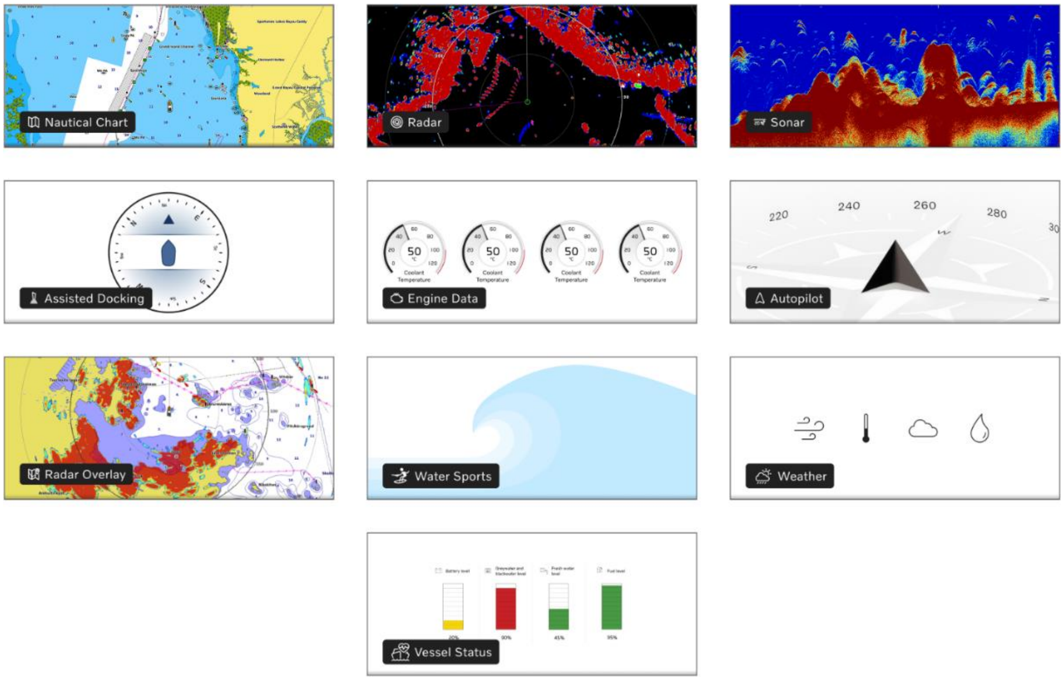


Figure 31. The different visualizations of data and functions available in the scrollable menu.

Evaluation with users

The interviewees responded positively to the proposed profile-creation views. When asked to rate the usefulness of the feature, it received an average score of 9 out of 10, see Figure 32. One participant explained, “Everyone has different preferences for the type of data they want to see, so it’s convenient to customize the display to your own needs. It also improves safety and efficiency because you know exactly where everything is”. However, several respondents emphasized the importance of having a guest profile available for users who are not interested in creating a personal profile and instead want quick access to the chart and other functions through a set of default views.

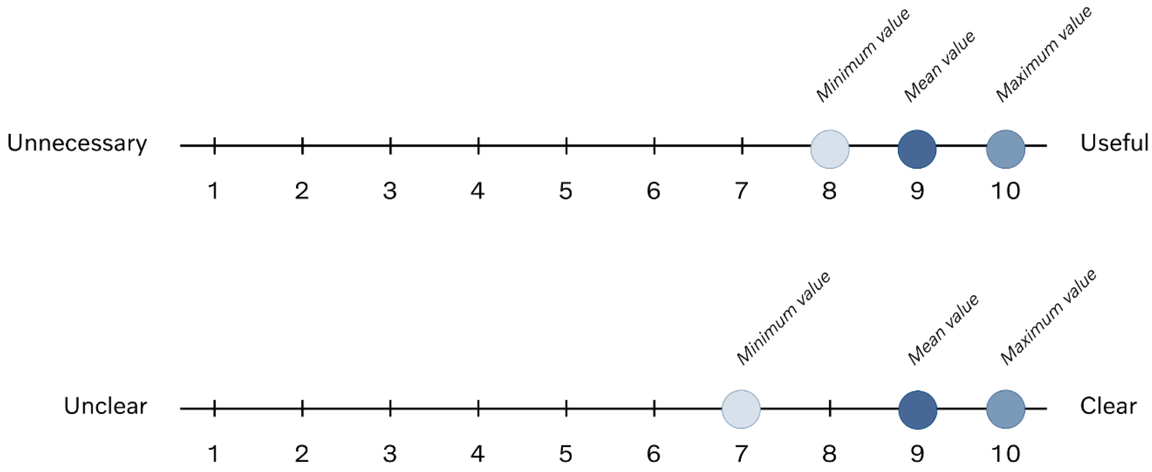


Figure 32. Results of the semantic scales from the interviews regarding the new profile creation feature.

Participants also expressed a desire to be able to modify their profile afterward, as well as to customize the default views to better suit their individual preferences. Drivers especially appreciated the addition of a search function when customizing their view. As one participant noted, “The search function is very relevant, it makes selecting data much smoother”.

When asked how intuitive and clear the feature felt, it again scored an average of 9 out of 10 on the semantic scale, see Figure 32. One driver commented, “It was nice to be able to create your own views, it also looked very easy to use”. However, one interviewee suggested an improvement to reduce the number of clicks: instead of requiring users to press “Tap to add” one of the boxes could be selected automatically, allowing the user to immediately choose a function from the dropdown menu.

9.2.2 System Check

Another feature that was developed was *System Check,* which provides the operator with necessary information before the trip, with the goal of creating a feeling of control and safety. The information that is presented is battery level, greywater and blackwater level, freshwater level, and fuel level. Four different alternatives of how the information is presented were created, which either used text or visualizations in different ways, see Figure 33.

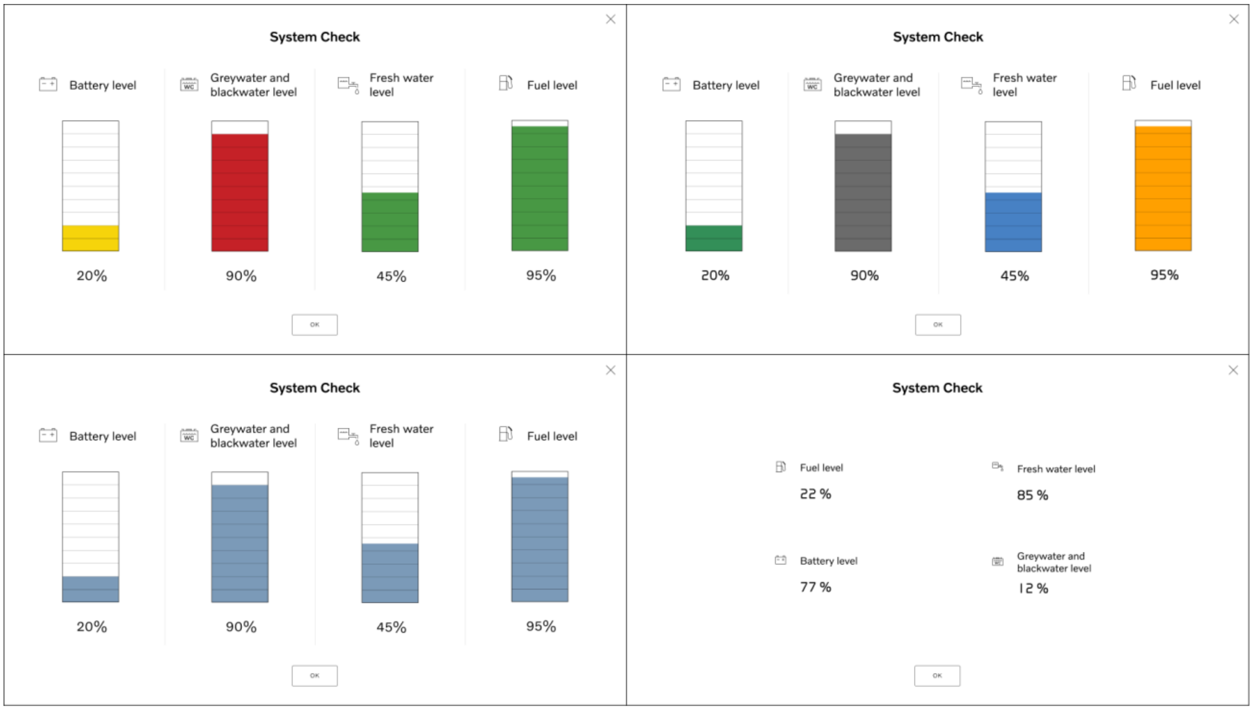


Figure 33. Four alternative designs on the System Check.

Evaluation with users

When asked how they preferred the *System Check* to be visualized, all interviewees stated they favored using bars along with color indicators (red, yellow, green) to represent status levels. As one driver explained, “The colors provide clarity and signal if something is at risk”. This approach offers a quick overview of the tank statuses. “I can glance at it and instantly get a sense of the situation, press OK, and still retain the image in my mind”, another participant explained.

However, it was suggested that the colors could be adjusted slightly, as they were considered quite bold. For example, reducing the saturation and making them a bit lighter would make them easier on the eyes. Another proposal was to reorder the bars based on priority, placing fuel level first, followed by battery, and water levels last, as water is not critical for the boat's propulsion.

When asked how reassuring the feature felt, it received an average score of 8.5 out of 10, see Figure 34. One driver commented, “It’s like a health check, it gives me an idea of the situation, which helps me feel at ease”. Regarding how annoying or satisfying the feature was perceived to be, respondents found it satisfying, though it might not appeal to everyone. As one driver noted, “I think it’s great, but there’s a risk that if there are too many pop-ups, it could start to feel a bit annoying”. One suggestion was that the *System Check* window should display for 5–10 seconds and then automatically close.

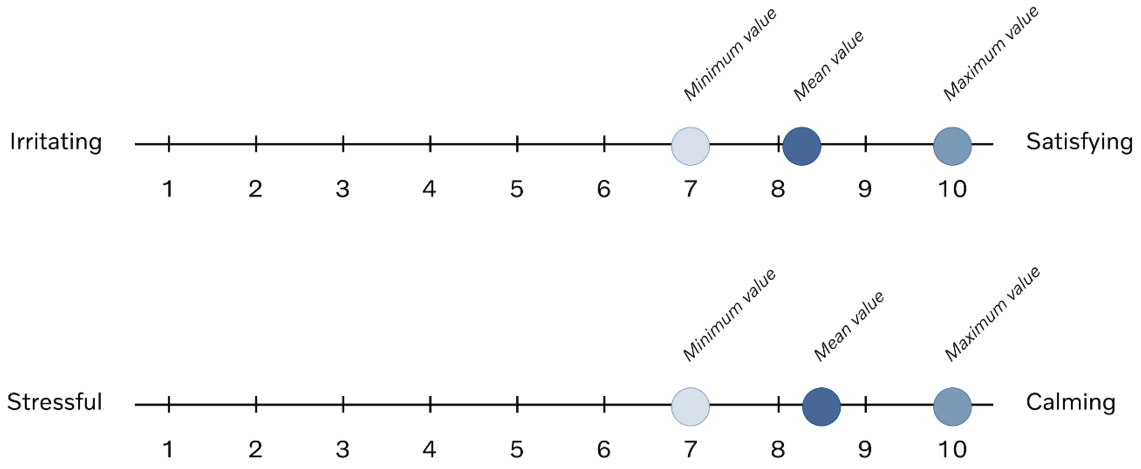


Figure 34. Result of the semantic scales from the interviews regarding the System Check feature.

Among the respondents that answered the evaluation survey, see appendix H, there were divided opinions regarding the usefulness of the *System Check* feature. The semantic differential scale yielded an average score of 6.6 out of 10, see Figure 35. One respondent gave the lowest rating and explained, “If I am restarting the engines in an emergency, nothing should cover my nautical chart”. Another respondent felt it did not add any value and found the pop-ups irritating. They also expressed uncertainty about whether the display would be able to read such values if the EVC system were turned off.

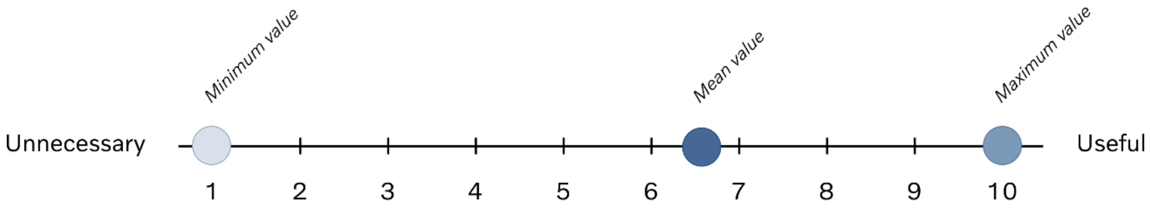


Figure 35. Result of the semantic scale from the survey regarding the System Check.

The remaining respondents were positive about the proposal. One person noted, "It's good to have this information clearly visible at the beginning, so I don't forget to check the different levels." Another driver stated, "These are levels you need to have control over." One respondent suggested it would be helpful to customize this view and possibly add other features, such as time remaining until household batteries are empty, freezer temperature, and other sensors users may find useful. Another respondent proposed an optional window for an engine check, showing coolant and oil levels, among other things.

To summarize, when comparing the evaluation of the *System Check* feature, the survey and interview responses were aligned, with a few deviations that lowered the average score in the survey. Some survey respondents were critical, expressing that they saw little value in the feature and found the pop-up windows annoying. Those who responded positively, however, agreed that the information was helpful to review before departure and was something they would have needed to check anyway.

9.2.3 Recommended Views for Different Driving Sequences

Different design proposals for a standard layout were created for two driving sequences, one for *Cast off/Docking*, and one for *Driving*. The proposals utilized the result from the user studies to create the most optimal view for a yacht operator. For the first sequence, departure/docking, different alternatives were created showcasing different ways of showing important data, placement of different components, and different combinations of functions, see Figure 36.

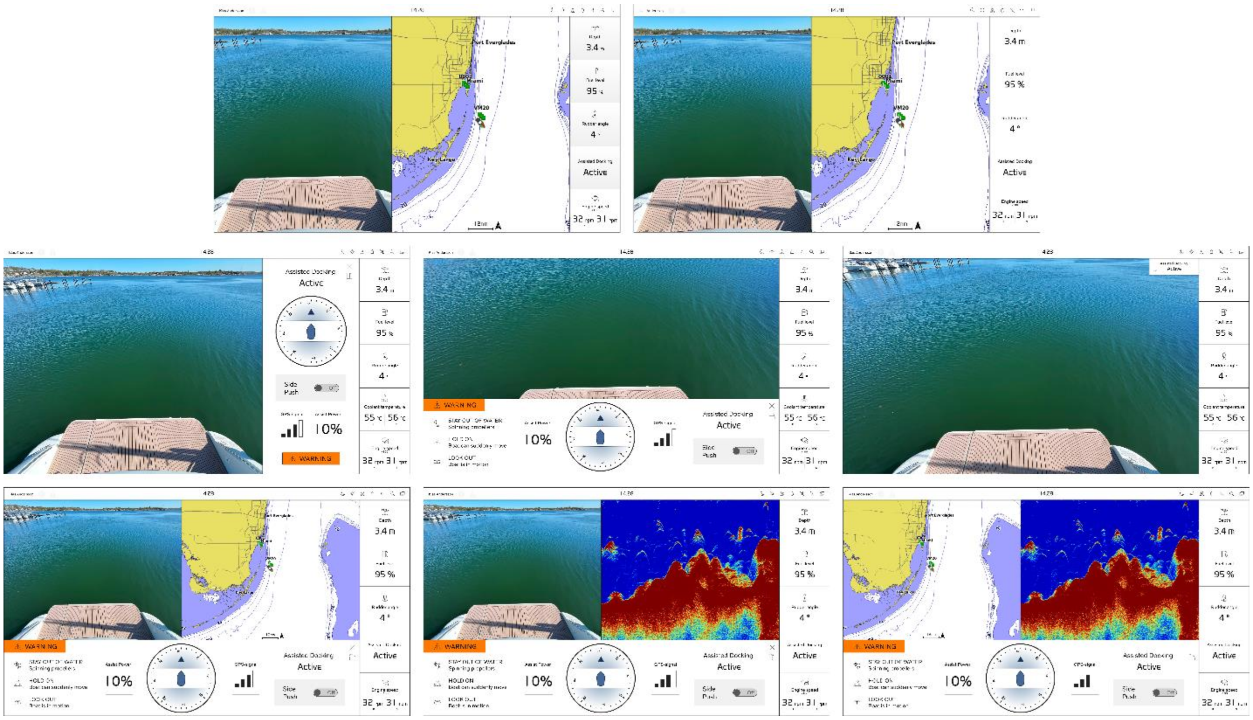


Figure 36. Design proposals for a recommended view for the Cast off/Docking sequences.

For the second sequence, *Driving*, placement of gauges and other data were explored, as well as different colors and day vs dark mode, see Figure 37.

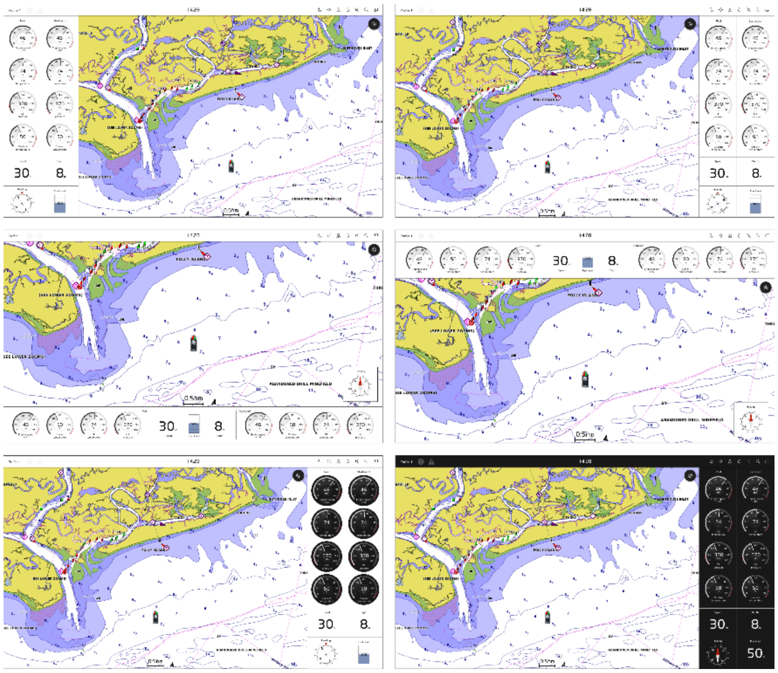


Figure 37. Design proposals for a recommended view for the Driving sequence.

Evaluation with users

When asked about their preferred layout for casting off or docking, responses varied. Most drivers said they wanted to see the chart and camera, along with depth and rudder angle. However, one driver noted that layout preferences are highly personal. He mentioned he would probably prefer to have the camera and sonar as the default view, since he had already prepared by reviewing the chart beforehand and did not need to see it again at that moment.

Regarding the size of the Assisted Docking banner, one driver felt it was a bit too large and explained, "I would probably prefer to have Assisted Docking shown in the right-hand menu instead, so I can have larger camera images and so on". Another driver said it was enough to simply indicate that the function was activated and that he would not use the Side Push feature via the screen, so there was no need to display it. "I pay more attention to what's outside the boat than inside when I'm docking, so that [Assisted Docking] feature doesn't need to be so prominent", he explained.

When asked how they would like engine data to be visualized, most drivers preferred a slimmer side panel with less information. "I think it's good to try to reduce the amount of data in the right-hand column, just to leave more screen space for the chart and camera", one driver noted.

Engine and fuel data were not considered particularly relevant in this situation. As one driver put it, "I already checked that [engine data] while the engine was warming up". If the fuel level had already been shown in the *System Check* window, it was seen as redundant to display it again during docking. More important was having access to depth, speed, and rudder angle. One driver explained, "The less cluttered it is, the quicker you can find the information you're looking for". One suggestion was to combine the port and starboard engine data into a single gauge. A driver also expressed a desire to see some wind data, such as wind direction, ideally integrated with the compass.

When evaluating the *Driving* operating sequence view, all interviewees stated that they preferred having the engine data displayed on the right side of the screen, primarily due to familiarity. "It feels natural for it to be on the right side; it's usually placed there on other boats", one driver explained. Another reason given for placing the data on the side was to avoid obstructing the forward view of the chart. "If you place the data at the top or bottom of the chart, you lose visibility of the forward area on the chart, which you don't want. I want to see what's ahead of the boat", one driver explained.

However, one participant suggested that if the data were to be placed at the bottom of the screen, the engine information should be mirrored, so that the port and starboard engine data are evenly spaced from the center on either side.

Regarding the shortcut for radar overlay, it was well received by the drivers, who described it as a useful feature that provides quick access. However, many felt that the symbol was not very intuitive and would have preferred a more classic radar icon, ideally with an added needle and gradient extending from it. That said, several drivers noted that the symbol becomes familiar over time and appreciated that it was not too large, as this prevents it from covering the chart display.

Looking at the results from the survey, they were similar to the interviews', placing engine and other data on the right side is the most preferred option, 87.6% of respondents agree with this layout, see Figure 38. In comparison, only 7.1% prefer the left side, and 14.3% prefer having the data at the bottom.

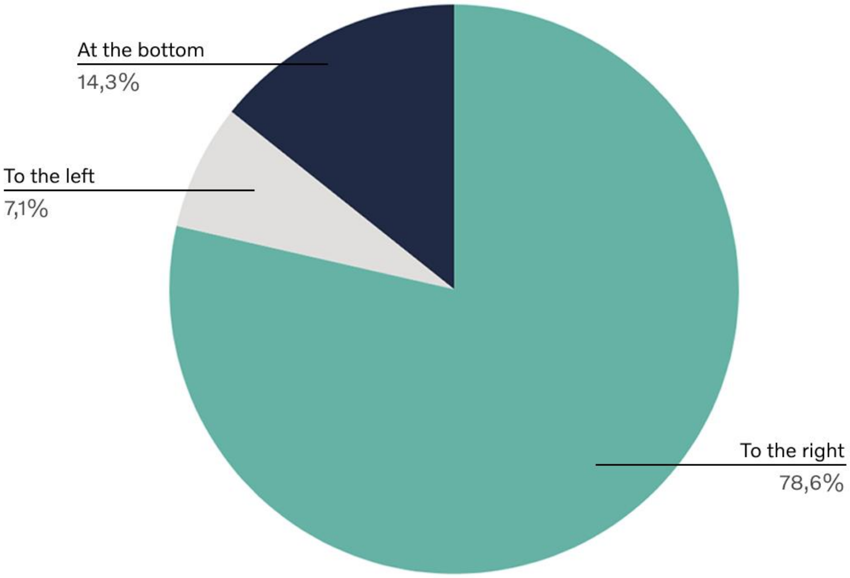


Figure 38. Pie chart of preferred placement of engine data in the recommended view for Driving sequence.

Despite the strong preference for the right side, comments reveal that the side itself does not matter, what matters is that the nautical chart is as large as possible, and mainly in the direction in front of you. One respondent uttered that "Left or right doesn't matter on a wide screen. What matters is how much chart you can see in front of the boat". That said, many users mentioned that the right side feels more 'natural', which explains its clear popularity.

Summarizing the findings, most operators preferred a clear view of the chart, camera, depth, and rudder angle during docking, with minimal on-screen clutter. Engine and fuel data were seen as less important during docking, and a slimmer side panel was favored. Most users preferred engine data on the right, mainly to keep the chart's forward view clear. The Assisted Docking banner was considered too large, and the radar shortcut useful but needed a more clear icon. Overall, users prioritized screen space and clarity.

9.2.4 Gauges

Gauges were not originally intended to be a focus of exploration. However, due to the adoption of a new design system with no existing gauge components, new gauges had to be developed. A wide range of digital analogue gauge concepts were created, see Figure 39, varying in how information was presented, through text, numbers, or symbols. Various methods for indicating critical conditions were also explored.

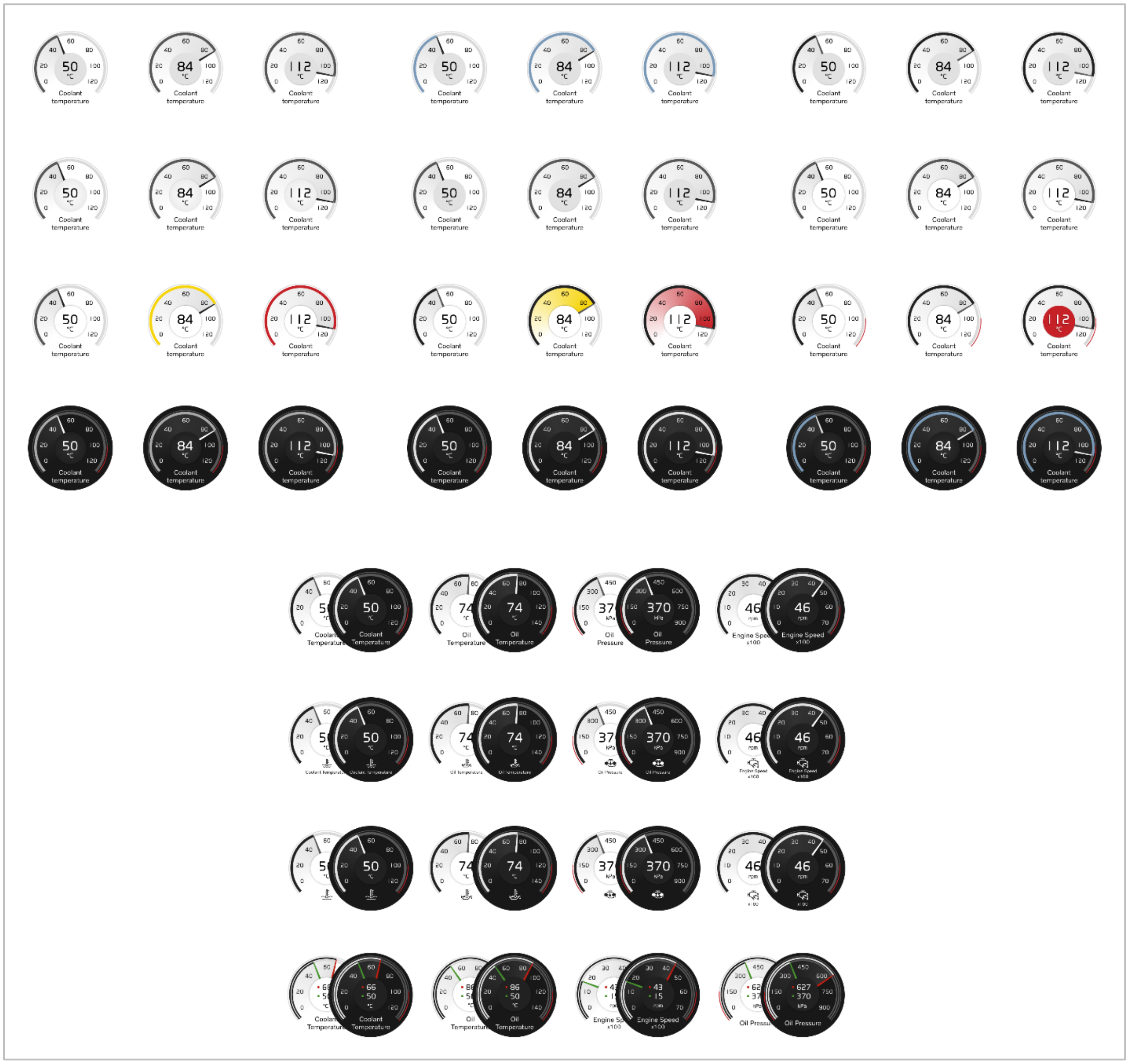


Figure 39. Ideation of different gauge designs.

From these concepts, several were selected for further development. Variations were developed where information traditionally shown on analogue gauges was presented in more digital formats using numerical values. It was also explored whether the data should be presented as text only, a combination of text and symbols, or symbols only, see Figure 40.

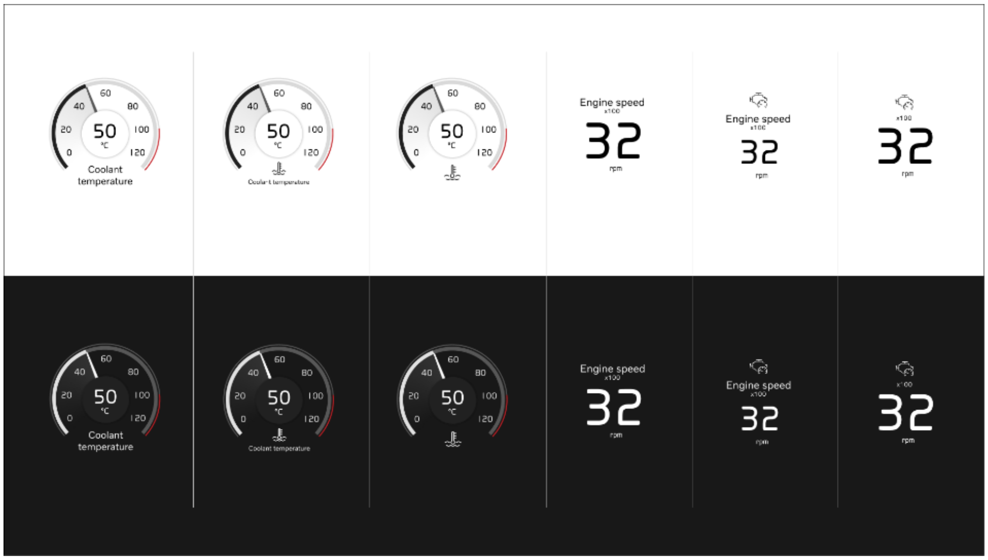


Figure 40. Design proposals for visualizing engine data, using analog gauges or solely numerical values, accompanied by descriptive text and/or symbols.

The design was also explored in the context of a dual-engine system to understand how such a layout would impact the interface, see Figure 41.

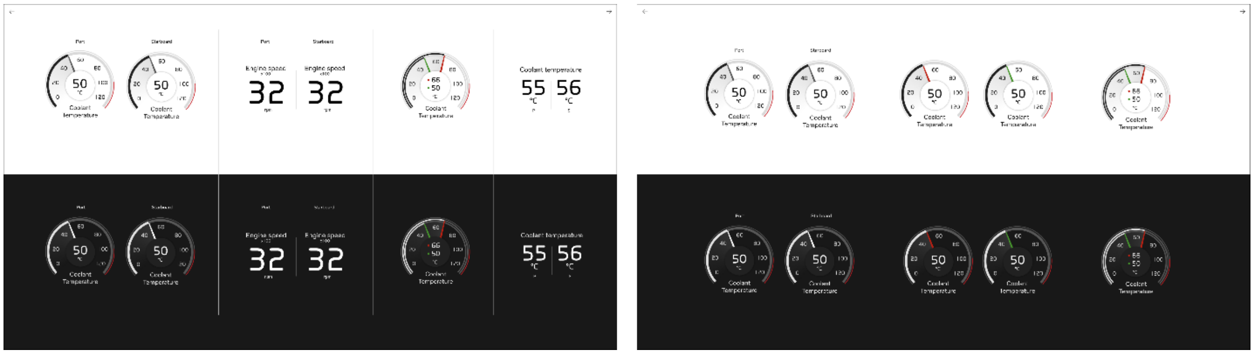


Figure 41. Visualization of how engine data for dual engines in a twin installation can be presented.

Evaluation with users

When asked how they preferred the gauges to be visualized, all interviewees said they preferred engine data to be presented in the form of digital analog gauges rather than just numbers. This was because analog gauges made it easier to get a quick overview of the situation. Most drivers also explained that they wanted a descriptive text accompanying the data presented. “Just showing a thermometer doesn’t tell you much about what is being measured; you need some explanatory text”, one interviewee said.

Three out of four participants also wanted to combine the text with a symbol, partly to avoid language barriers, but also because symbols allow for a quick understanding of the data being displayed.

When asked whether they preferred to have engine data from two different engines shown in the same analog gauge or split into two, most said they preferred to split the data into two separate gauges. “If there’s room on the screen, it’s better to have two analog gauges next to each other. It gives clearer information compared to having to read both the port and starboard indicators in the same gauge”, one driver noted.

When the data is split into two gauges, there is no need to color-code the needles. As one driver explained, “That could lead to confusion, with the green one being interpreted as OK while the red one is not”. All drivers noted that while combining the gauges saved some screen space, it was appreciated, but it took slightly longer to read.

Most drivers preferred that the gauges match the background, using white gauges in light mode and black gauges in dark mode. However, one driver also preferred black gauges to a light background, as it was perceived to be clearer.

Looking at the answers from the survey, they aligned with the answers from interviews. The chart, see Figure 42, shows that 46.2% of respondents prefer two separate gauges labeled 'port' and 'starboard', while 23.1% favor two gauges with red and green needles to differentiate between the two sides. In contrast, 30.8% prefer a combined gauge displaying both values.

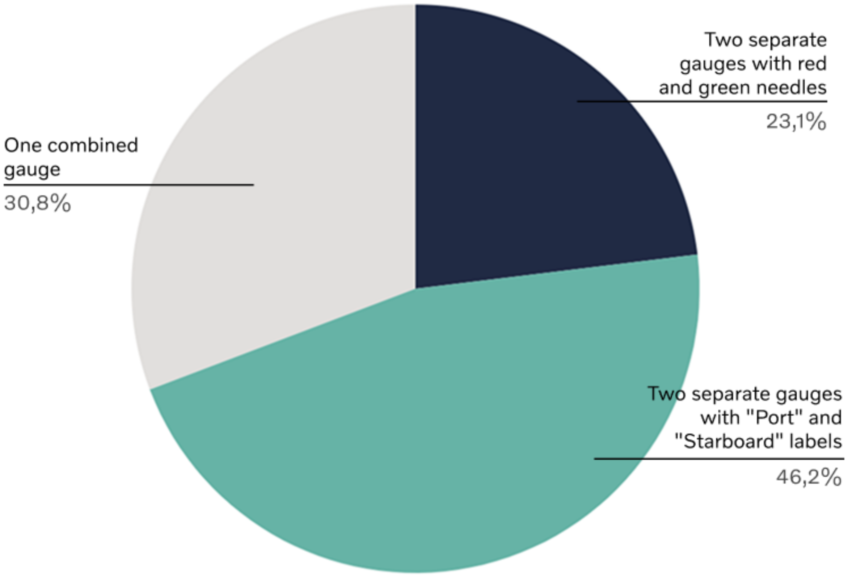


Figure 42. Pie chart of preferred gauge type in the recommended view for Driving sequence.

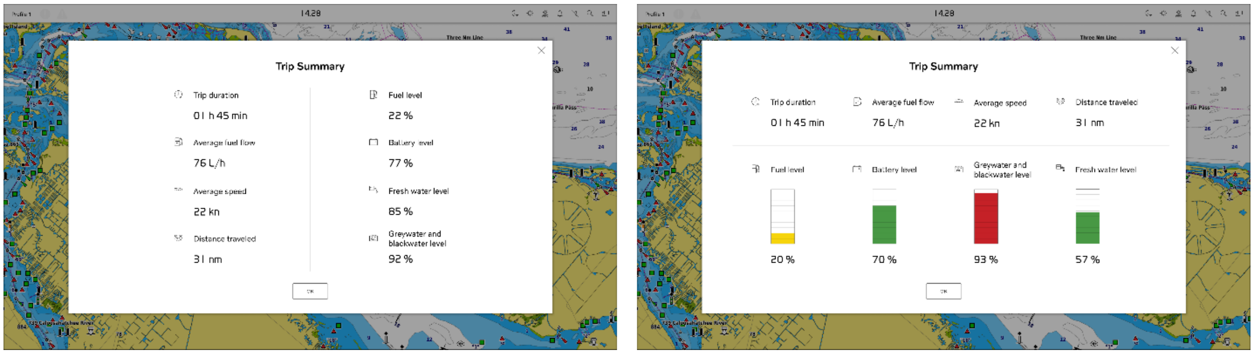
There are several reasons why separate gauges are favored. One respondent uttered that "Two gauges give you instant visual feedback without the need to think. Red and green are not ideal for those with color blindness". This highlights two key considerations. Firstly, increased clarity – having one gauge per engine simplifies interpretation, as each gauge clearly represents one value. Second, accessibility – color coding with red and green may not be effective for users with color vision deficiencies. Additionally, red and green are commonly associated with status indicators (e.g., red for danger, green for normal), which could cause confusion when used purely for directional differentiation.

On the other hand, some users expressed that a combined gauge improves display efficiency by presenting more data in a smaller space. One respondent mentioned "I believe the panel will look less scattered, it is also easier to compare the values", which highlights that combined gauges can utilize the display more efficiently, as well as facilitate a quicker comparison between port and starboard values.

To summarize, both respondents from the survey and the interviews preferred two separate gauges for the engine data but considered the combined gauges to be more space efficient and perceived less cluttered. They were also in agreement that the engine data should be placed on the right side of the screen.

9.2.5 Trip Summary

Similarly to the *System Check* at the start of trip, it was explored how a summary of the trip could be designed, see Figure 43. The goal was to provide the operator with necessary and/or interesting information that could be used either to take actions on, or simply fun things to know. The information presented is trip duration, average fuel flow, average speed, distance traveled, fuel level, battery level, freshwater level, and greywater and blackwater level. Thus, an extended *System Check*.



Trip duration 01 h 45 min
Average fuel flow 76 L/h
Average speed 22 kn
Distance traveled 31 nm
Fuel level 22 %
Battery level 77 %
Fresh water level 85 %
Greywater and blackwater level 92 %

Trip duration 01 h 45 min
Average fuel flow 76 L/h
Average speed 22 kn
Distance traveled 31 nm
Fuel level 20 %
Battery level 70 %
Greywater and blackwater level 93 %
Fresh water level 57 %

Figure 43. Two design proposals for the Trip Summary, one number-based and one with a combination of numbers and visual elements.

Evaluation with users

When evaluating the *Trip Summary* feature, the interviewees were generally positive about the suggestion. As one driver said, "For me, it would be really convenient if this popped up, as it's something I would have checked anyway, and now I don't have to". However, another driver felt that it was more of a fun feature rather than something particularly critical or necessary. When rated for usefulness, the semantic scale resulted in a score of 8 out of 10, see Figure 44.

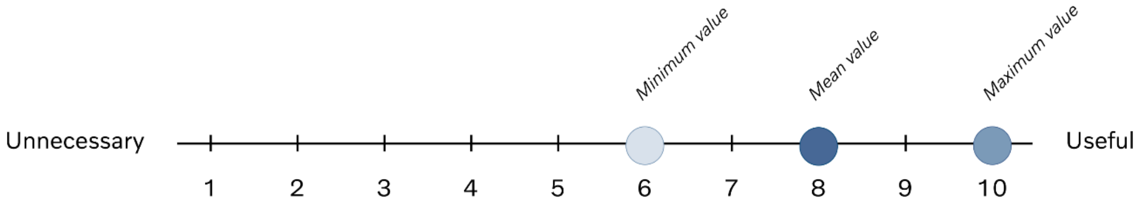


Figure 44. Result of the semantic scale from the interviews regarding the Trip Summary.

Regarding how they preferred to visualize this type of information, all interviewees agreed that they preferred using bars for the different tanks rather than just displaying numbers. "Bars are good, they give a clear indication of when something is off. However, it's enough for the upper trip information to be presented with numbers", explained one driver.

In the survey evaluation of the Summary Trip feature, the semantic differential scale yielded an average score of 6.5 out of 10, see Figure 45. Similar to the *System Check* feature, two drivers were skeptical, noting that while the information was useful, it did not need to appear automatically, and that pop-ups could be irritating. One driver instead suggested a smaller button labeled 'View trip data' for those who wished to access the information manually.

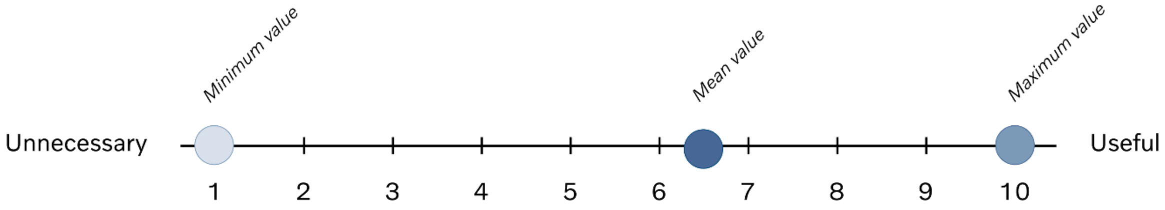


Figure 45. Result of the semantic scale from the survey regarding the Trip Summary.

The remaining respondents were more positive. "This information is a nice feature! It makes me reflect on how I've been driving, like an instant After Action Review. Can I improve my driving next time?" one driver explained and continued, "It also gives me the opportunity to consider whether everything is as it should be". The respondent further noted that the feature helps build a subconscious understanding of how long different routes take, which makes planning future trips easier.

Another driver proposed integrating the feature with a logbook, allowing users to enter details such as destinations, activities, number of passengers, and more, to enhance its usefulness. One respondent also wished for a map view displaying the route taken, providing a visual overview of the journey.

However, some expressed that the trip information was less important than fuel, water or battery status and believed it should be optional to view.

To summarize, respondents in both the surveys and interviews were generally positive about the *System Check* feature, with a few exceptions. The information was considered both interesting and valuable, offering a helpful status overview of the boat before leaving it for the day. However, it was also noted that the information was not relevant to all drivers and should therefore be optional.

9.2.6 Alerts

The design of alert messages and what type of information they should convey was also explored. Several respondents expressed frustration with current alerts, noting that they often lack guidance on how to resolve the issue. This feedback made it relevant to design a new alert that addresses this problem.

Various proposals were developed, see Figure 46, illustrating different approaches to presenting the information, varying popup sizes and amount of text showing. The alternatives are

- Wide box with action plan displayed
- Wide box with action plan hidden
- Narrow box with action plan displayed
- Horizontal banner with action plan displayed

Figure 46. Different proposals of alerts. Top left: wide box. Top right: wide box with action plan hidden. Bottom left: narrow box. Bottom right: Horizontal banner.

Evaluation with users

Regarding how alerts should be visualized, two interviewees said they preferred the first option, with a wider box in the left corner displaying an action plan. "I think it's good that it shows how I should act to handle the alert", explained one driver. The other interviewees preferred the third option, featuring the narrow box, stating that they did not want the alert to obscure the nautical chart in front of the boat.

When asked if they preferred the alert to be placed elsewhere, all participants agreed that its current position was ideal. "I don't want it [the alert] on the right side, partly because it blends too much with the engine data and becomes hard to distinguish, but also because if the alert, for example, relates to high engine speed, I don't want these gauges to be covered by the alert pop-up", one driver said.

It was important for the alerts to be large and clear so they would not be missed, but at the same time, they should not cover too much of the chart.

The answers from the survey differed from the ones from the interviews. As shown in the chart, see Figure 47, the most preferred option for displaying alerts is a horizontal banner, displaying the action plan, at the top left corner, chosen by 42.9% of respondents. This is followed by the narrow box with the action plan displayed, preferred by 28.6%. The remaining two options were equally preferred, each receiving 14.3% of the votes.

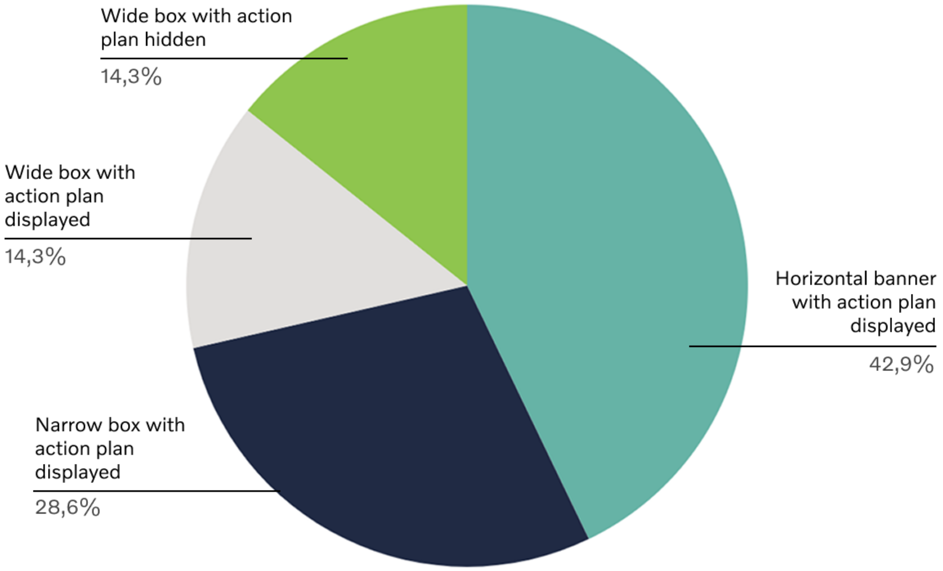


Figure 47. Pie chart of preferred design of an alert pop-up.

However, comments reveal that several respondents were dissatisfied with all the proposed alternatives, primarily because they obstruct the chart, especially the area in front of the boat. As described by one driver, "The area in front of the boat should remain unaffected by the alert message.

Position it as much to the side as possible". One respondent expressed a preference for alerts to cover the engine data instead, while another suggested placing the alerts in the bottom left corner to minimize interference with important chart areas.

Some respondents preferred being able to click to access the action plan, arguing that it did not need to be visible at all times. Others felt that keeping it displayed made things more clear for the driver, who would not have to interact with the screen to know what to do. "You shouldn't have to think about what actions to take, clear instructions straight away", explained one driver who preferred the action plan to remain visible. "The warning and all info are still visible, without any clicking. Fewer clicks to acknowledge", another driver explained. This highlights a key advantage: a banner with action plan displayed reduces interaction steps, making it quicker and easier to process critical information.

To summarize, the respondents from the survey preferred alerts as a horizontal banner or a narrow box with action plan displayed, while respondents from the interviews preferred either a wide box or a narrow box with action plan displayed. Respondents from the survey also suggested placing the alerts over the engine data, while an interviewee explained that they did not want the alerts to cover the data that is at risk.

9.2.7 Autopilot

The Autopilot is a function that is primarily activated when operating in open waters and not necessarily when the boat is docked in a marina. For that reason, this function has been visualized in the recommended view for the *Driving* operating sequence. Different proposals on how it could be visualized were explored, showcasing different placements, sizes and information available, see Figure 48 and 49.

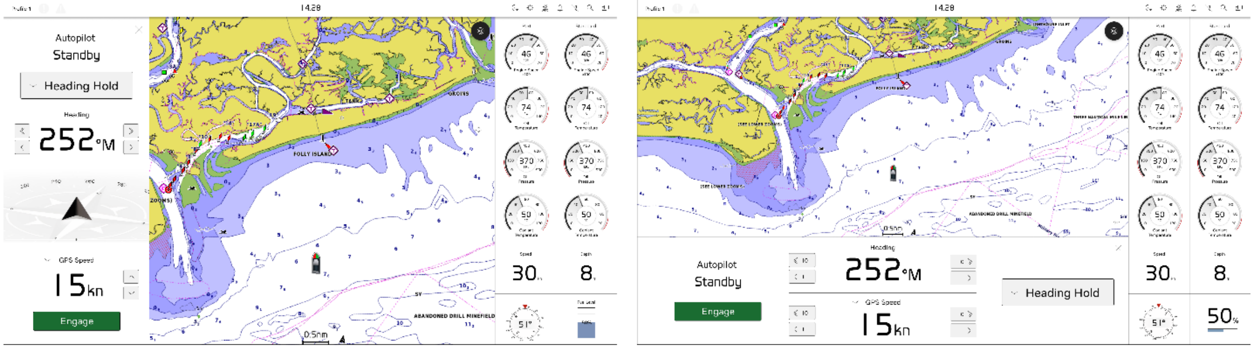


Figure 48. Design proposal for the Autopilot feature, presented as either a vertical or horizontal banner.

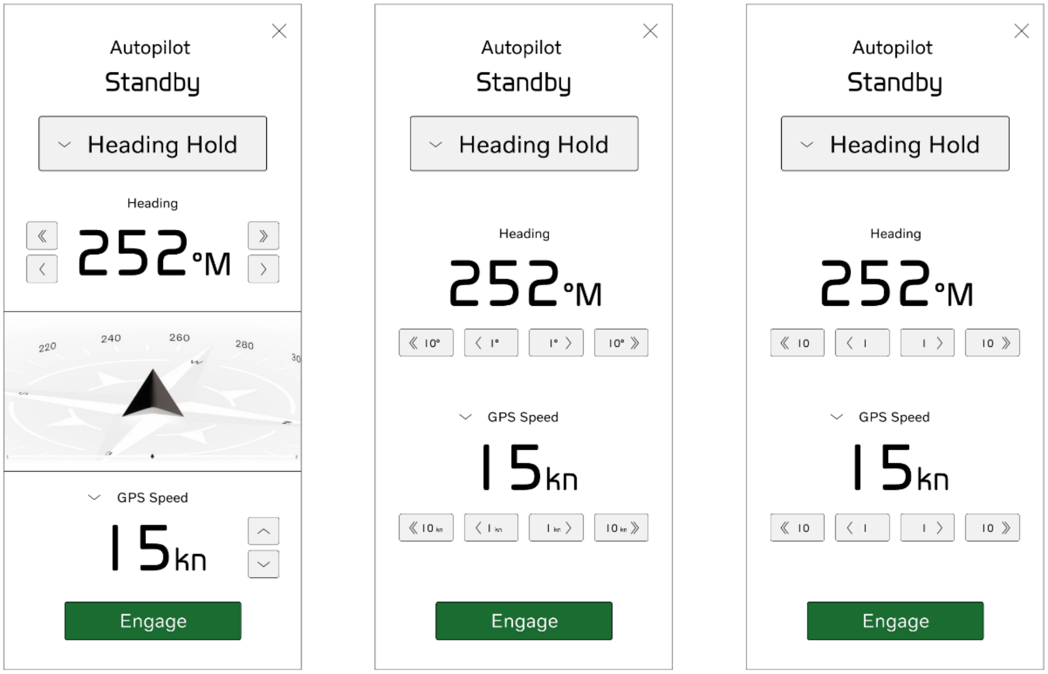


Figure 49. Button design proposals for adjusting values such as degrees, with variations including arrows only, arrows with text, and arrows with both text and units.

Evaluation with users

When asked how the Autopilot should be visualized, most interviewees said they preferred a smaller vertical version of the feature placed on the side of the screen, as this leaves more room for the chart. "When you're going fast, it's more important to see further ahead, so I'd rather have the Autopilot in a vertical banner instead of a horizontal one", one driver explained. Another driver also felt that the vertical banner created more visual symmetry, making it look nicer.

However, one driver noted that the compass rose in the Autopilot's "Heading Hold" mode was somewhat unclear: "The arrow is very large, and it's hard to read north, west, south, and east. The small compass in the engine menu is much clearer".

When asked about the design of the buttons used to increase or decrease heading and boat speed, responses varied. Two participants preferred arrows without numbers, as they felt it looked more minimalist and stylish, and that users would quickly learn how much each press adjusts the value after a few interactions. Another participant preferred arrows with numbers but without text, as it made it clearer how much each press would change the setting. One person also wanted to see the unit of measurement included to make it even more understandable.

Furthermore, one driver pointed out that the relevance of magnetic degrees can vary by country. "In Sweden it doesn't matter, since magnetic degrees and true degrees are basically the same, but in the

U.S., it can differ by over 30 degrees. So, it would be good to have the option to choose between true or magnetic", he explained.

Similar to the interviewees, the majority of the respondents (78.6%) from the survey favored a vertical banner on the side for the Autopilot, see Figure 50. Only 21.4% preferred a horizontal banner in this context.

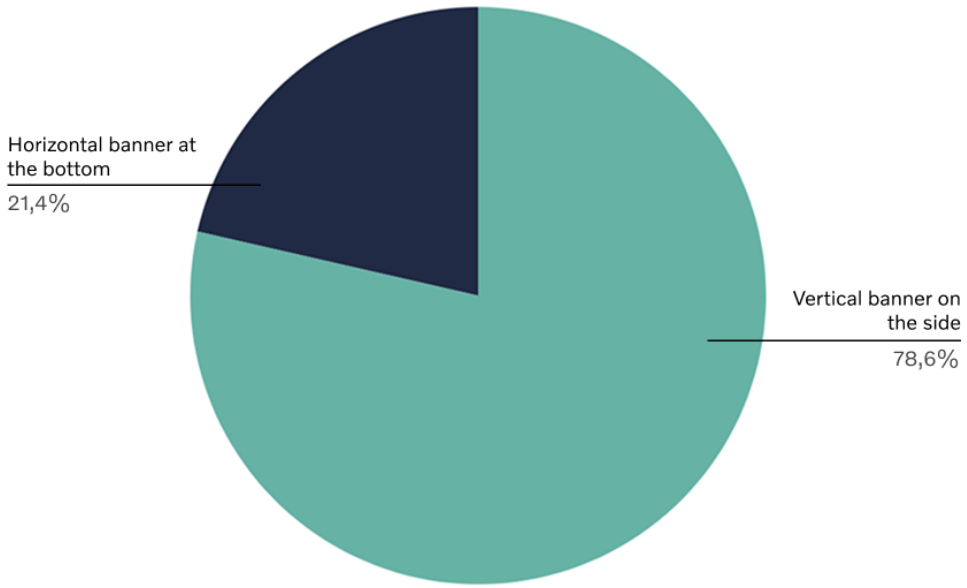


Figure 50. Pie chart of preferred design of the Autopilot banner.

The most common reason for this preference, mentioned by five respondents, was the desire to see as far ahead of the boat as possible, something more easily achieved with a vertical banner that leaves more of the forward view unobstructed. However, some drivers pointed out that the vertical design was larger than necessary and would have preferred a more compact layout. One respondent also considered the compass rose unnecessary and suggested it could be removed. Those who supported a horizontal banner suggested it should be smaller in size to minimize its impact on screen space.

To summarize, both interview and survey respondents agreed on the vertical banner being the most suitable option for visualizing the Autopilot between the two options. Both parties explained that they wanted to see as much as possible of what is in front of the boat on the nautical chart and that the horizontal banner would be inefficient because of that. Some skepticism was also expressed regarding the compass rose in the Autopilot, as it was perceived to add little value.

9.2.8 Assisted Docking

Assisted Docking is a function that can be activated at any time but is most commonly used during casting off and docking. Hence, it will be displayed alongside the recommended view for the *Cast* *off/Docking* sequence. In the initial ideation phase, the design of the function was explored in combination with a camera view.

The original Assisted Docking banner was a large horizontal element that covered nearly half of the screen. This proved to be unnecessary and frustrating for most users, which led to the exploration of new design alternatives. To preserve essential information and visual elements while minimizing screen obstruction, three new versions were developed: one horizontal, one wide vertical, and one narrow vertical, see Figure 51.

In addition, an alternative version was created that displays only critical warnings. In this version, all other elements are removed and replaced with a small box in the upper-right corner, indicating that Assisted Docking is 'Active'.

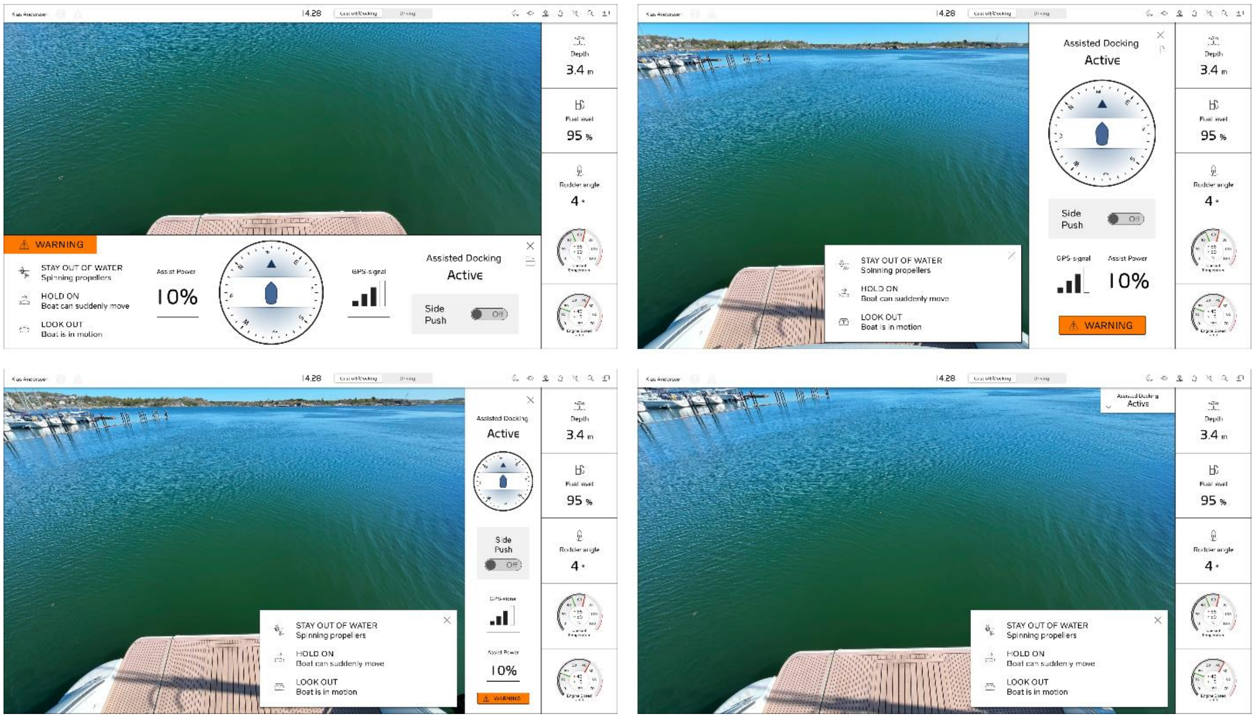


Figure 51. Different proposals of an Assisted Docking banner.

Evaluation with users

When evaluating how drivers wanted the Assisted Docking feature to be displayed, most interviewees said they preferred it as a sidebar. "It leaves more space for the chart or camera, otherwise everything gets more cramped", one participant explained. The ability to minimize the feature was also appreciated among drivers. One suggestion was to make the sidebar even narrower, similar in size to the engine data panel, to occupy less screen space.

However, one driver preferred the more traditional horizontal banner. "I think the warnings are necessary, whether you like it or not, they're important", he explained. Another driver pointed out that the horizontal banner might actually be more practical when showing both the chart and the camera on the display, as the vertical banner could otherwise make those views too narrow.

The results from the survey indicate that the horizontal banner is the most preferred option, with 50% of respondents selecting it, see Figure 52. The narrow vertical banner followed with 28.6%, while the wide vertical banner was chosen by 14.3%. The least popular option was a small status box in the corner, preferred by just 7.1%.

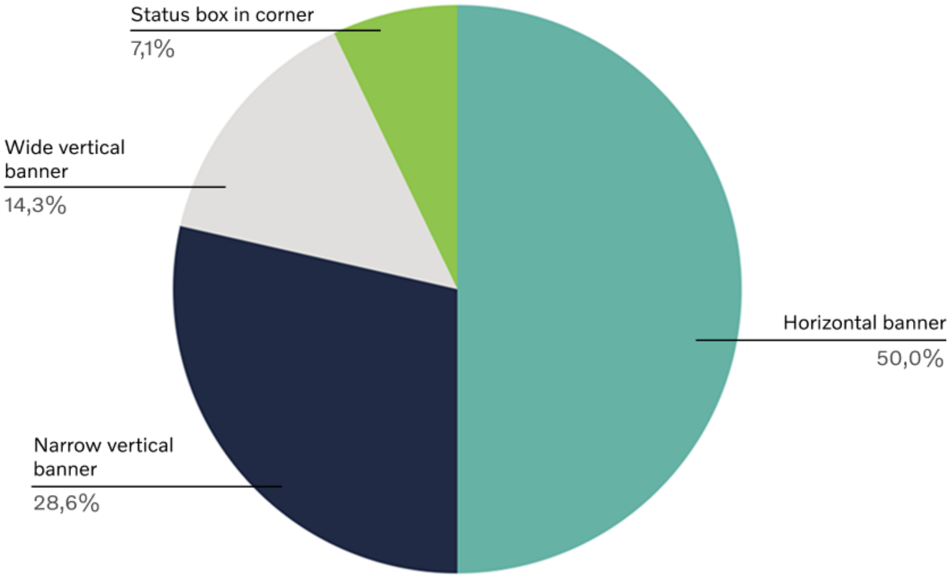


Figure 52. Pie chart of preferred design of the Assisted Docking banner.

The strong preference for the horizontal banner is noteworthy. One possible reason could be familiarity, as this format closely resembles the current layout, making it feel more intuitive and convenient to users. However, based on the comments, the horizontal banner is also appreciated for its clarity and visibility. On the other hand, respondents who preferred the vertical banners highlighted their space-saving benefits, particularly in terms of preserving more of the camera view, which they considered more valuable.

To summarize, the respondents disagreed with how they wanted the Assisted Docking feature displayed on the screen. Survey respondents preferred the horizontal banner at the bottom of the screen, while most interviewees wanted a vertical banner on the side. However, both agreed that it would be easier to visualize multiple features, such as nautical chart and rear camera view, using the horizontal banner compared to the vertical one.

9.2.9 Rudder Angle Symbol and Visualization of Heading

As part of the recommended views, two new visual elements were added to the side column containing engine and other operational data. In the *Cast off/Docking* sequence, a rudder angle indicator was added, while in the *Driving* sequence, a compass indicating the current heading was introduced. The designs of these two elements were explored in detail.

For the rudder angle symbol, both functionality and visual design were considered equally important and therefore explored. Variations with different symbol sizes and angle number presentations were developed, as well as the addition of colors indicating port and starboard, as shown in Figure 53.

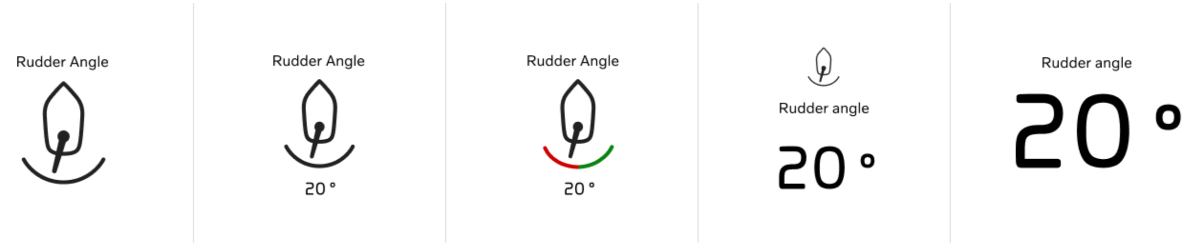


Figure 53. Different variants of a rudder angle symbol.

For the heading visualization, several compass designs were tested, as shown in Figure 54. The variants differed in both appearance and functionality, for example, whether the needle should rotate with changes in heading, or if the entire circle and degree markings should rotate instead.

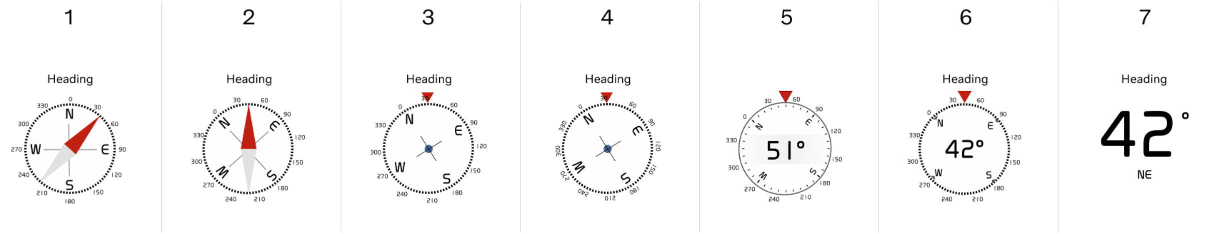


Figure 54. Different variants of a compass.

Evaluation with users

When evaluating how the rudder angle should be visualized, all interviewees said they wanted to see a dynamic symbol that actively displayed the rudder's position, along with a number. "This way, you get a quick overview while also having precise degree readings", explained one driver.

There was also a request from two drivers to color-code the port and starboard sides of the boat to further indicate the rudder's position. "Just the degree reading can make it difficult to know whether it's port or starboard, but the colors make it clearer", said one driver.

Regarding how the interviewees preferred heading to be presented, all participants said they wanted some form of compass, as it was more clear than just displaying direction with numbers. However, the responses varied in terms of how the compass should look. Two drivers preferred a compass with the direction in numbers at the center, as one of them explained, “With this, I can clearly see the cardinal directions and also exactly what course I'm on”. Two other drivers, on the other hand, preferred a more traditional compass with two opposing needles, explaining that it felt more like using a real compass. Regardless of the preferred style, all drivers agreed that the numbers and cardinal directions should rotate, while the needle should remain stationary.

Among the survey respondents, option 7, a digital compass displaying only the heading as a number, was the clear favorite, receiving 6 out of 14 votes, see Figure 55. Options 1 and 6 each received three votes, while option 5 received two votes.

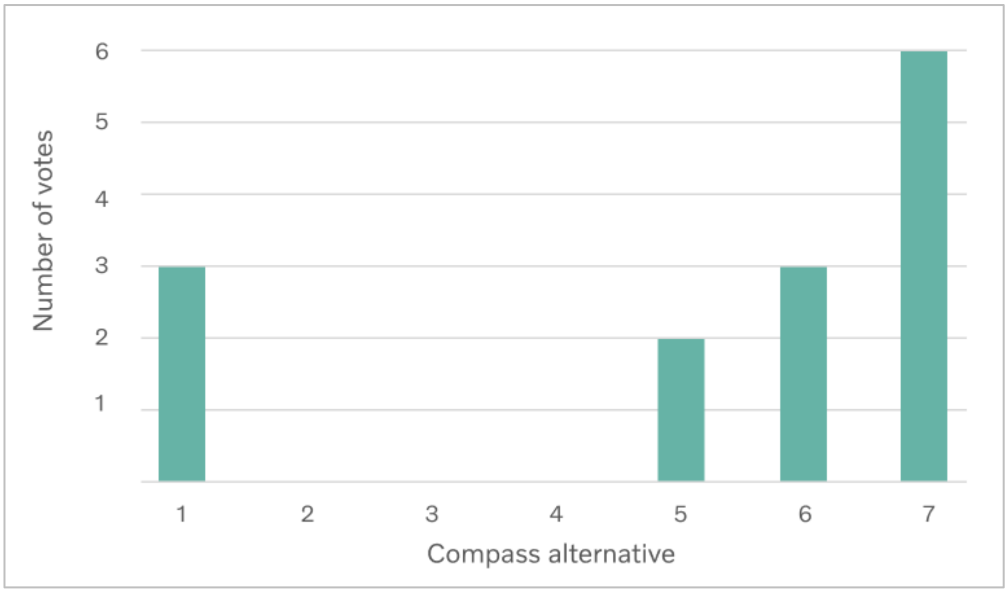


Figure 55. The distribution of votes for the different compass alternatives.

The main reason for the preference toward the digital compass was its simplicity. One respondent explained “Because I'm so used to steering by numbers, all the moving circles are mostly confusing, but they can be useful for a less experienced helmsman”. This response highlights a difference in experience levels, with more experienced users favoring the directness of numerical information.

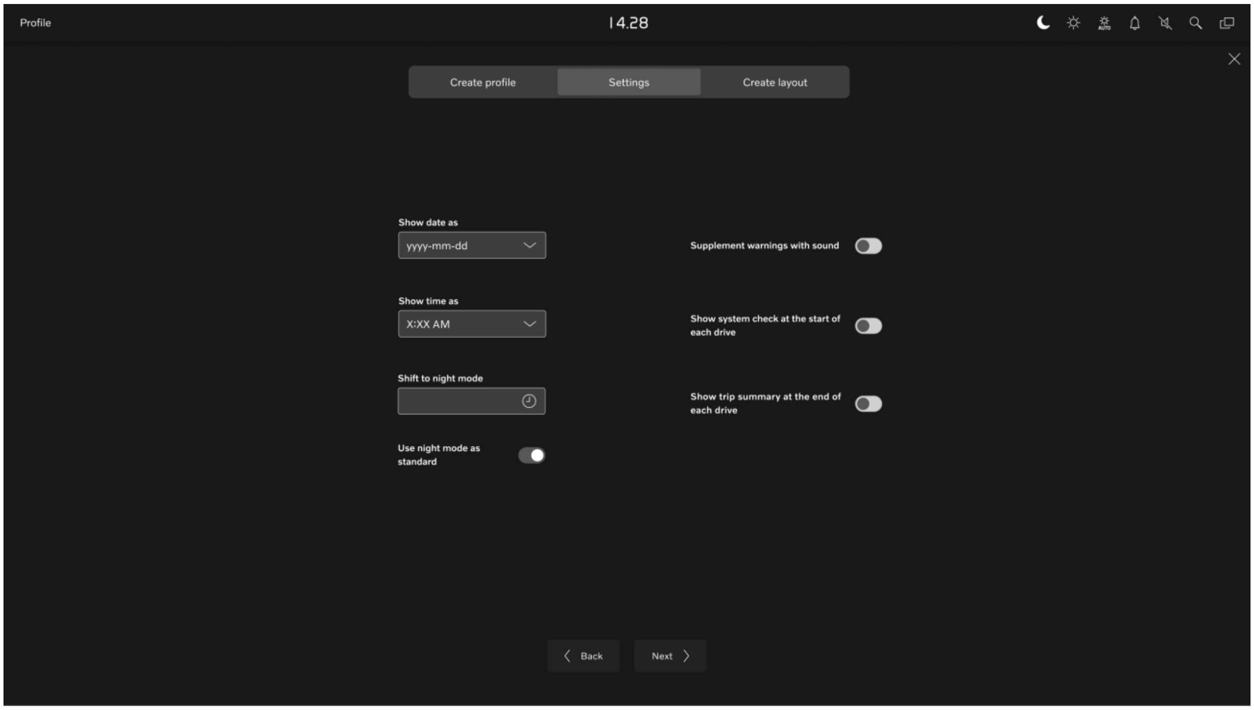
Regarding compass number 6, another respondent uttered “Heading as a digit is important. It’s also valuable to get a quick real compass. No. 5 or 6 fulfills both needs”. This indicates that while digital heading is crucial, some users appreciate a hybrid design that includes both numeric and visual compass elements. Interestingly, two respondents suggested combining elements of options 1 and 6, proposing a design that incorporates the digital digits from number 6 into the layout of number 1.

What is particularly notable is that these results contrast with earlier evaluation interviews, where no one preferred a digit-only compass. If this is a consequence of the different evaluation formats, or if it simply is different opinions, is difficult to assess.

To summarize, a notable difference between the survey results and the interviews was the preference for how heading information should be visualized. Nearly half of the survey respondents preferred the heading to be displayed as numbers only, without a compass, whereas all interview participants favored the use of a compass. However, there was greater consensus regarding the preferred compass design, participants tended to favor either the version with numbers at the center or the more traditional layout with opposing arrows.

9.2.10 Dark Mode

The Volvo Experience System, which was used as the foundation for the new user interface, differs significantly from the current interface design. The Experience System uses light mode as its default, whereas the existing Glass Cockpit interface primarily uses dark mode. Although the project team was instructed to follow the Experience System guidelines, a dark mode variant was also explored, see Figure 56. Initially, dark mode was intended as an option for nighttime driving only. However, it was further investigated to determine whether operators might prefer it as the standard mode. In the dark mode, the color scheme is inverted, elements that are white in light mode become black, and black elements become white.



Show date as: yyyy-mm-dd

Show time as: X:XX AM

Shift to night mode:

Use night mode as standard: ●

Supplement warnings with sound: ○

Show system check at the start of each drive: ○

Show trip summary at the end of each drive: ○

Figure 56. Example of the dark mode.

Evaluation with users

When evaluating whether the respondents preferred a dark or light mode for the interface, most said they favored the light mode but wanted the option to switch to dark mode when it got dark outside. This was primarily because the light mode could risk blinding the driver and distracting them from navigation. “Dark mode is good when you're driving at night, but during the day I prefer the light theme”, one driver said. However, one driver preferred the dark mode, explaining that it felt more clear and easy to read.

9.2.11 Summary

To summarize, this chapter presented several design concepts and their evaluation through user feedback. The evaluations revealed that most of the designs were well received by the operators, indicating that the proposals effectively addressed existing problems or fulfilled other operator needs.

However, some areas for improvement were identified based on the feedback provided. The autopilot was a design proposal that received some criticism. The compass rose was considered unclear and did not provide any real value for certain boat operators. There were also requests for more clear indicators when gauges approached critical levels. Additionally, one operator suggested that the data in the System Check and Trip Summary should be prioritized by importance, with the most critical information displayed first. Lastly, the importance of having access to a quick profile with standard views was emphasized, for operators who do not need or want to create their own profile or personalize their views.

The features that received the most positive feedback included, first and foremost, the overall design of the profile creation process. It was regarded as simple and intuitive, contributing to a more user-friendly and effective display experience. The system check and trip summary were also well-received, as they provided both useful information and engaging details about the journey, fostering a sense of control and reassurance. Additionally, several smaller design elements, such as gauges, symbols, and banners, were considered improvements over the current interface.

10. FINAL DESIGN

The project resulted in several sub-concepts that demonstrate how the Human Machine Interface in future digital displays in yachts can be designed, with an emphasis on usability and safety. These will be presented in the following sections. The different sub-concepts are based on the findings from the empirical studies, which highlighted areas of interest and opportunities for improving usability. See Figure 57 for a visualization of the final concept on a boat display.

Figure 57. The final design displayed on a screen in a boat. Used and modified with permission Volvo Group.[11]

10.1 My Profile

The new feature *My Profile* enables users to create and save their own preferences. This feature supports several stages in Wickens' model for human information processing by fostering familiarity, which particularly aids the perception stage, reduces the workload on working memory, and ultimately simplifies decision-making. The *My Profile* feature was added in response to users' need to save their settings without them being altered when another boat operator uses and reconfigures the boat display. By allowing users to save and recall their personalized views and configuration preferences, the feature

---

[11] Volvo Group. (2022). *Glass cockpit shoot 2022* [photograph]. Retrieved May 8, 2025, from https://media.volvogroup.com/dam/contentitems/726024c64a464e34acbdb0a3015609ce

helps streamline the overall user experience. It is designed not only to save valuable time but also to enhance user satisfaction by ensuring consistency and familiarity each time a user returns to the vessel.

When the display is activated, the operator is greeted by the start page, see Figure 58. Here, the user can select an existing profile, create a new one, or use the *Guest User* profile, which includes predefined settings based on the most common preferences among operators.

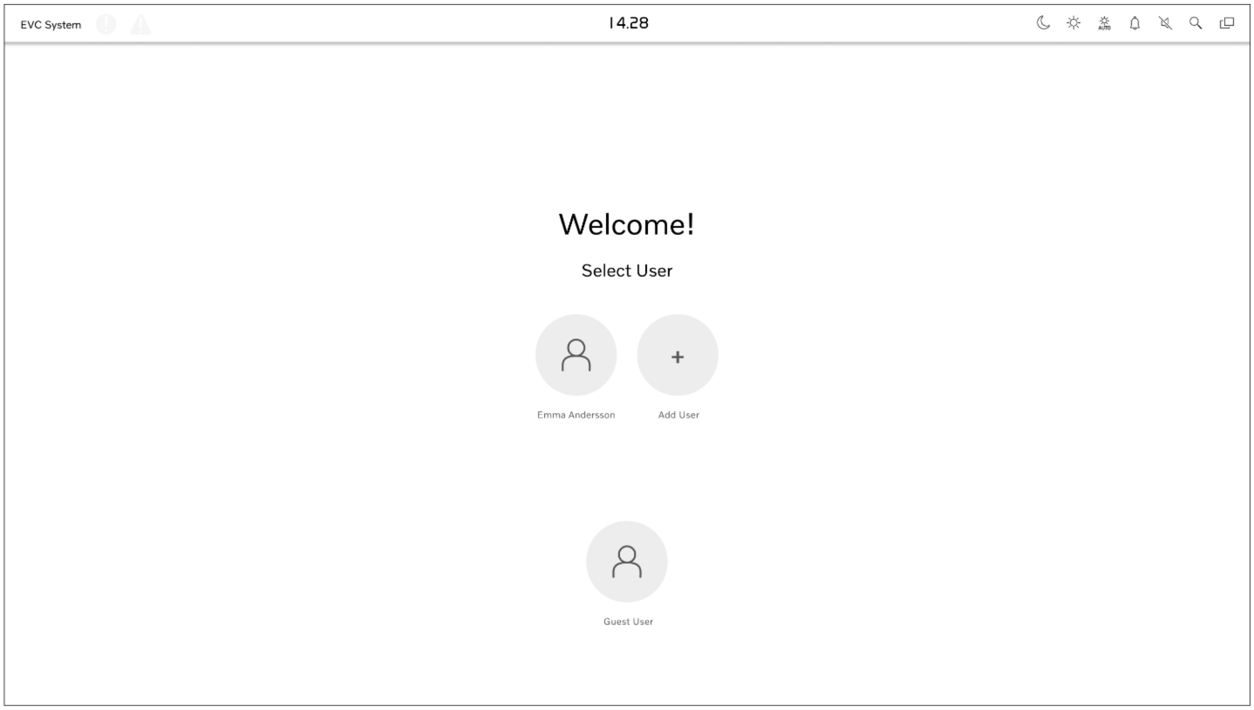
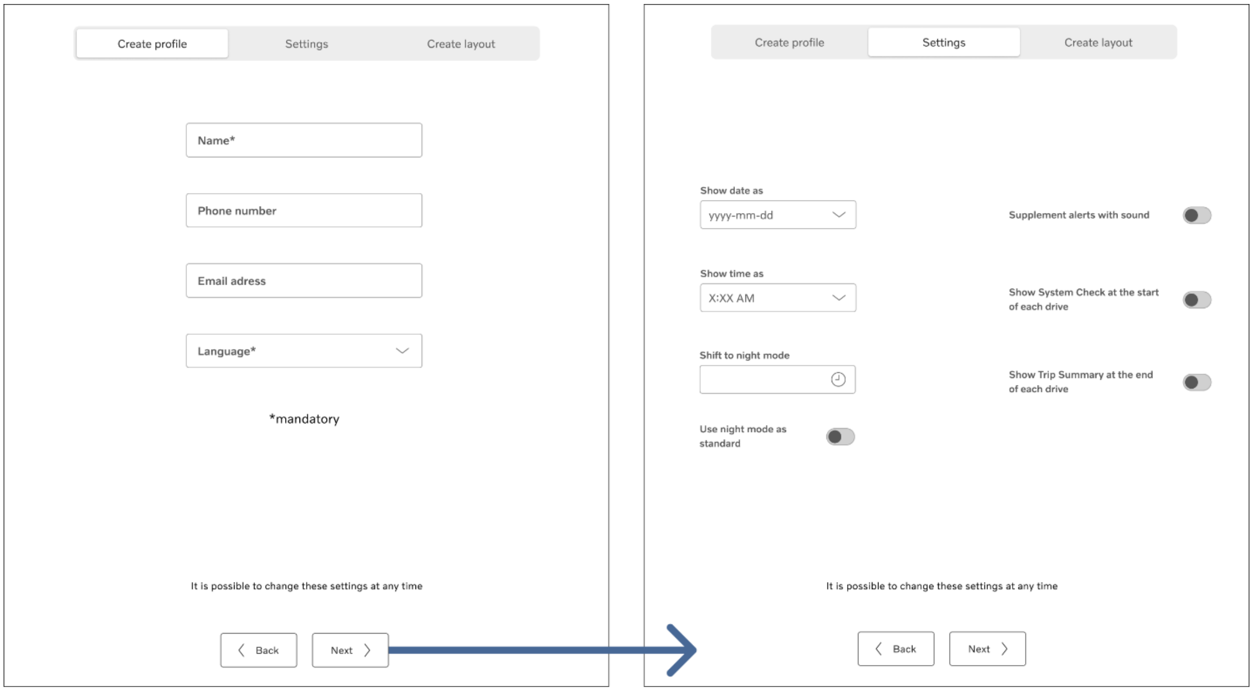


Figure 58. Welcome page in the My Profile feature where the operator can select or create a new user, alternatively use the guest profile.

To create a new profile, the user follows a three-step process. The first two steps are *Create Profile* and *Settings*, see Figure 59. In the *Create Profile* step, the user enters their name, phone number, email address, and preferred language. Providing an email address and phone number is not mandatory; however, if the user chooses to do so, they can receive updates about the display and other notifications related to the EVC system. After clicking 'Next', they proceed to *Settings*, where they can configure how the date and time are displayed, choose whether the display should automatically switch to dark mode, or remain in dark mode permanently, and decide if alerts should include sound. They can also choose whether the *System Check* and *Trip Summary* should be displayed at the start and end of each trip.



It is possible to change these settings at any time

Show date as: yyyy-mm-dd

Show time as: X:XX AM

Shift to night mode

Use night mode as standard

Supplement alerts with sound

Show System Check at the start of each drive

Show Trip Summary at the end of each drive

It is possible to change these settings at any time

Figure 59. Two first steps of My Profile, creating a profile and settings.

In the final step, *Create Layout*, the user customizes the layout of the display and selects which functions and data should be shown in their preferred view, see Figure 60. At the top of the screen are the recommended views, the default layouts from the Guest profile, followed by various layout templates to choose from.

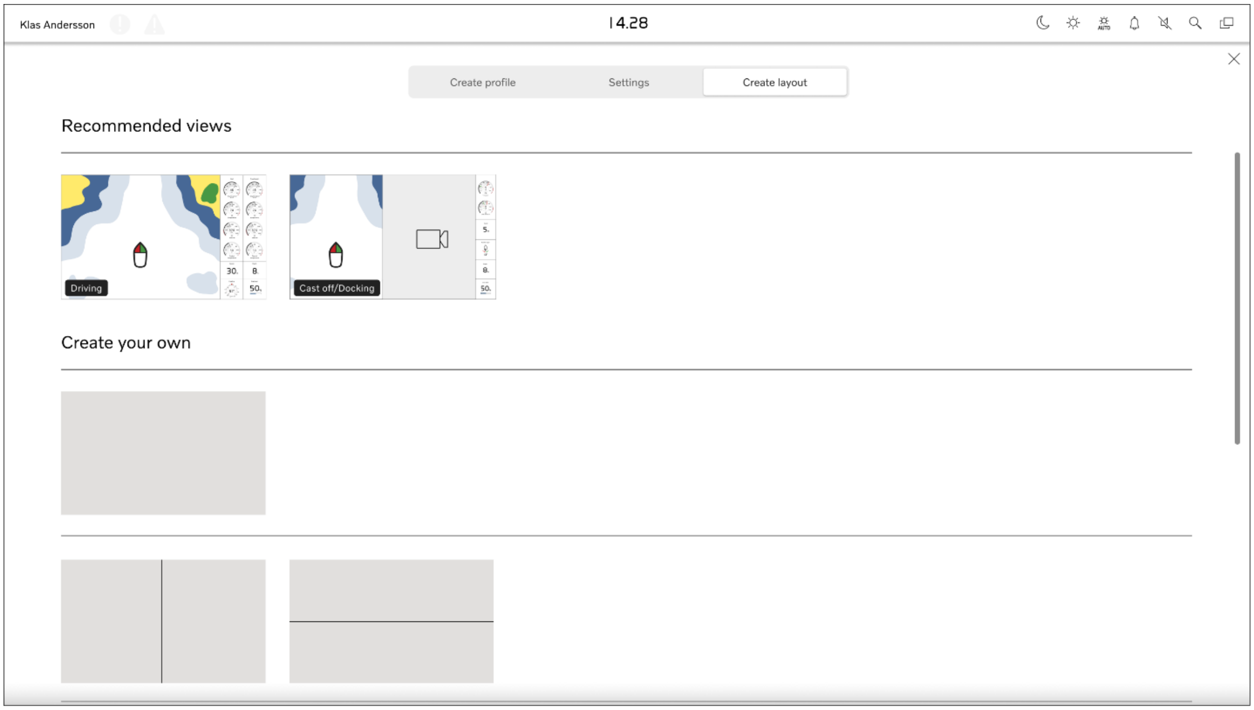


Figure 60. Last step of My Profile, creating a layout or choosing one of the recommended views.

After selecting a layout, the user can further customize it by resizing individual sections and adding new ones for greater flexibility and structure, see Figure 61. If the operator changes their mind about the selected layout, they can click 'Back' or 'Change layout' to return to the previous page.

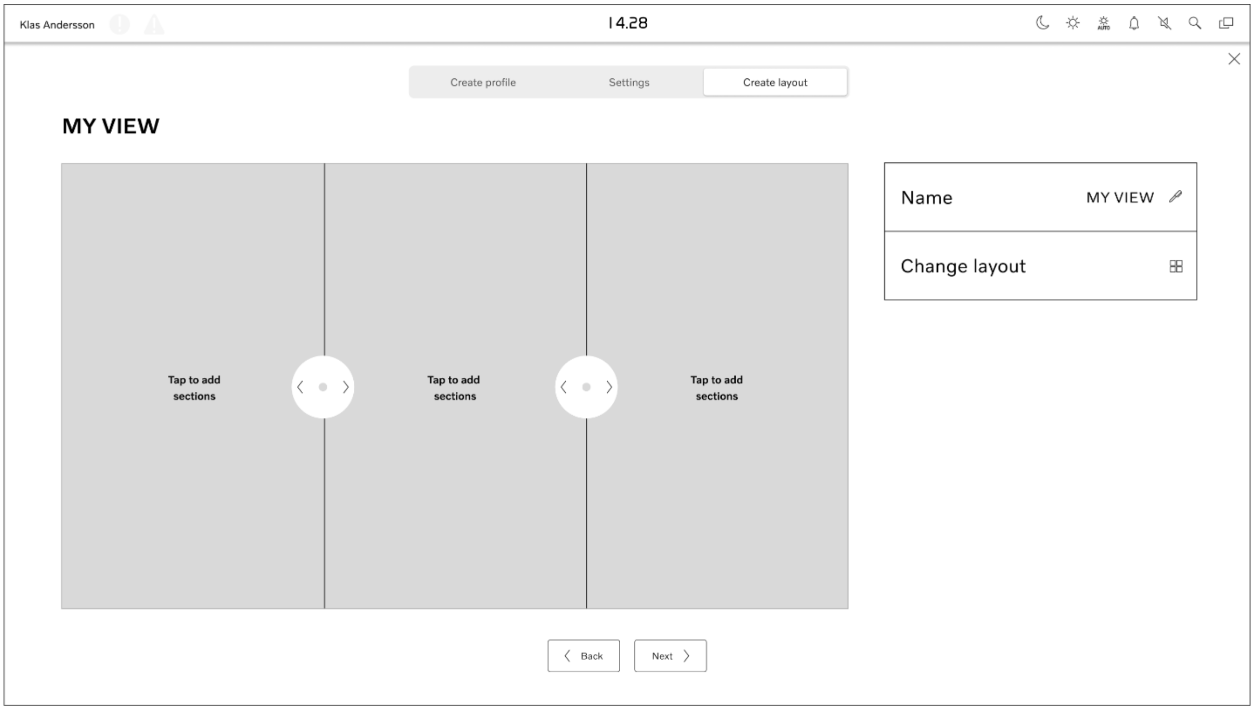


Figure 61. The option to modify the layout and assign a name to the view.

Once the user is satisfied with the layout, they click *Next* to move on to the following page, where they can choose the types of data and functions to display in each section, see Figure 62. To streamline the process and reduce the number of clicks, the leftmost section is automatically selected first. This aims to minimize the time it takes for the user to create a desired layout and thereby reduce cognitive workload. If the user prefers to configure a different section of the layout instead, they can simply click on one of the grey sections labeled 'Tap to select', which will then become active and change color to white with the label 'Choose data'. The user can then select from the available functions and data in the scroll menu on the right. Some functions, such as the chart plotter, occupy an entire section, while others, like engine data, include submenus that enable more specific selections, for example, if the user only wants to add a gauge for engine speed.

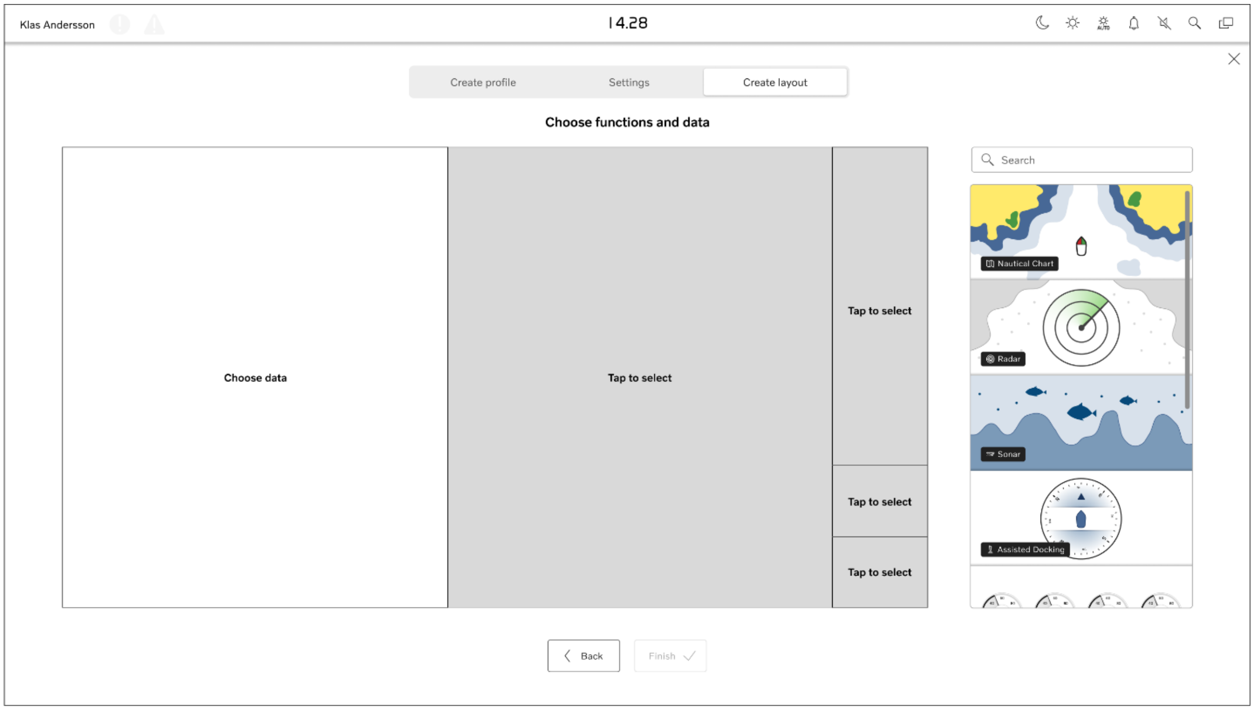


Figure 62. When choosing between data and functions for the layout, the leftmost section is automatically selected.

To create a more cohesive and consistent interface, the design of the scroll menu's functions and data has been revised, see Figure 63. The design adopts a minimalist approach, featuring a reduced color palette and less details, making them more visually soothing.

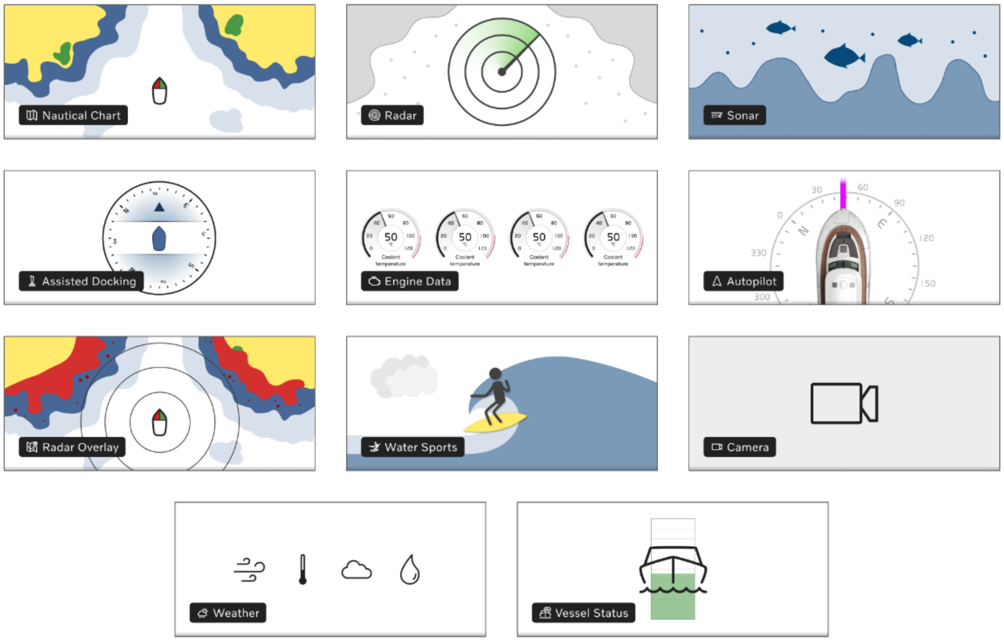


Figure 63. The final design of the list of functions in the scroll menu.

If the user selects the wrong data from the scroll menu, they can press and hold the selected data in the layout. A 'Remove' button will then appear, allowing them to delete the function, see Figure 64. If the user regrets their decision, they can simply press 'Cancel' or tap anywhere outside the 'Remove' button to dismiss it. This feature is designed to make it easy for the user to correct any errors if they accidentally select data or a function they do not want displayed in their layout.

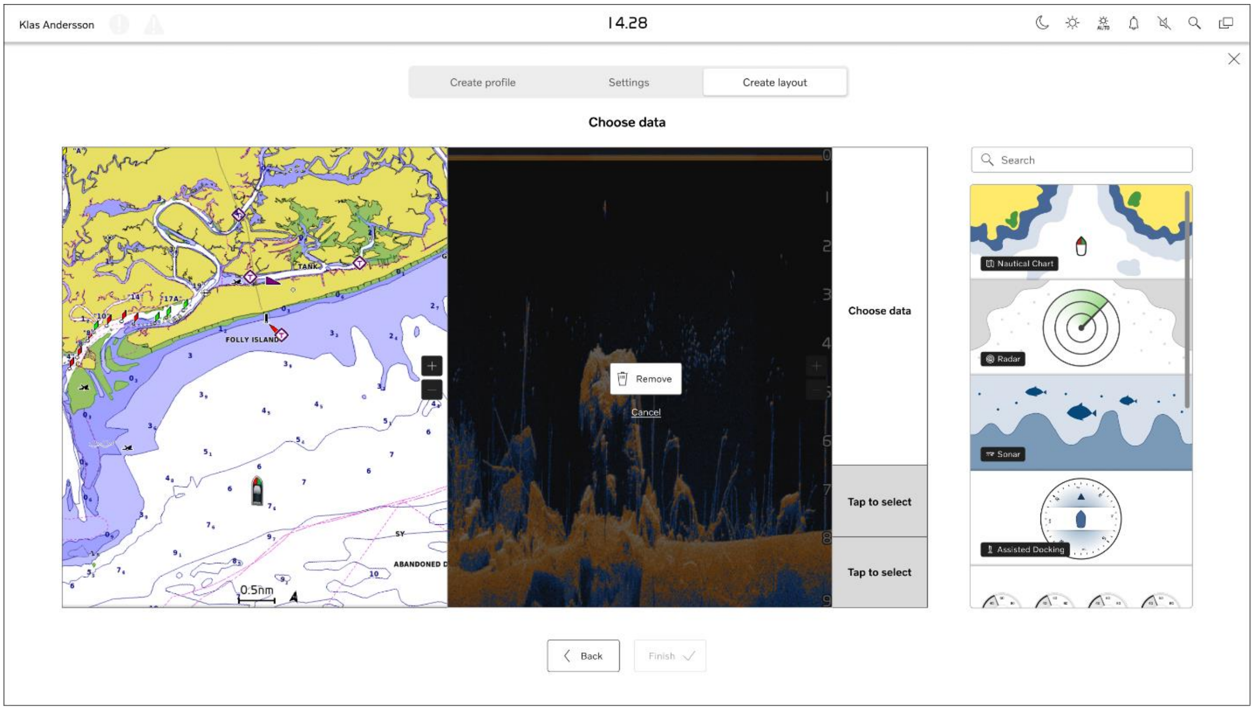


Figure 64. The option to remove data from the layout.

When the user selects engine data, they are automatically directed to a new menu where they can choose to display the data in either separate gauges or a combined gauge, see Figure 65. If the driver prefers to view the data as plain numbers, they can tap the gauge in the layout to switch from a graphical to a numeric gauge.

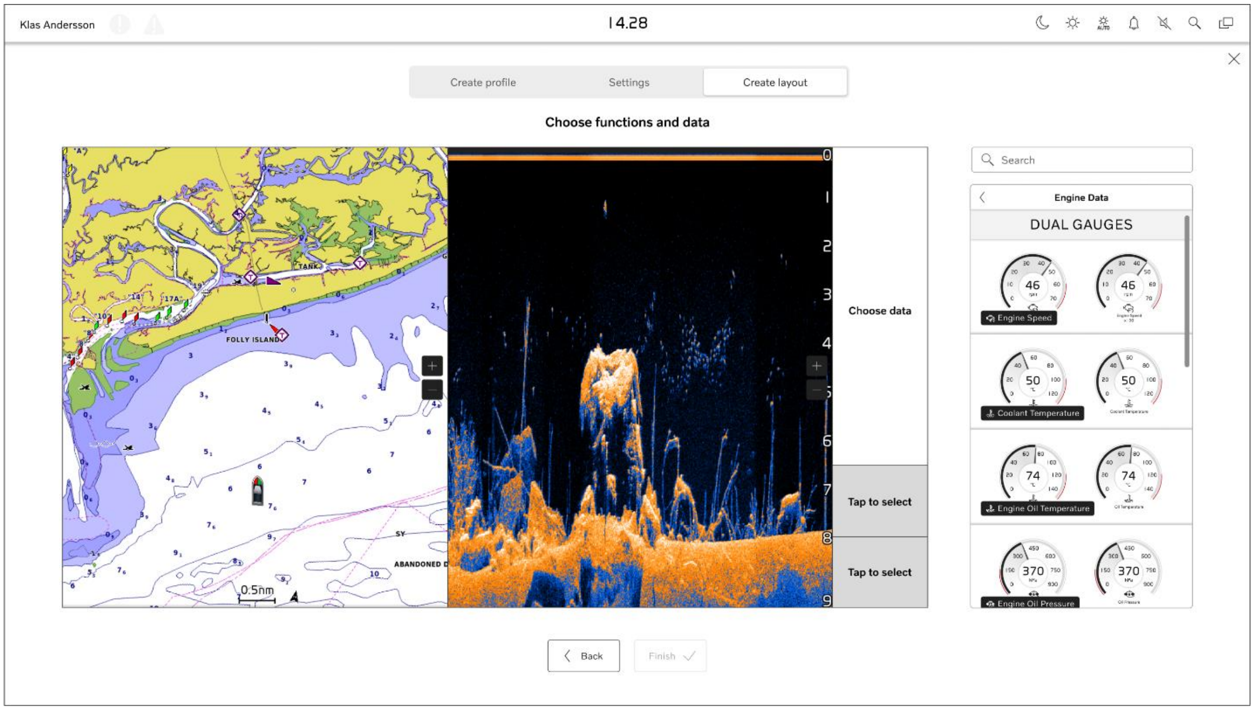


Figure 65. Submenu in the scroll menu for different visualizations of engine data: either in separate gauges or a combined gauge.

If the user is unsure where to find what they are looking for in the scroll menu, they can use the search function located above, see Figure 66. When the user taps the search bar, a keyboard appears at the bottom of the screen. As the user begins typing, the search function starts suggesting results. Recent searches are displayed at the top, followed by recommended results listed in alphabetical order. This design choice aims to enhance usability by making it faster and easier for users to locate specific data. The inclusion of recent searches and alphabetically ordered suggestions improves efficiency and supports both habitual and first-time users in quickly finding relevant content.

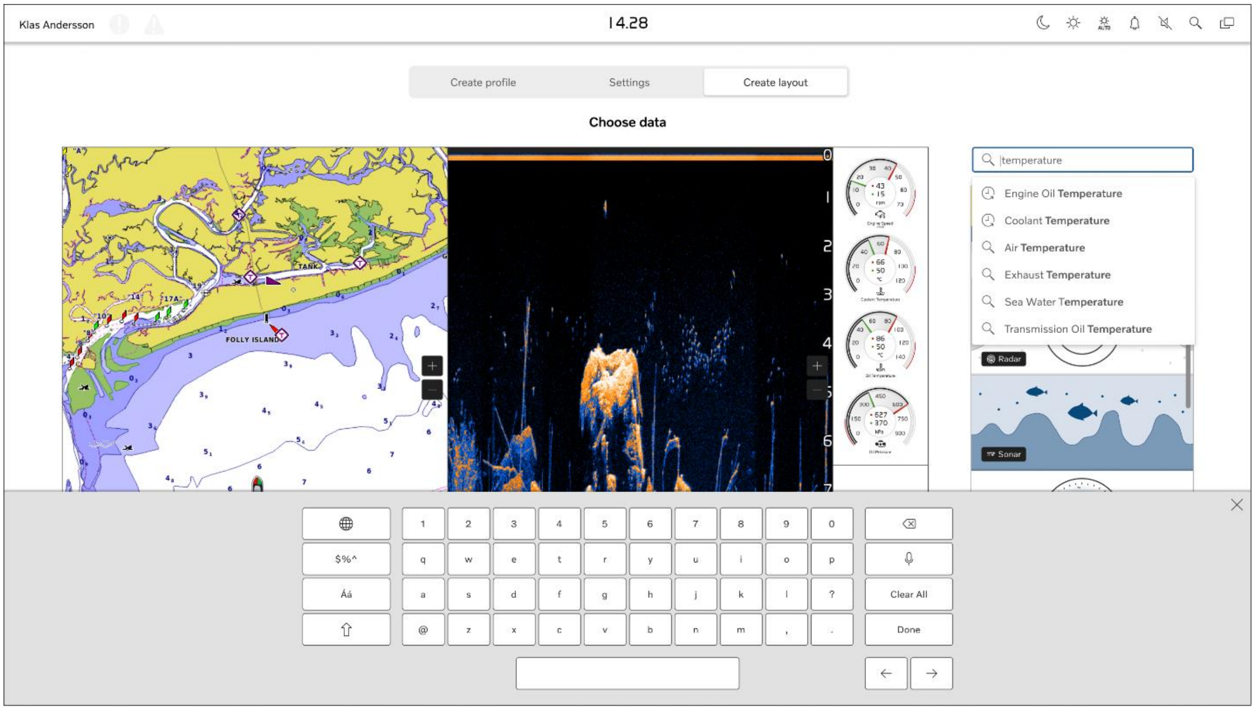


Figure 66. The keyboard and the search function with suggested results for 'temperature'.

All sections must be filled with functions or data before the user is allowed to save the view. To ensure this, the 'Finish' button remains inactive until all required sections are completed. This design choice helps guide users through the process, reducing the risk of incomplete or incorrect setups. After completing the layout and clicking the *Finish* button, the customized view is saved and will appear under *Saved Views*, see Figure 67. The driver can now choose to create additional views or select one of the existing ones to begin the trip.

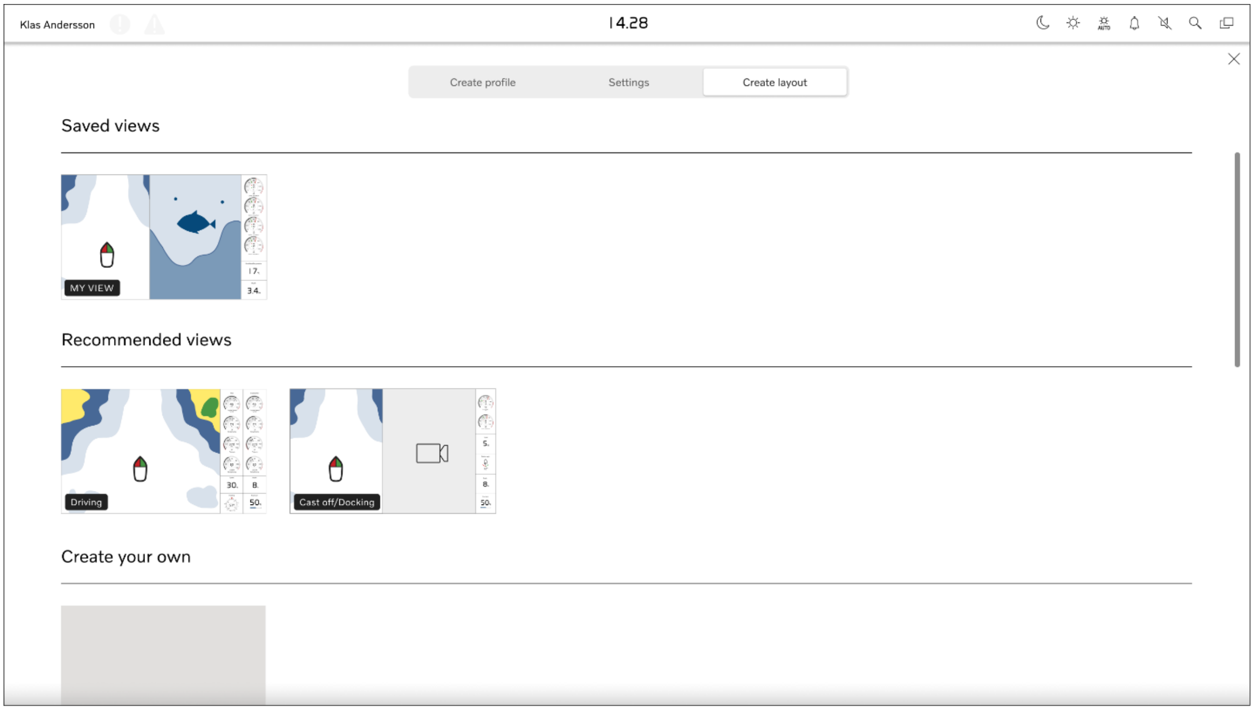


Figure 67. The newly created view visible under 'Saved views'.

This feature, along with the top bar displaying the driver's name, is designed to create a more personal connection to the display, ultimately enhancing the overall user experience. By offering views that are customized to the driver's specific needs and preferences, the design seeks to foster a sense of ownership, making the interface feel more intuitive and aligned with the individual user. This personal touch not only aims to improve usability but also strengthen the emotional bond between the driver and the system.

10.2 System Check

After the operator selects a view in *My Profile*, a *System Check* will appear, if the user has enabled this option in their settings. This feature is designed to give the operator a clear and reassuring overview of the boat's tank status, fostering a sense of control and peace of mind. By presenting this critical information early in the process, it helps ensure that any potential issues are identified before the boat leaves the harbor. This proactive approach reduces the risk of unexpected problems during the journey, enhancing safety and allowing the operator to address concerns promptly and confidently.

The final design of the *System Check*, see Figure 68, displays four key data points: fuel level, battery level, grey and black water levels, and fresh water level. These levels are visualized using vertical bars, with color coding to indicate severity, green for normal, yellow for caution, and red for critical levels. The colors dynamically change according to the tank's status.

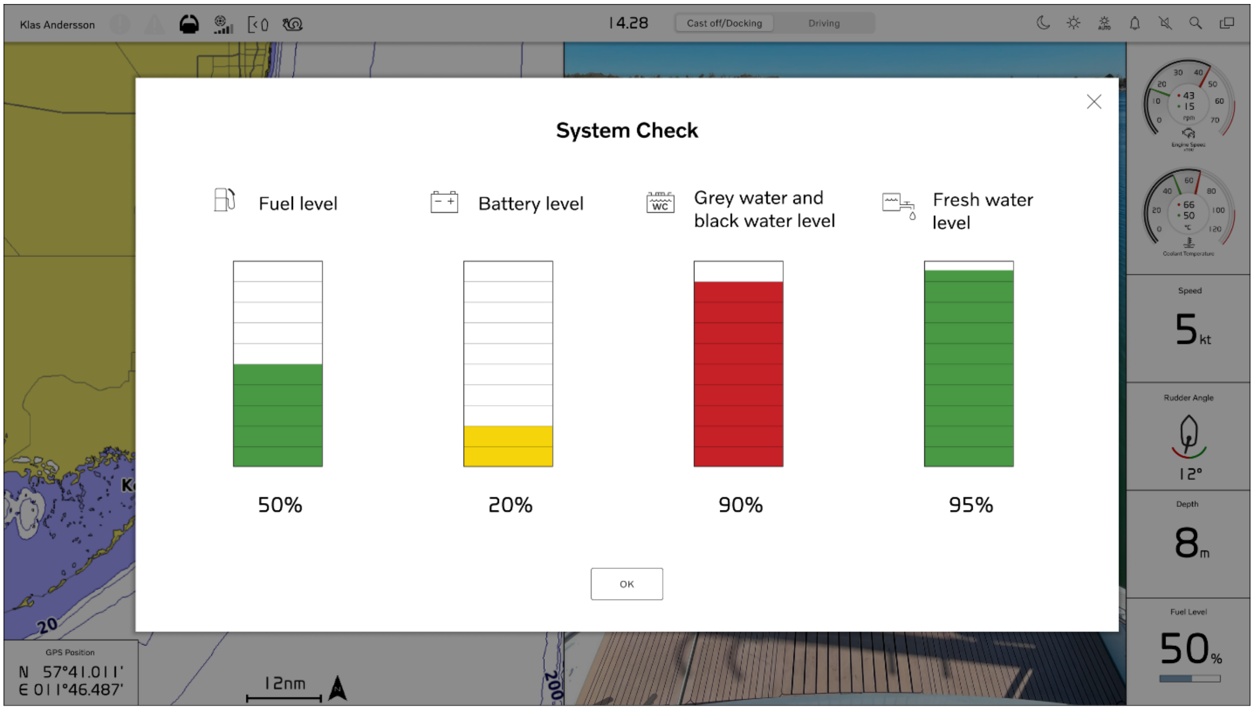


Figure 68. The final design of System Check.

This design was a result of the user feedback from the evaluations. Users appreciated the vertical bars and color coding, noting that it made the information easy to interpret at a glance, which indicates that this design supports the stage of perception in Wickens' model for human information processing. They also found it easier to remember the levels without needing to read exact values, as they could quickly scan the colors and relative bar heights, leaving more space for other things in the working memory.

The ordering of the bars was influenced by a suggestion from one operator, who recommended arranging them based on their importance to the vessel's operation. As a result, fuel and battery levels, which were considered more critical, are placed to the left, aligning with the natural left-to-right reading direction. This reflects Jordan's (2002) principle of prioritization of functionality and information by making essential data more immediately accessible.

The *System Check* feature will automatically pop up when the engine is started and will disappear once either the OK button or the close, 'X', button is pressed. When creating a user profile, operators can choose whether the *System Check* should appear or not at startup, helping to avoid unnecessary interruptions and potential frustration for users who do not require this information.

10.3 Recommended Views for Different Driving Sequences

An important takeaway from the interviews was one respondent's desire to switch between different driving modes, as the information needed on the display varies depending on the driving sequence. This observation proved to be relevant for most operators, who mentioned they preferred seeing different information on the screen when casting off, while driving, and when docking. The information needed during departure and docking was found to be quite similar, whereas the driving mode required a different set of data.

This insight led to the creation of two recommended views: one for *Cast off/Docking* and one for *Driving*. These views were designed for users who may not want to, or have time to, create their own layouts in the *My Profile* feature presented earlier. They also serve as the default views for the guest profile. The content shown in these views is entirely based on the results from surveys and interviews and has gone through a full cycle of user testing and redesign.

10.3.1 Driving Sequence

When navigating on open water, it was particularly important for the drivers to know where they were headed and what potential obstacles laid ahead of the boat. Based on this, a proposal for the recommended *Driving* view was developed, see Figure 69. The most important function during navigation was the nautical chart, which assists the operator with route planning and real-time positioning on the water. Following that, specific engine data and additional operational information were also considered essential. The engine data displayed includes engine speed, engine oil temperature, engine oil pressure and coolant temperature. Other key data shown includes boat speed, water depth, heading and fuel level. In addition, precise coordinates are displayed in the bottom-left corner of the screen. The coordinates were included for safety reasons, as many drivers highlighted the importance of being able to quickly relay their location in the event of an accident or similar incident.

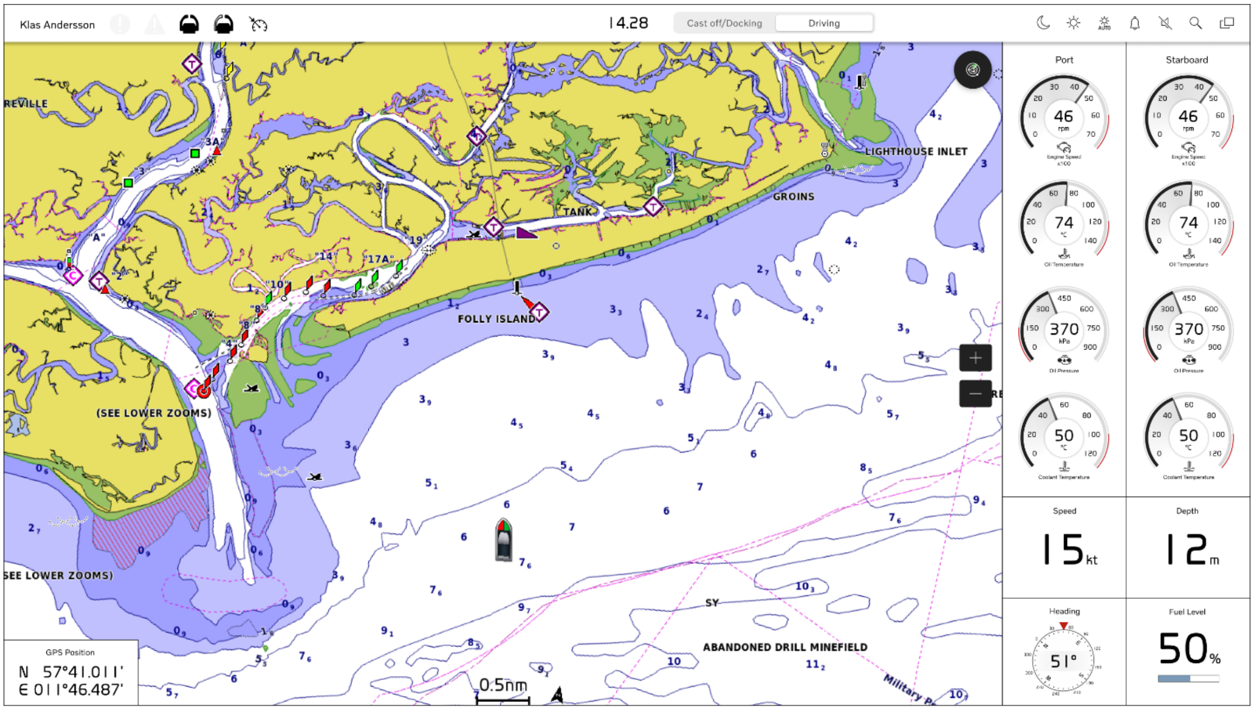


Figure 69. The final design of the Driving sequence view.

Moreover, radar was frequently mentioned as well, primarily used as an overlay on the chart. For those who relied on radar, it was seen as essential, though not all operators used it regularly. As a result, a Radar Overlay shortcut has been added to the upper right corner of the nautical chart, providing quick access for those who prefer to use it. The symbol for Radar Overlay, however, has been modified following user feedback. Many drivers felt it lacked clarity and suggested that it should resemble traditional radar symbols. Based on this, a needle has been added to the symbol, along with a subtle green gradient, see Figure 70. These changes aim to make the function more intuitive and easier to understand, consequently facilitating perception.

Figure 70. The final design of the Radar Overlay button.

While navigating in open waters, drivers preferred to view engine data split across two separate gauges. This layout made the information easier to interpret compared to when it was combined into a single gauge. Drivers also favored having labels above the gauges indicating port and starboard sides, rather than using color-coded needles to differentiate them. Additionally, most respondents expressed a desire for the gauges to include both text and symbols, making it easier to identify the type of data being displayed. Based on this feedback, a final design for the engine data gauges has been developed, see Figure 71. At the end of the outer arc, there is a red area representing critical values. If a gauge reaches a critical value, such as an unusually high coolant temperature, the inner circle will light up red, see Figure 72. This visual alert is intended to draw the driver's attention to potentially hazardous conditions.

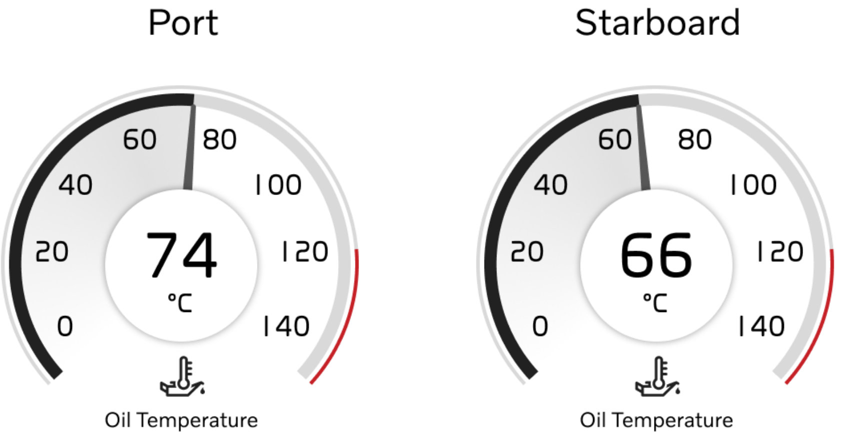


Figure 71. The final design of the gauges in the Driving operating sequence.

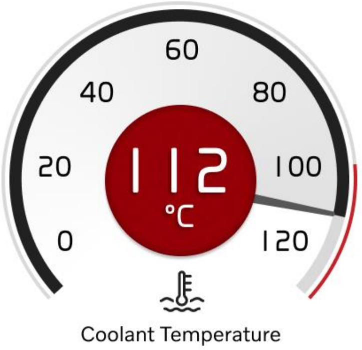


Figure 72. A gauge indicating high coolant temperature.

Based on the user study and evaluation, a new design for the heading has also been developed. Users expressed a need to view direction using cardinal points, along with a dynamic compass that clearly indicated changes in direction. This design was preferred because it closely resembled a real compass, making it easier to read and interpret. At the same time, several drivers also wanted to see an exact numerical value of the current heading. As a result, the heading was visualized using a circular compass along with numbers displayed at the center, aiming at supporting perception, see Figure 73. At the top of the compass, a red triangle indicates the current direction, while the numbers and cardinal points rotate around the compass in sync with directional changes.

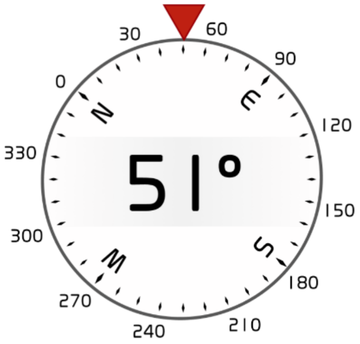


Figure 73. The final design of the heading compass.

The interviews revealed that the Autopilot design in the Glass Cockpit is currently considered unnecessarily large, occupying a significant portion of the screen. The design proposals from the first iteration were also viewed as too large. As a result, a new Autopilot design was developed, see Figure 74. The new design features a more narrow banner. At the top of the banner, the Autopilot's status is displayed, such as "Standby" or "Engaged," followed by the selected Autopilot function. Respondents also criticized the compass rose used in the original design, finding it unclear and difficult to read. Furthermore, they felt it provided little useful information, with one driver stating that they could more easily read the direction from the compass on the right engine list. In response, the compass was removed and replaced with an image of a boat featuring marked directions, where the orange line represents the current heading, and the pink line shows the set course of the Autopilot. These lines are also displayed on the chartplotter, allowing the driver to understand the Autopilot's intended course and make adjustments if obstacles or other hazards are present.

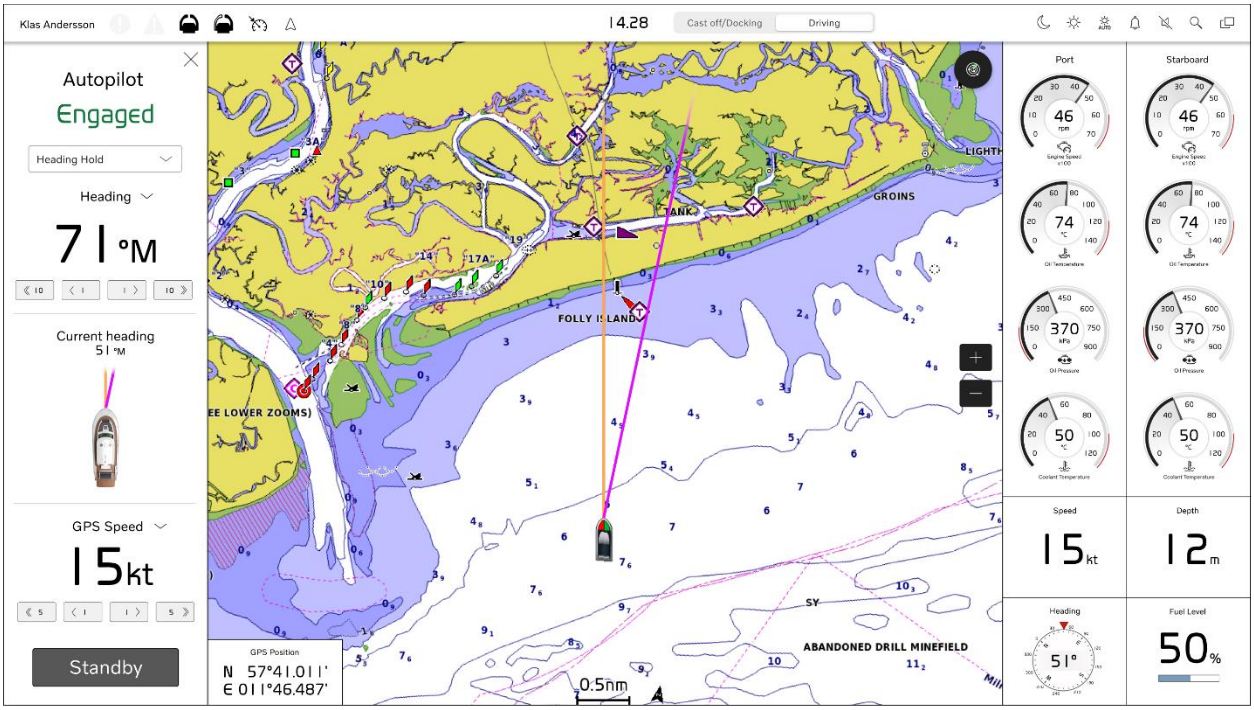


Figure 74. Driving sequence with Autopilot activated.

The content of the banner changes depending on the selected function, see Figure 75. For 'Heading Hold', the Autopilot's heading is shown along with buttons to adjust it, as well as the GPS speed the boat should maintain, with buttons to increase or decrease this speed. For the 'Pattern Steering' function, the time for the pattern steering operation is displayed, along with the selected pattern the boat will follow. Under 'Circle' the operator can choose between other patterns, such as zigzag, U-turn, Williamsson turn, cloverleaf, and spiral. GPS speed is also shown in this mode. Additionally, the GPS speed can be switched to engine speed [RPM] if the driver prefers to set the speed based on engine revs.

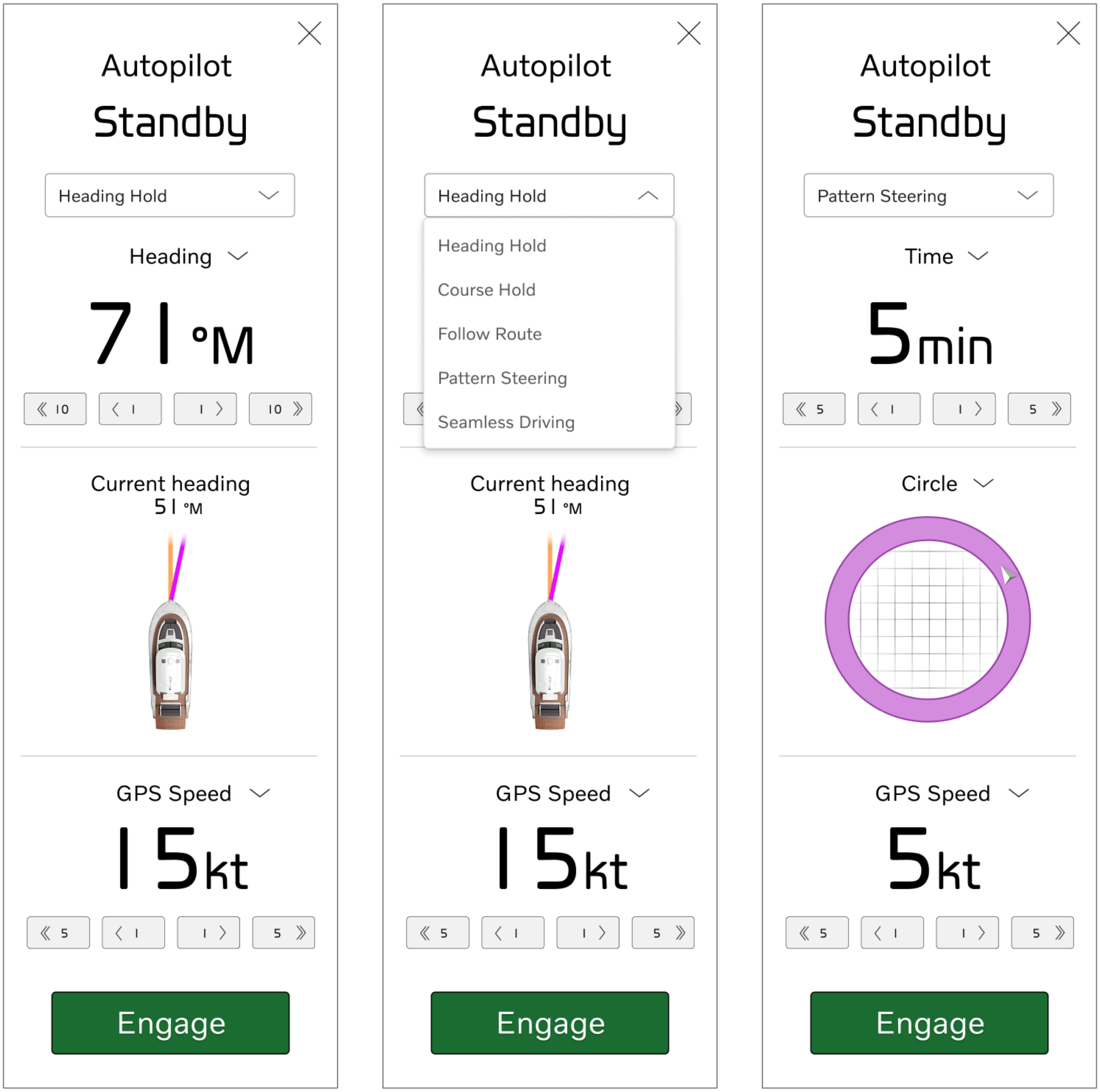


Figure 75. The final design of the Autopilot banner, displaying different functions available.

10.3.2 Cast off/Docking Sequence

Engine data was not considered as important for drivers during the *Cast off/Docking* sequence. The engine data was primarily used to provide operators with confirmation that everything was functioning properly, but it was not closely monitored beyond that during this sequence. Additionally, the amount of engine data deemed relevant was smaller compared to the *Driving* sequence, and based on user feedback, it has been reduced to display only engine speed and coolant temperature. Instead, information such as depth, speed, and rudder angle were deemed more critical. Fuel level was also of interest to some drivers, particularly if they had not already seen it in the *System Check*. Additionally, drivers preferred to allocate more screen space to the chart plotter and the stern camera, or the sonar when anchoring in a natural harbor. As a result, the engine data banner on the side has been reduced to half its original size, with the purpose of keeping attention on what is important at the time. See Figure 76 for the recommended view for *Cast off/Docking*.

GPS Position
N 57°41.011'
E 011°46.487'

Figure 76. The final design of the Cast off/Docking sequence view.

In this view, the engine data is shown using combined gauges to save space, as it was not seen as essential in this sequence to separate them. These combined gauges feature two needles, one for each engine: red for the port engine and green for the starboard engine, see Figure 77. The colors adhere to standard color codes for starboard and port sides on the water. The needles are accompanied by soft gradients and circular arcs around the gauge to further indicate their values.

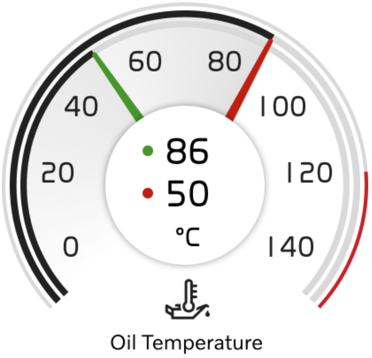
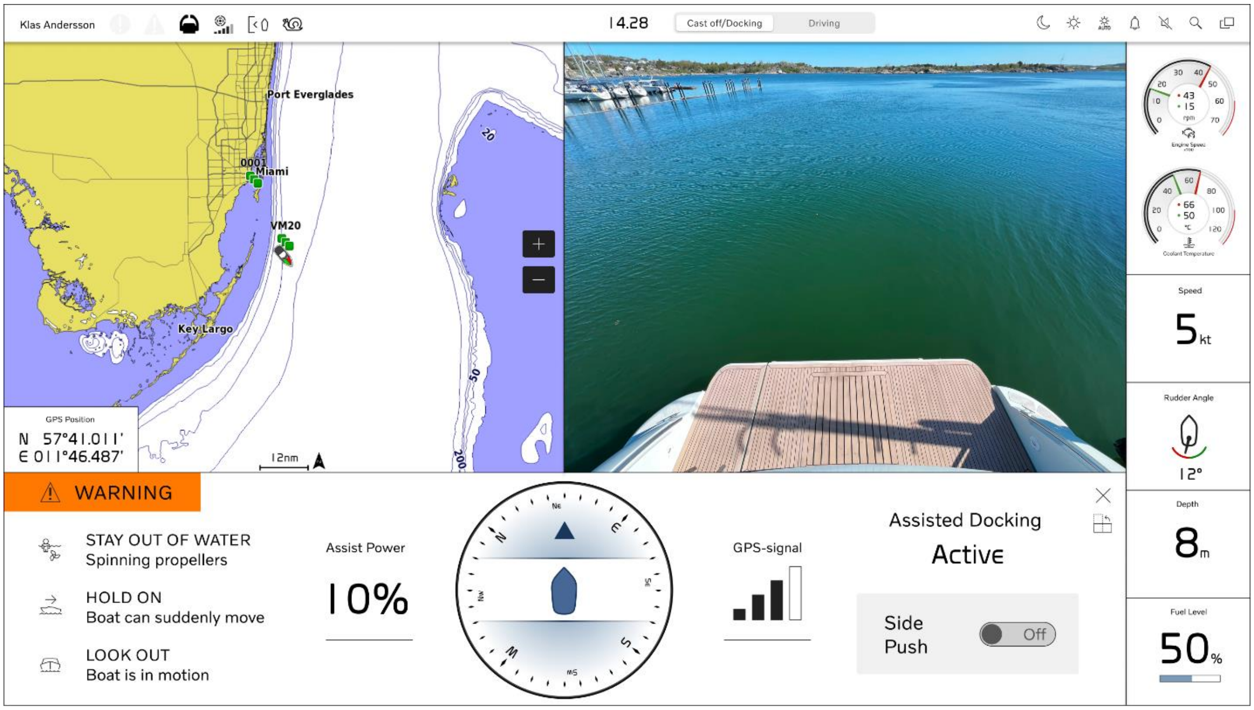


Figure 77. The final design of the combined gauge displaying oil temperature from two engines.

A design for visualizing the rudder angle has also been developed. Users expressed a desire for a dynamic symbol that would actively display the rudder's position in relation to the boat. They also wanted to see the exact rudder angle in degrees, along with an indication of whether the rudder was positioned to port or starboard. Based on this feedback, the following symbol for the rudder angle was created, as shown in Figure 78. The rudder in the symbol moves in sync with the actual rudder of the boat and is color-coded: red for port and green for starboard. This design aims to help the driver quickly assess the rudder's position and predict how the boat will respond when shifting gears, consequently facilitating perception and decision making. The symbol is accompanied by a number at the bottom, which shows the exact angle. When the rudder is centered, the angle is zero. As it moves to the port side, the value becomes negative, while it becomes positive when shifted to the starboard side.

Figure 78. The final design of the rudder angle.

For boats with Assisted Docking installed, this feature will automatically appear on the display once it is activated. There were differing opinions among respondents regarding the design of the Assisted Docking banner. External users felt that the horizontal banner was too large and occupied too much screen space, while internal Volvo Penta employees preferred the horizontal design. As a result, two alternative visualization options have been developed for Assisted Docking: a horizontal banner at the bottom of the screen and a vertical banner along the side, see Figures 79 and 80. To switch between the two modes, the driver can simply click the rotating icon on the top right side of the banner to toggle the layout. The function displays a compass that updates as the driver uses Side Push and similar controls. The driver can view confirmation of whether Side Push is activated, along with the GPS signal strength and the amount of assist power.



STAY OUT OF WATER
Spinning propellers

HOLD ON
Boat can suddenly move

LOOK OUT
Boat is in motion

Assist Power 10%

GPS-signal

Assisted Docking Active

Side Push Off

Figure 79. The final design of the Assisted Docking feature, displayed as a horizontal banner.

Assisted Docking Active

Side Push Off

GPS-signal

Assist Power 10%

STAY OUT OF WATER
Spinning propellers

HOLD ON
Boat can suddenly move

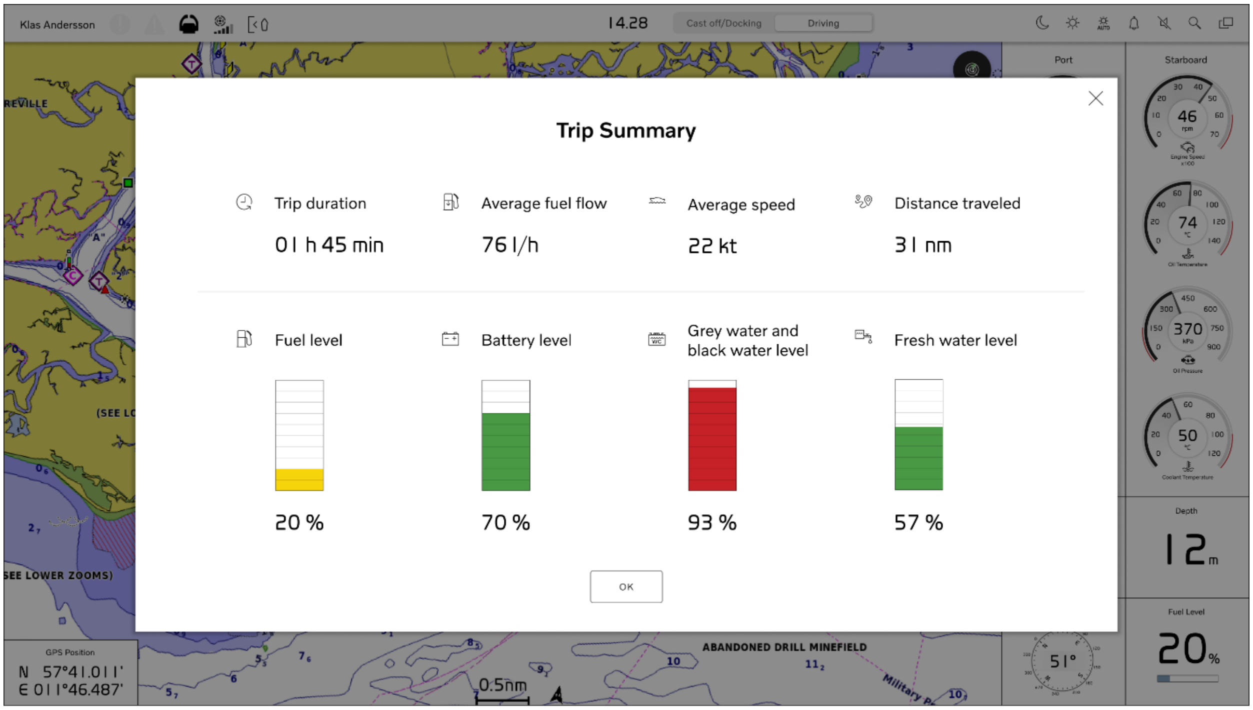
LOOK OUT
Boat is in motion

Figure 80. The final design of the Assisted Docking feature, displayed as a vertical banner.

Due to regulations requiring warnings that the engine is running and that the boat may move, this information must be displayed alongside the vertical banner. This placement ensures that the warnings are visible to the operator at all times. However, to avoid obstructing the interface unnecessarily, users have the option to dismiss these warnings by clicking the 'X' symbol located in the corner of the warning box. To view the warnings again, the operator can tap the orange 'Warning' box, and they will reappear. These warnings are included for the boat operator's safety and are intended to help prevent accidents and related incidents. Including these warnings is a critical safety measure designed to protect the boat operator and others on board by raising awareness of potential hazards. The balance between visibility and possibility to dismiss ensures safety without compromising user experience.

10.4 Trip Summary

The *Trip Summary* feature received overall positive feedback from the respondents. Since the majority of users preferred visual representations, such as bars for vessel status, it was decided to include this in the final design, see Figure 81. However, the trip-related data was seen more as "fun facts" and did not require graphical elements for easy interpretation. This trip-data was viewed as less important to remember afterward, being more interesting in the moment. In contrast, vessel status data was something users preferred to retain, and graphical elements made it easier to recall.



Trip Summary

Trip duration: 01 h 45 min

Average fuel flow: 76 l/h

Average speed: 22 kt

Distance traveled: 31 nm

Fuel level: 20 %

Battery level: 70 %

Grey water and black water level: 93 %

Fresh water level: 57 %

OK

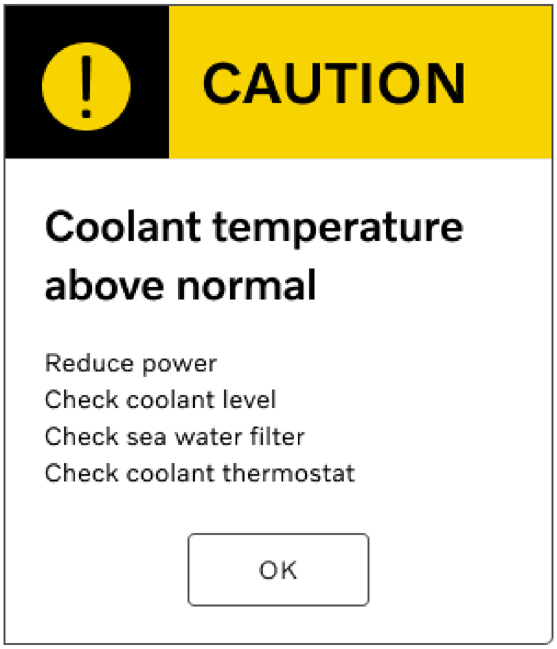
Figure 81. Final design of Trip Summary.

This feature aims to provide operators with an overview of the boat's tank status, allowing them to see if any water tanks need to be emptied or refilled, or if there is an issue with the battery. The feature is designed to give a sense of control and allow for timely maintenance as well as preventing potential problems.

Furthermore, the trip data is designed with the long-term goal of encouraging drivers to adopt more sustainable driving practices. Metrics like average fuel flow and average speed offer valuable insights into the boat's operational efficiency. By displaying these figures, drivers can gain a better understanding of their fuel flow and speed patterns. This enables them to adjust their driving behavior, helping to reduce their environmental impact and promote more sustainable practices while on the water. Additionally, the feature was included because boat operators found it enjoyable and interesting to review after their trip, making it a valuable addition that could potentially enhance the overall boating experience.

10.5 Alerts

Based on user preferences gathered from both interviews and surveys, it was decided that alerts should be displayed in a narrow box with the action plan always visible, with the aim to facilitate the decision making process. While many users favored a horizontal banner, several emphasized that nothing should obstruct the nautical chart in front of the boat. This concern was even expressed by some who personally preferred the horizontal layout. For this reason, a narrow alert box was selected, see Figure 82. The alerts are divided into two levels, 'caution' and 'warning', and are color-coded according to severity, with yellow indicating caution and red indicating the more critical alert level. This color coding is most likely encoded in the long-term memory, consequently facilitating information processing.

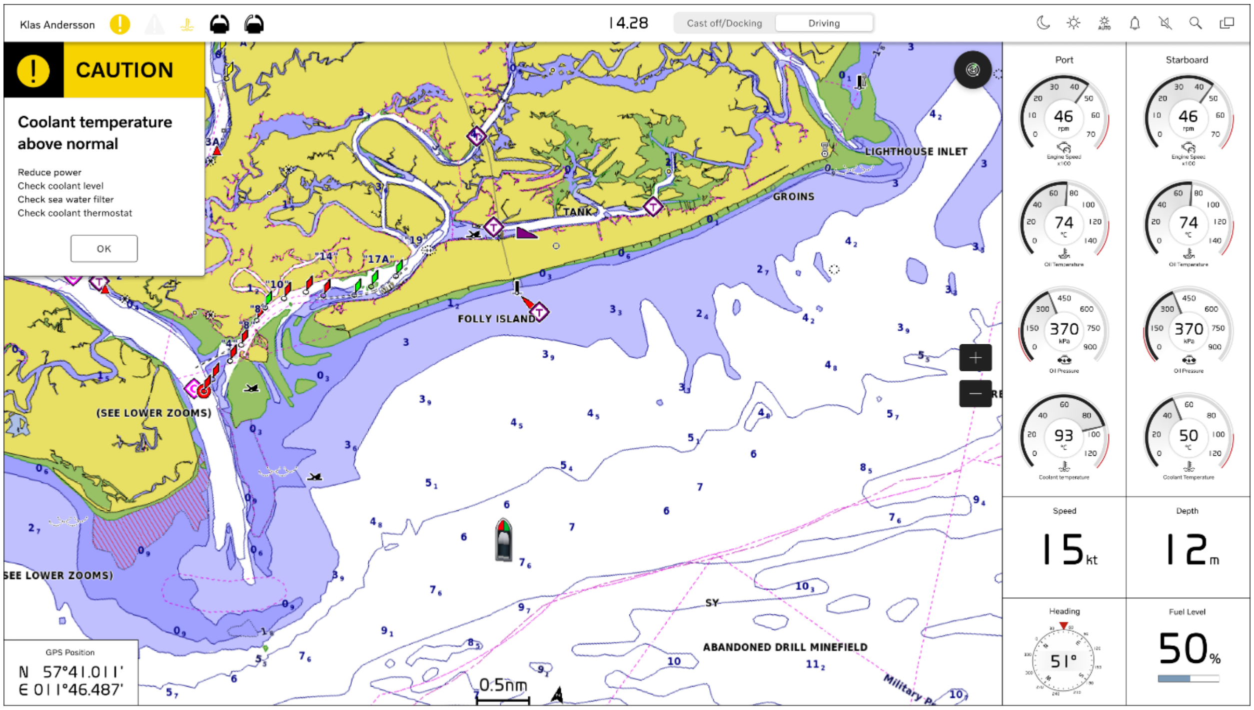


Coolant temperature above normal

Reduce power
Check coolant level
Check sea water filter
Check coolant thermostat

Figure 82. The final design of the alerts notification, displaying the level of severity – indicated by yellow color and 'caution' text – and action plan.

The alerts are placed on the opposite side of the engine data to avoid covering any potentially relevant information, see Figure 83. This placement also makes the alerts more noticeable, as they stand out better and do not blend in with the engine data, supporting the operator's ability to focus their attention.



CAUTION

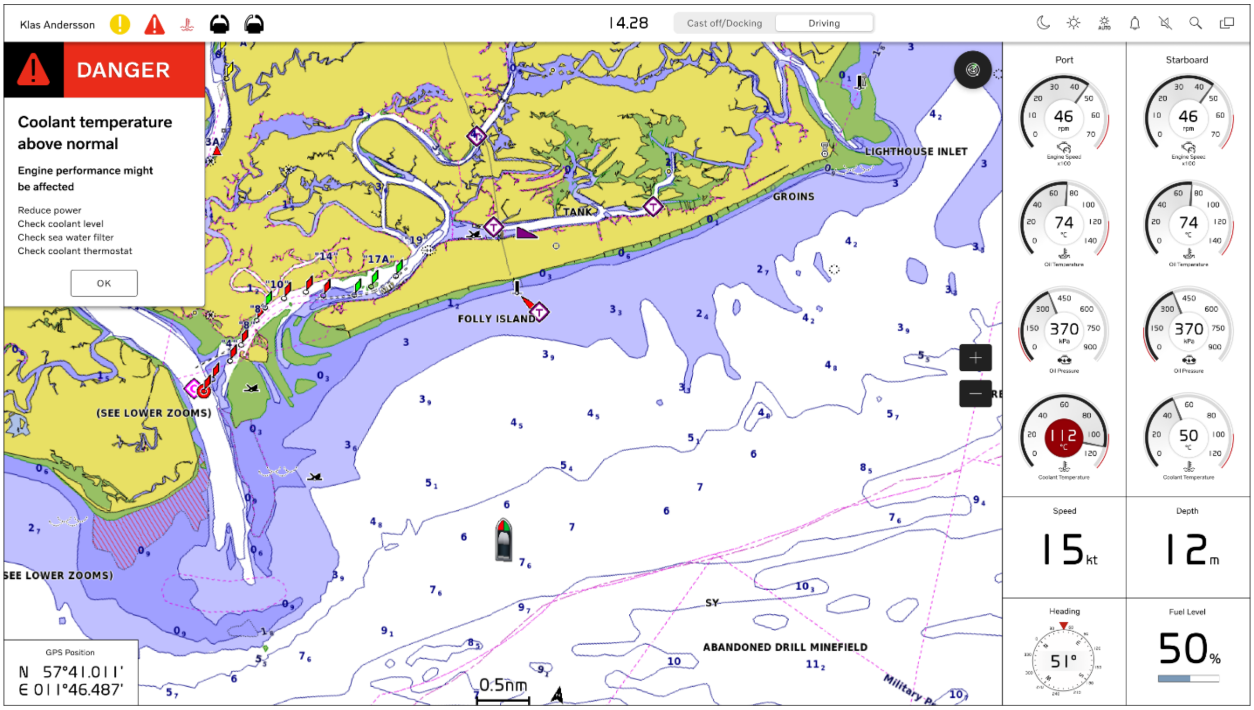
Coolant temperature above normal

Reduce power
Check coolant level
Check sea water filter
Check coolant thermostat

Figure 83. The 'caution' alert, positioned on the left side of the screen, opposite the engine data, to enhance visibility and ensures it is more easily noticed by the operator.

It was further decided that the action plan should remain visible at all times. Although some drivers felt that constant visibility was not necessary, the information was included for safety reasons. Not all users are as experienced with these types of alerts as some of Volvo Penta's test drivers were, and in emergency situations, it is crucial that drivers can quickly and clearly understand how to respond. This action plan is designed to support operators by providing clear guidance on how to respond when a alert appears. Instead of leaving users uncertain about what steps to take, the plan offers structured and easy-to-understand instructions that help them react appropriately and promptly. This not only aims to reduce stress in potentially critical situations but also to enhance safety on board by minimizing the risk of incorrect handling or oversight. Ultimately, the goal is to empower operators with confidence and knowledge to manage alerts effectively.

When alerts appear, an alert icon also lights up in the top bar. This ensures that if a driver chooses to close the alert box, they are still notified that something is wrong. For instance, if the alert concerns high coolant temperature and reaches critical levels, the alert box will turn red, the corresponding gauge in the engine data menu will also turn red, and the top-bar alert icon will be activated as well, see Figure 84.


Klas Andersson

14.28

DANGER

Coolant temperature above normal

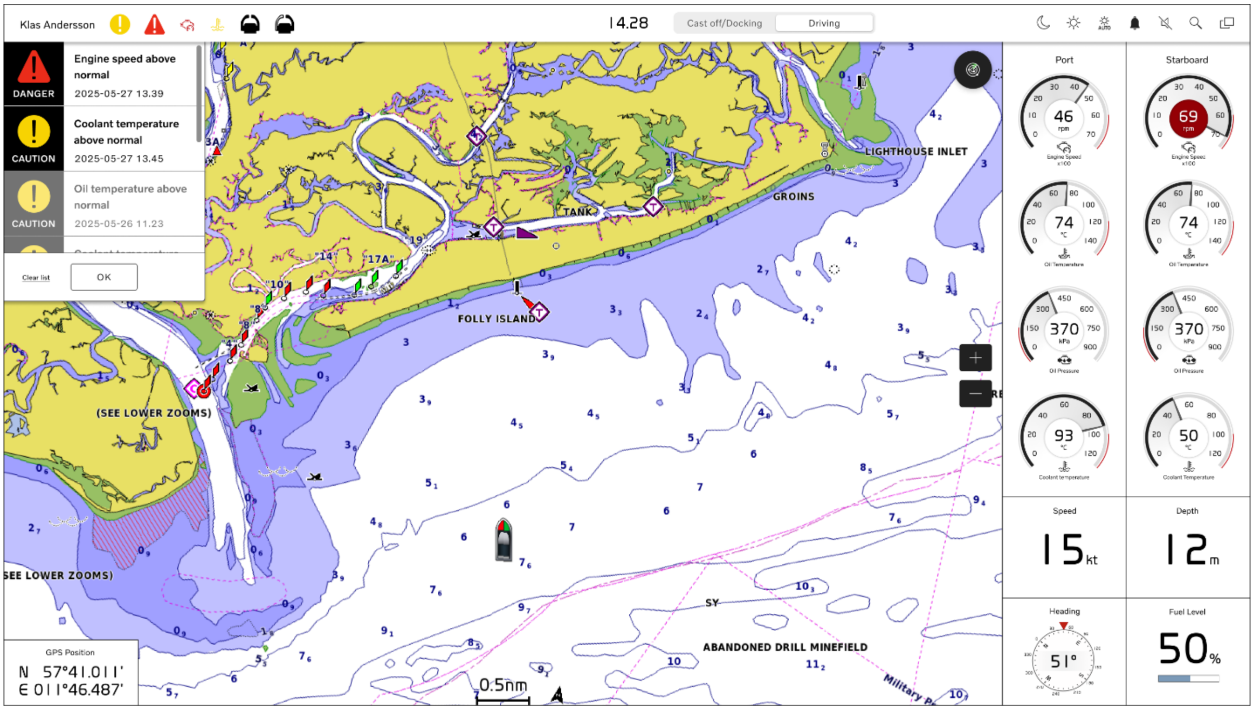
Engine performance might be affected

- Reduce power
- Check coolant level
- Check sea water filter
- Check coolant thermostat

OK

Figure 84. The 'danger' alert, displayed on the screen accompanied by a red gauge indicating high levels.

If the operator no longer wishes to see the alert, they can simply press OK to dismiss it. However, the alert icons ('!') on the far left of the top bar will remain illuminated until the issue is resolved, and the coolant temperature returns to normal levels. To revisit the alert, the operator can click on the bell icon on the right side of the top bar. If multiple alerts occur simultaneously, they will be compiled into a list, with the most critical and important alerts displayed at the top, see Figure 85. In this list, past alerts are also visible, allowing the driver to review previous alerts and identify any recurring issues. These are displayed in a grey tone to indicate that they are no longer active. The driver can also choose to clear the list, which removes all inactive alerts, while active ones remain visible at the top.



DANGER
Engine speed above normal
2025-05-27 13.39

CAUTION
Coolant temperature above normal
2025-05-27 13.45

CAUTION
Oil temperature above normal
2025-05-26 11.23

GPS Position
N 57°41.011'
E 011°46.487'

Figure 85. *The compiled list of alerts that is displayed when the operator presses the bell icon on the right side of the top bar.*

10.6 Top Bar

Following common design conventions for digital displays, a top bar was added to the upper edge of the screen, see Figure 86. At the center of this top bar, the current time is shown. On the left side, the selected profile is displayed along with any active alerts and features, such as Active Station, Cruise Control and Autopilot. On the right side, icons are provided for dark mode, brightness adjustment, alerts, audio settings, search function, and selection of different views. If the driver chooses to operate using one of the recommended views, a shortcut for switching between these views is available to the right of the clock. This feature is intended to make it easier for drivers to quickly change views based on the current driving mode, reducing the need to focus too much on the screen and allowing them to concentrate more on operating the boat.

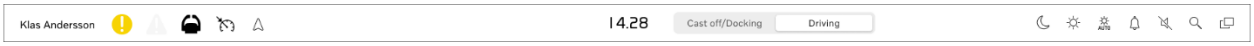


Figure 86. The final design of the top bar.

When the user taps the sun icon, a brightness adjustment slide appears, allowing the user to adjust the display brightness, see Figure 87. The slide closes when the user taps outside of it.

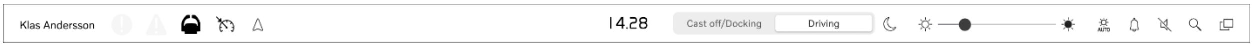


Figure 87. The top bar with the brightness adjustment slide visible.

Many drivers mentioned that navigating menus in various boat displays could be quite challenging, largely due to unstructured submenus and an illogical hierarchy. For this reason, a search function has been included in the new interface, see Figure 89. With this feature, the operator can search for the information they need, which reduces the need to use the long-term memory to find what they are looking for, such as the display manual. This is designed to save users time and effort, sparing them from having to navigate through multiple menus and submenus to find what they are looking for. When tapping the search bar, an on-screen keyboard appears. As the user begins typing, the search bar provides suggestions in real time. Previously searched terms are shown at the top, followed by other results listed in alphabetical order. Once inside a document, the driver can continue searching for specific terms to further filter the content, see Figure 90. This feature aims to make it easier for the operator to locate the desired information.

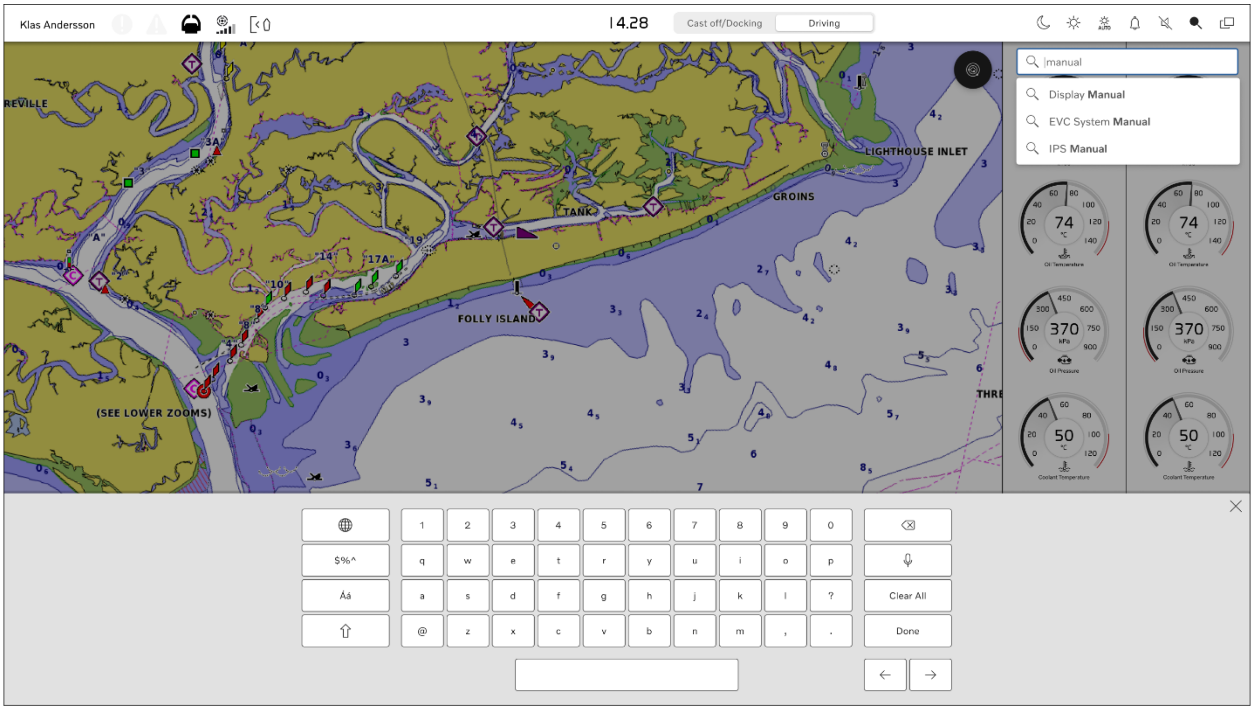


Figure 89. The final design of the search function, with 'manual' typed in in the search bar.

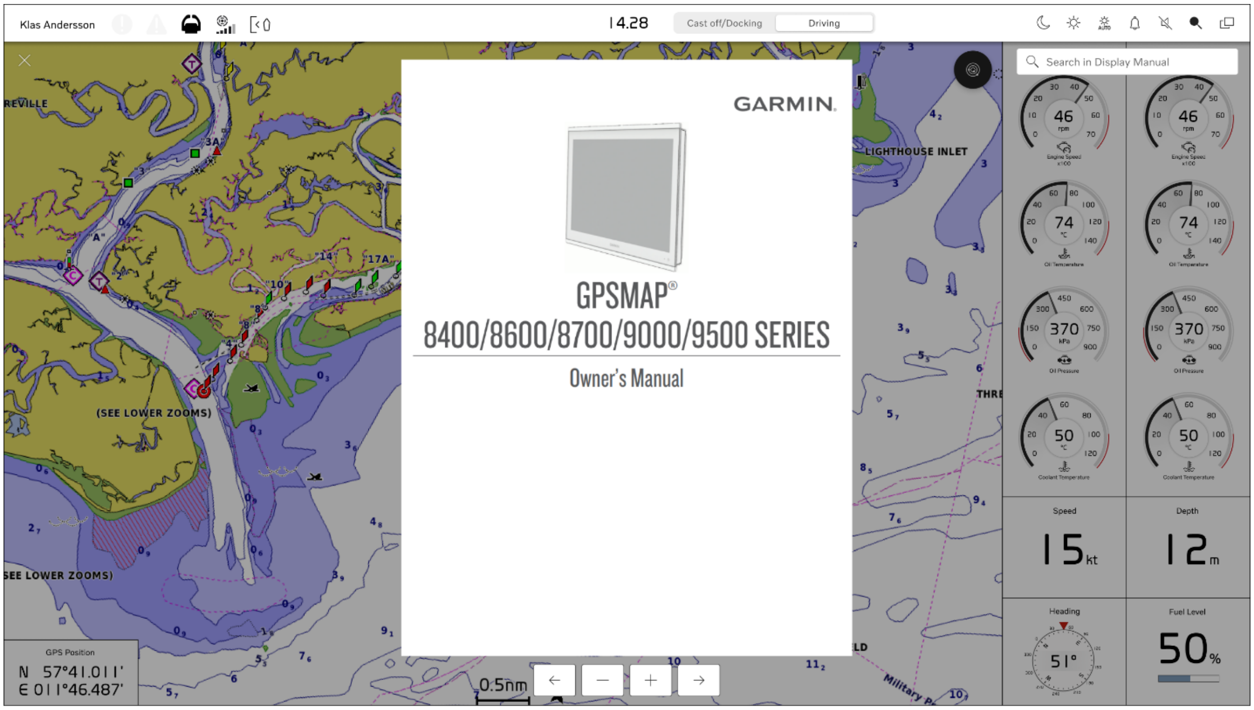
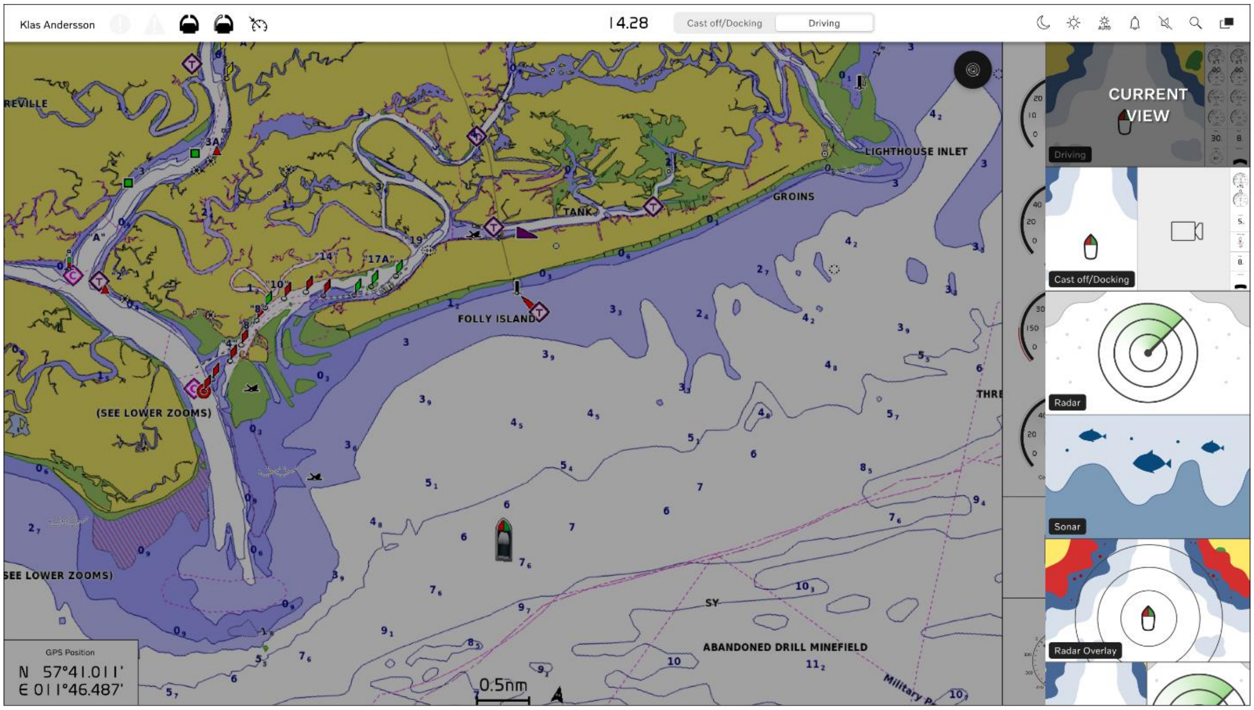


Figure 90. The search function with the display manual opened.

To change the view, the operator can click the icon on the far right of the top bar. A dropdown menu will appear with suggested views that the driver can choose from, or they can create a new view if desired, see Figure 91. If the driver changes their mind and wishes to remain on the current view, they can either click 'Current view' or anywhere outside the dropdown menu to close it.



GPS Position
N 57°41.011'
E 011°46.487'

Figure 91. The dropdown menu with different views available for selection.

10.7 Dark Mode

As some drivers prefer a dark interface, and to prevent glare during night-time operation, a dark mode has also been developed. This feature not only addressed personal preferences, making the interface feel more tailored and user-friendly, but also played an important role in enhancing safety. By reducing screen brightness and harsh contrasts in low-light conditions, dark mode helped prevent eye strain and distractions, allowing drivers to maintain better focus on navigation and their surroundings during night-time boating.

As previously mentioned, it can be configured in the profile settings, either as the default mode or to activate automatically at a specified time. The views in dark mode are identical to those in light mode, with the primary difference being a dark background and white text. See Figures 92, 93, and 94 for visualizations of how the interface appears during different operating sequences and with various functions activated.

Autopilot Engaged

Heading Hold

Heading 51 °M

Current heading 45 °M

GPS Speed 15kt

GPS Position N 57°41.011' E 011°46.487'

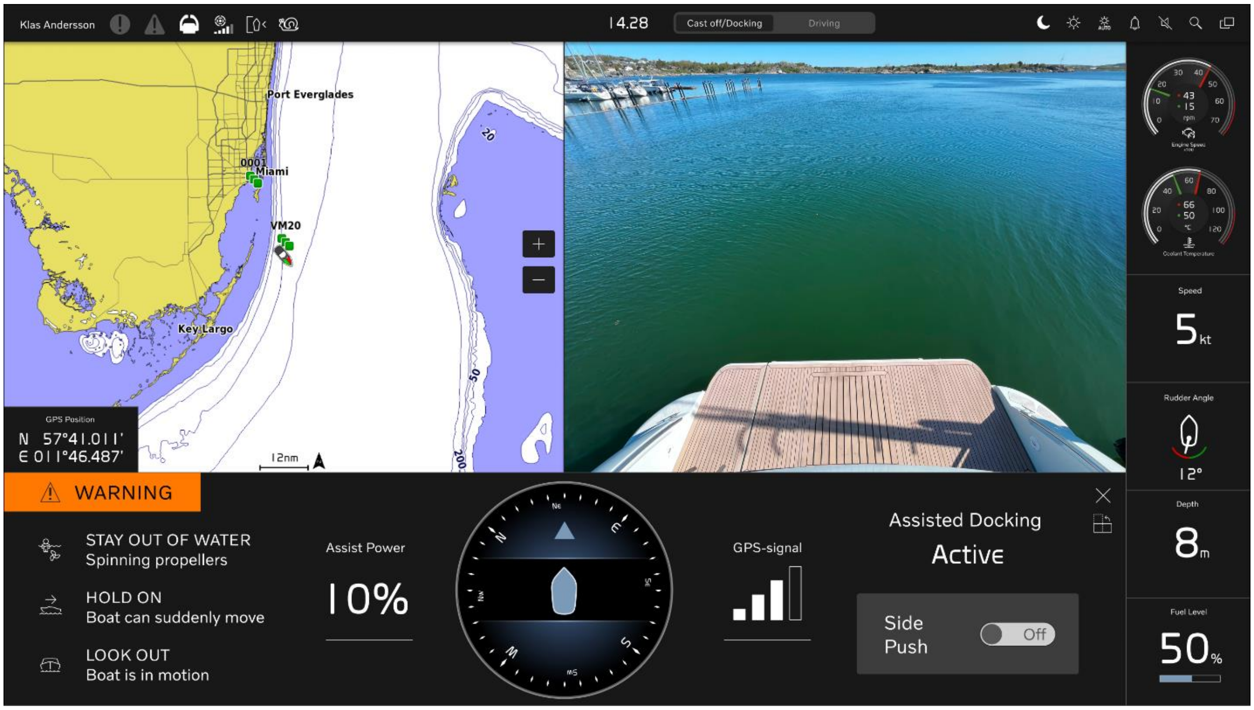
Speed 15kt

Depth 12m

Heading 51°

Fuel Level 50%

Figure 92. *The final dark mode design for the Driving view with Autopilot activated.*



⚠ WARNING

STAY OUT OF WATER
Spinning propellers

HOLD ON
Boat can suddenly move

LOOK OUT
Boat is in motion

Assist Power 10%

Assisted Docking Active

Side Push Off

GPS Position N 57°41.011' E 011°46.487'

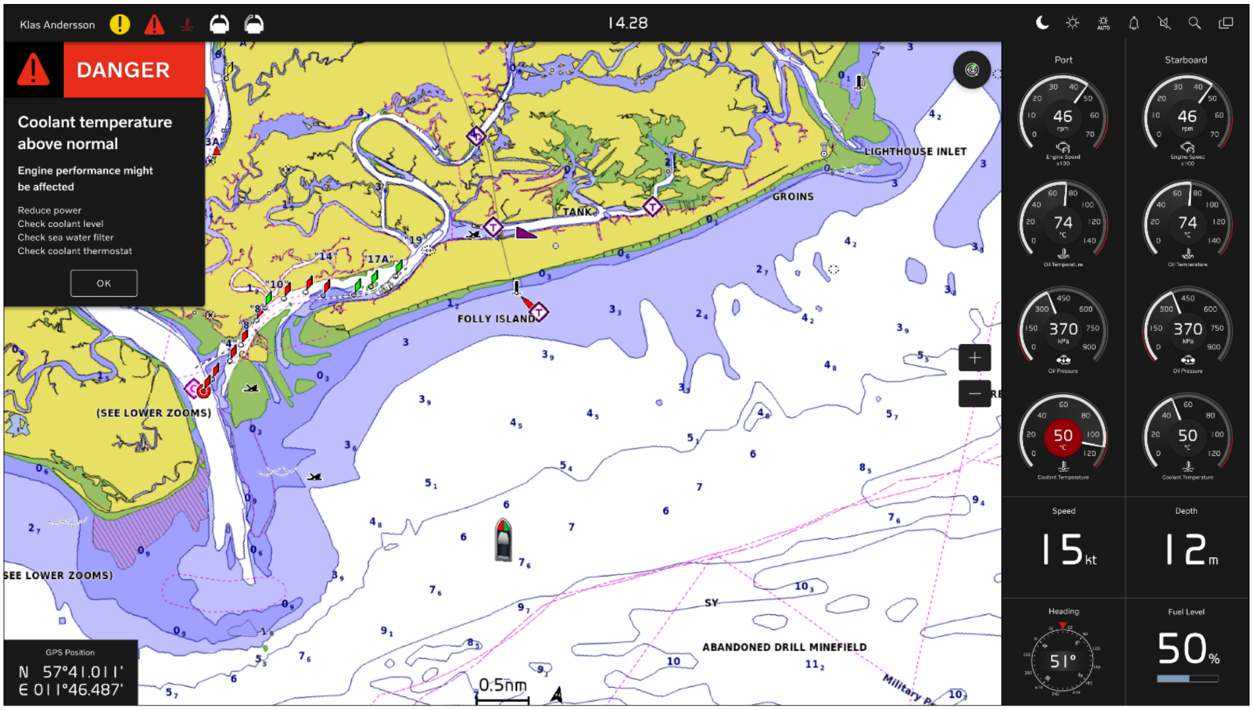
Speed 5kt

Rudder Angle 12°

Depth 8m

Fuel Level 50%

Figure 93. *The final dark mode design for the Cast off/Docking view with Assisted Docking activated.*



DANGER

Coolant temperature above normal

Engine performance might be affected

Reduce power
Check coolant level
Check sea water filter
Check coolant thermostat

GPS Position
N 57°41.011'
E 011°46.487'

Figure 94. The final dark mode design for the Driving view with an alert pop-up.

10.8 Additional Recommendations

Some findings were not addressed further in the design process as they were out of the project's scope or the knowledge of the team members. However, some of these were considered to be relevant improvements that would improve the user experience, which is why some recommendations have been formulated.

Automatic Zoom Function

Several respondents uttered frustration over the current nautical chart and its zoom function. They found it difficult to maneuver as it includes interaction with small buttons and is a feature that needs to be maneuvered often as the surroundings are constantly changing. The operators consequently requested an automatic zoom function, one that zooms in when entering shallow areas or narrow passages and zooms out when leaving them. This is a relevant improvement for the nautical chart, as it would create a feeling of control, and removes recurrent tasks that often fail or cause frustration, such as pressing small buttons to zoom in or out.

Physical Buttons

Although it was outside the scope of the project, many opinions were shared regarding physical buttons versus digital touch controls. Several drivers expressed a clear need for physical buttons, particularly for interacting with the display in rough conditions. Functions requiring high precision, such as zooming in and out on nautical charts, were highlighted as areas where physical controls could improve usability during heavy waves. As such, it is recommended to explore the integration of physical buttons. These should be positioned near the driver's armrest to ensure easy access and improve ergonomic comfort. The buttons should be designed to support muscle memory, allowing users to operate them with minimal visual attention. To avoid clutter, physical buttons should be limited to essential and frequently used functions. Additionally, buttons should provide tactile feedback and be appropriately sized to avoid obstructing the view or distracting the driver from other instruments and controls in the helm.

10.9 Implementation of Usability and UX Design Principles

The final design incorporates a wide range of established usability and UX principles, described in chapter 4.2. These principles were central to shaping a user-centered interface. Affordances for instance, according to Norman, have been addressed in the design. During layout customization in the *My Profile* feature, the interface presents editable sections styled as interactive modules, visually suggesting they can be modified.

Signifiers have been integrated into the design as well, such as the color-coded alert system where yellow and red indicate different levels of severity. These visual cues immediately signal the need for user action. Additionally, selected layout sections turn white and display a 'Choose data' label, guiding users to their next step. These signifiers play a key role in helping users navigate the interface with confidence.

Conceptual models are reinforced through consistency and predictability in how the interface behaves. For instance, the autopilot banner uses a visual representation of the boat with direction lines, which helps users understand both the current and intended heading. The compass rotates with directional changes, reflecting how users expect a real compass to behave. These design choices support users in forming accurate mental models of how the system works, which is essential for safe and efficient operation.

Constraints are applied thoughtfully, such as the inactive buttons in the *My Profile* feature that remain disabled until the user completes their layout configuration. This prevents premature actions that could lead to errors or confusion, ensuring that users follow the intended sequence of steps. By guiding users through a structured process, these constraints enhance usability, reduce the likelihood of mistakes, and support a smoother, more intuitive interaction with the system.

The design also reflects several of Jordan's design principles. Consistency is evident in the use of uniform icons, layouts, and interactions – for example, the top bar behaves consistently across all screens and modes, allowing users to transfer knowledge seamlessly from one part of the system to another with minimal friction.

Consideration of user resources is reflected in the minimalist layout, predefined templates, and automatic selections that help reduce both cognitive and physical effort. The search function minimizes the need to recall menu hierarchies, streamlining navigation and enhancing usability.

Feedback is well-integrated into the design. Alerts, dynamic gauge color changes (e.g., turning red at critical levels), and visual confirmations, such as section highlights during layout selection in *My Profile*, provide users with immediate, meaningful responses to their actions, supporting confident and informed decision-making.

Visual clarity is achieved through a restrained color palette, clean typography, and simple graphical elements, such as bar graphs and design of different functions (e.g. nautical chart, radar and sonar). These choices enhance readability and reduce visual clutter, which can be important to avoid distracting the driving but also to ensure visibility under varying lighting conditions.

Prioritization of functionality and information is demonstrated through context-sensitive information display. During docking, critical data such as rudder angle and stern camera feeds are emphasized, while in cruising mode, navigation charts and engine data are brought to the forefront, ensuring the most relevant information is always prominent. The ordering of the bars in the *System Check* is another example of how this principle was applied, making the most important data immediately accessible.

Explicitness is conveyed through clear system status indicators, including top bar icons for active features, distinct autopilot states, and color-coded alert severity levels. This transparency reduces ambiguity and enables users to make well-informed decisions quickly.

In summary, the result demonstrates a successful implementation of key usability and UX principles, resulting in a user-friendly Human Machine Interface that integrates Volvo Penta's EVC system into a multi-functional display.

11. DISCUSSION

This chapter discusses key aspects of the project in relation to its overall purpose and objectives. The purpose of this project has been to explore the future of marine display solutions in yachts and identify needs related to this subject. The objective was to develop a concept for a digital Human-Machine Interface that integrates Volvo Penta's EVC system into a multifunctional display.

This chapter covers the final result, choice of process, theoretical frameworks, applied methods, feasibility, ethical aspects, and sustainability. It reflects on the overall execution of the project and evaluates how well the final concepts address the goals of enhancing safety, usability, and the overall boating experience.

11.1 Purpose and Objective

Based on the results, it can be concluded that the design successfully addresses the project's research questions. The study has identified the most important functions and data that should be displayed for boat operators. Additionally, concepts have been developed that demonstrate how a Human-Machine Interface can be designed to integrate Volvo Penta's EVC system into a multifunctional display.

Addressing the first research question "What information and functions are most relevant and essential for users from a usability and safety perspective?", the findings presented in Chapters 8.2 and 8.3 provide a comprehensive answer. Additionally, the newly introduced feature offering two recommended views for different driving scenarios, see chapter 10.3, serves as a practical example of how these essential functions and pieces of information are applied in the actual HMI design. Every aspect of the design, from the prioritization of information to the functionality itself, has been shaped by real user research, ensuring that every decision directly reflects operator needs. This user-centered foundation greatly strengthens both the credibility and effectiveness of the final solution.

Turning to the second research question "How should a Human Machine Interface be designed to integrate Volvo Penta's EVC system into a multi-functional display", the sub-concepts presented in chapter 10 collectively respond to this inquiry. More specifically, the four features*: My Profile, System Check, Trip Summary,* and the *Recommended Views*, serve as clear examples of how the EVC system is effectively integrated into an independent display. Each of these functions processes and communicates data from the EVC system, enabling safer and more efficient boat operation. Moreover, the entire design adheres to the Volvo Experience System guidelines, ensuring brand consistency. This strengthens the user experience by enhancing recognition and satisfaction, ultimately contributing to higher overall usability.

11.2 Result

With both research questions addressed, the overall purpose and objective of the project can be considered fulfilled. However, whether the final result represents the optimal design from a user perspective remains open to discussion.

Firstly, it is worth discussing whether there truly is a need to continuously display engine data while driving. As one respondent explained, ”engine oil pressure is important, but for this, there are often well-functioning alarms, so I don’t need to see it continuously”. Many drivers justified the need for displaying engine data by saying they wanted to ensure everything was functioning properly, though they admitted they did not check the data frequently unless there was an issue. This raises the question of whether it might be sufficient to only display the data when it approaches abnormal levels, for example, high coolant temperature or high engine speed. However, drivers noted that being able to glance at the engine data and confirm that everything was normal gave them a sense of reassurance, allowing them to relax. In future development, it could be valuable to explore how this feeling of reassurance can be maintained without constantly displaying engine data, as it occupies a significant portion of the screen.

Secondly, in the proposed design, the fuel level is shown in both operating sequence views: *Cast off/Docking* and *Driving*. This decision was based on users expressing a need to access this data in those specific scenarios. However, now that fuel level information is included in both the *System Check* and *Trip Summary*, it may be perceived as excessive to display it so frequently. A logical next step would be to evaluate this with users to determine whether fuel level data is still necessary in all views, especially if users prefer seeing it in the *System Check* and *Trip Summary*. Similarly, it can be debated how relevant it is to display the rudder angle for users with Assisted Docking activated, as the function already visually shows how the boat moves in response to interactions with the controls. This opens the possibility of rethinking the data displayed in different views, certain types of data may no longer be considered as critical and could potentially be removed or replaced with something more relevant.

Thirdly, it is important to note that not all parts of the interface have been equally evaluated with users. This is partly due to the varied methods used, ranging from short surveys to longer interviews, but also because some elements were introduced late in the project and could not be tested in time. One such example is the scroll menu of functions in the *My Profile* feature, where users can browse and select functions and data when creating a new view. Initially, this list included detailed still images of charts, sonar, and radar, but in the final design, these were replaced with graphical illustrations that better aligned with the overall visual style of the interface. However, it remains debatable whether these new visuals are as effective as the previous ones. The original still images may have been easier for users to recognize and associate with their respective functions, while the new graphics could take longer to interpret and may not be as intuitive upon first use. In a future design iteration, it would therefore be worthwhile to evaluate this aspect with users, gathering feedback on their preferences and exploring whether adjustments could be made to better meet their needs.

Fourthly, the final design was developed to function solely as a digital interface, marking a shift away from traditional physical controls such as buttons, levers, and knobs. As described in Section 1.1.2, Flanders (2023) emphasizes that such physical elements often create more intuitive and interactive user experience by providing haptic feedback, which in turn reinforces the user's sense of control and satisfaction. This raises the question of whether a fully digital interface truly is the most optimal solution. Although no physical elements have been integrated, the design has been developed with a strong focus on usability and user feedback. To compensate for the lack of haptic response, other types of feedback - primarily visual, have been prioritized. However, during the project, it became evident that many operators appreciated physical elements, with some even stating that they are essential for certain functions and in certain contexts. One of the project’s defined limitations, however, was to create a fully digital interface. From that perspective, the outcome aligns with the project scope. Whether it is optimal from a usability perspective remains uncertain and would require long-term user evaluation. As physical controls have been the norm for decades, user habits and preferences may change over time, and digital interaction methods could potentially become the new standard.

However, within the scope of exploring a fully digital interface, the design presents a well-considered example of how such a system could be implemented. Considering that several usability and UX design principles have been applied to the final design, it can be concluded that a certain level of usability has been achieved, thereby fulfilling the project's objective to some extent. The system’s use of affordances and signifiers guides users through interactions without requiring extensive explanation or training. This intuitive design is especially important in high-stakes or time-sensitive contexts, where users must act quickly and confidently. Meanwhile, the minimalistic design and prioritization of critical information can help reduce cognitive load, enabling users to focus on what matters most at any given time. Together, these elements result in a coherent, practical interface that aligns closely with the real-world needs of its users.

Lastly, the result has been designed with safety as a guiding principle throughout the whole process. Excessive information or poorly structured UI elements can distract the skipper during use, posing a potential risk of accidents. A significant part of the work has focused on prioritizing information to ensure quick and intuitive access. One example of this is the set of recommended views tailored for different driving sequences. These views intentionally display a limited amount of information, presenting only what is essential for the operator to maintain awareness of the vessel and its surroundings. They serve as a clear illustration of how safety and usability can be effectively balanced in the interface design. This focus on safety strengthens the result, and it can be argued that the overall goal, to contribute to Volvo Penta’s vision about creating safe and enjoyable passages at sea while also elevating the boating experience, is fulfilled.

11.3 Choice of Process

The process model used in this thesis was an iterative, user-centered design approach that combined both investigative and exploratory methods. The process was divided into two main loops where the first loop focused on understanding the problem and gathering data, while the second loop concentrated on concept development, prototyping, and user evaluation. The iterative nature of the process allowed the project team to revisit and reassess insights or design decisions in light of new information. This was especially important in this project, where user preferences and needs proved to be highly varied. Iteration enabled a more precise and flexible solution, leading to better-informed decisions.

Dividing the process into two loops was also necessary to provide structure to the project. The first loop aimed to define a clear project scope based on theoretical and empirical studies, as well as Volvo Penta's interests. This was particularly relevant given that the project started with a broad and open-ended research question.

The process placed strong emphasis on involving users through both qualitative and quantitative methods. This was crucial for addressing the project's research questions related to usability and safety, as it offered direct insights into what matters most to users in different contexts. Combining interviews, observations, benchmarking, and surveys provided both depth and breadth, resulting in a robust foundation for analysis.

To enhance the process further, additional iterations in the second loop would have been beneficial. Only one iteration of concept development and user evaluation was conducted due to time constraints and difficulties in recruiting users for the studies. Given the diversity of user needs and preferences identified, further iterations might have refined the solutions even more and improved the accuracy of the design decisions.

In summary, the process was considered highly effective for this project. The iterative and user-focused model was well-suited to this design-oriented work, which involved understanding complex user requirements and translating them into practical, safe, and user-friendly solutions.

11.4 Wickens' Model as a Basis for the Project

As mentioned in Chapter 4.1, Wickens' model for human information processing served as the theoretical foundation for this project. The aim was to support a deeper understanding of the user and their needs, thereby laying stronger groundwork for the upcoming design process. Looking back at the completed project, it can be concluded that the model influenced both the process and the outcomes to a certain extent, however, less than expected.

Although the model outlines clear and easily understandable steps, especially when visualized, the reality is more complex and less straightforward. For example, designing empirical studies based strictly on the model proved challenging, as many of the processes it describes occur subconsciously in humans. The primary goal was to understand the user, their thought processes, and the problems they encounter, which led to a shift in focus. The questions for the empirical studies were instead shaped by the chosen scope of the project, where curiosity played a central role. Even though Wickens' model faded somewhat into the background, many of the questions still addressed the stages in the model. This alignment occurred naturally, as much of user-centered design inherently involves understanding how humans think and process information.

The same applies to the first design iteration. The focus was on identifying pain points and addressing them through design solutions. As a result, attention shifted away from the model's specific steps and toward creating user-friendly designs. However, the model remained present in the background, as several of the design decisions addressed elements described in Wickens' framework. By the end of the first design loop, it was clear that all the proposed solutions had, in one way or another, touched on different stages of the model, proving that it was subconsciously guiding the design process throughout.

To summarize, Wickens' model is a valuable theoretical framework for understanding human cognitive abilities and how information is processed, an essential component in creating user-friendly interfaces. However, building an entire design process strictly around the model can be challenging, as it describes subconscious processes that are not always visible in real-world scenarios. However, for the project team, it has proved to be subconsciously present during the entire design process, and thereby many design decisions have been informed by Wickens' model.

11.5 Empirical Studies

Before the interviews began, the participants were asked to respond based on their personal experience with their own boats, rather than their professional experience as test drivers. However, despite this request, it became apparent that their answers may have been influenced by their profession. Four of the interviews were conducted with current test drivers at Volvo Penta, and an additional two interviews were held with former test drivers who are now employed as engineers at the company. As a test driver, one operates boats almost daily throughout the year, following specific testing procedures, often in cycles, to evaluate the performance and behavior of Volvo Penta's engines and EVC systems. This stands in contrast to typical recreational boat owners, who may only use their boat during the summer or on a few scattered occasions each year. There was, thereby, a risk that the priorities of a test driver when operating a boat may not fully align with those of a recreational boat owner. Interestingly, the responses from external participants were quite similar to those of the test drivers. This could suggest two things: either that operators of large boats (40–60 feet), regardless of profession, commonly seek extensive data on the boat's and engine's performance, likely due to the high costs associated with maintaining and operating a yacht, or that the test drivers truly answered based on their personal experience, rather than their professional background. Regardless of the reason, the consistency in responses was a valuable confirmation, as it reinforced the reliability of the data collected in the study.

Furthermore, the majority of the interviews with the test drivers were conducted on board a boat. While they carried out their tests, the project team had the opportunity to ask questions and observe their actions. The goal of conducting the interviews in this setting was to see how they interacted with the displays during navigation and how their usage varied across different segments and scenarios of the journey. However, a major challenge was that the project team had no control over the driving itself. The test drivers had to complete their scheduled tests, forcing the project team to adapt both the observations and questions accordingly. As a result, rather than being helpful, the contextual setting became a distraction, for both us and the respondents. For example, it became apparent that some drivers had difficulty explaining their answers or recalling the questions when they were focused on driving. Additionally, to avoid causing too much distraction, the project team chose to keep the questions brief and to the point, unlike during the remote interviews, where it was possible to use probing techniques and mediating objects to gather more in-depth information. That said, this limitation was compensated by the fact that, over time, the remote interviews transitioned from using the context-independent interview guide to the context-dependent one. This shift generated more responses linked to specific driving scenarios, aligning with the original intent of conducting context-based interviews.

Continuing on the topic of interview templates, the approach was to treat them as a question bank rather than a strict script to be followed in its entirety. This allowed the project team to select relevant questions based on each respondent's experience. However, as a result, not all questions were asked to every participant, which may have negatively impacted on the overall results by making the responses less statistically representative of the broader target group. That being said, Volvo Penta representatives did not see this as an issue. Instead, their primary interest was in uncovering insightful takeaways and compelling quotes from the interviews, nuggets of information that could potentially lead to something significant. This reduced the importance of ensuring that all responses were statistically representative.

Furthermore, the sample size for the interviews was relatively small, which can make the responses less statistically representative of the broader target group. However, considering it was off-season for boating and that yachts are relatively uncommon in Sweden during winter, the sample selection was valid. The sample included a variety of participants with different levels of experience and relations to yachts, which contributed to more nuanced results. This diversity helped ensure that the findings better reflected the target audience, compared to, for instance, if only Volvo Penta employees had participated. In a future study, it would be valuable to include a larger number of interview participants and to involve more women, in order to explore whether their needs differ in any way. Although a woman was interviewed for this project and her needs were similar to those of the men, the sample size is too small to draw any definitive conclusions from this result. That said, every effort was made to reach as many relevant users as possible.

11.6 Evaluation Methods and Deviations in Answers

The responses from the two evaluation methods, interviews and questionnaires, were in some cases aligned, but in other cases diverged significantly. In instances where the responses differed, the disparity in opinion was substantial enough to prompt the project team to question both the validity of the results and the evaluation methods themselves. Several factors may account for this discrepancy.

To start with, the interviews might have generated more positive answers than the questionnaire because during the interviews, the team could explain the reasoning behind every idea. This direct communication likely helped respondents develop a deeper understanding of the design rationale, which in turn could have led to more positive impressions. In contrast, the questionnaire was intentionally kept brief to encourage participation, which limited the amount of explanatory detail that could be included. This brevity may have left some respondents without a full understanding of the proposals, potentially contributing to more critical evaluations. Despite the somewhat more negative and divergent feedback received via the questionnaire, the responses were still highly valuable and contributed meaningfully to the development of the design.

Secondly, the questionnaire included images showcasing the various alternative designs that were developed. Unfortunately, these images were very small in size and had a low resolution due to technical limitations during publication. The low-resolution images likely limited the respondents' ability to fully grasp the details and nuances of the proposed designs, potentially affecting the quality of their feedback. In contrast, the interviews provided respondents with a more immersive experience, allowing them to see the designs in high resolution as well as the different steps of interaction, which likely led to a more clear understanding and more accurate feedback. This underscores the importance of presenting results in a consistent manner to ensure the outcome becomes more comparable.

Furthermore, the nature of the two methods likely influenced the tone of the feedback. Face-to-face interviews may have introduced a degree of social bias, with participants potentially offering more favorable feedback to avoid offending the team. In contrast, the anonymity of the questionnaire allowed respondents to express their opinions more freely, which may explain the more critical tone. That said, the interviewees did provide constructive criticism, though not to the same extent as questionnaire respondents.

The semantic scale results for features such as the *System Check* and *Trip Summary* also revealed variation. Notably, one questionnaire respondent rated both features as 1 on a scale from 1 to 10 (from ‘unnecessary’ to ‘useful’), while others rated them significantly higher, between 6 and 10. This specific answer lowered the mean score, which must be considered even though it reflects the opinion of a single participant. However, the design already addresses such differences in opinions through the *My*

Profile feature, which allows users to choose whether or not these elements should appear at the beginning and end of a journey. This functionality not only accommodates differing preferences but also reinforces the value of the profile creation concept within the overall design.

The composition of the respondent groups may have affected the results of the evaluation as well. All questionnaire respondents were Volvo Penta employees, and their familiarity with the company's existing interface may have led them to evaluate the new proposals more critically, comparing them with what they already are familiar with. In contrast, two of the four interviewees were external boat operators with no prior experience of Volvo Penta's systems. These external participants were generally more positive, offering valuable outside perspectives. However, their lack of familiarity with certain functionalities, such as Assisted Docking, may have limited their ability to offer well-grounded critique, potentially resulting in overly favorable evaluations.

During the interviews, some of the operators referred to displays from other brands, for instance Raymarine, Simrad, and other Garmin displays that were not Glass Cockpit. This was valuable as it provided insights into what users appreciate in external displays, without any bias toward Volvo Penta. However, this made it difficult to pinpoint the shortcomings of the current design, as different users referred to different interfaces which varied in appearance. To obtain more comparable results, it would have been beneficial to first evaluate the Glass Cockpit interface and identify any shortcomings in the current design, then have users assess the new interface, allowing for conclusions on whether the design suggestions had led to improvements. However, to avoid influencing users with Glass Cockpit, which is a well-established interface with many years of development, this approach was not pursued. Presenting it could have introduced subjective opinions based on an already familiar concept, rather than a new one with which drivers had no prior relationship.

Another limitation in the evaluation of the interface was that no driver had the opportunity to interact with it directly. This was due to all interviews and surveys being conducted remotely, which meant that users had no ability to control the computer on which the interface was presented. To better evaluate the usability and effectiveness of the design proposals, there is interest in allowing users to interact with the interface themselves and to solve certain tasks. This way, the users can gain a more clear understanding of how the interface is structured. This method also makes it easier to evaluate usability aspects such as effectiveness, efficiency, and satisfaction. By measuring the time and number of clicks required for users to complete tasks within the interface, for instance creating views in *My Profile*, it becomes easier to assess how well users understand the interface.

Finally, the interface has not been evaluated in its intended context – on a boat and displayed on an actual onboard screen – but was instead shown on a computer monitor. This was partly due to technical limitations that made integrating the interface into an onboard screen challenging, but also because the project team lacked access to a boat and operators for such testing. This could affect how the interface was perceived, especially if the participants viewed it on a small laptop screen, while the interface is intended for a 22" display. This aspect was not addressed in the evaluation, and it was therefore not investigated how users perceived the relative size of the components. It is possible, for example, that features such as Assisted Docking or Autopilot may have appeared disproportionately large on a larger screen. To generate more reliable evaluation results and gain a more accurate understanding of how the design is received by users, it would therefore have been valuable to conduct the studies in context, on a yacht and using the correct screen size. However, due to difficulties in accessing both drivers and a boat with the appropriate display setup, this was not possible.

11.7 Feasibility

Finally, it is worth discussing the feasibility of the solution. One of the objectives was for the final concept to be scalable, allowing the interface to be compatible with a wide range of multi-functional displays. While this has been partially addressed through the customizable views in *My Profile*, there is still room for improvement. The addition of a top bar may pose challenges when adapting the interface to smaller displays, as limited space in the menu could become problematic if multiple functions and alerts need to be shown simultaneously. This can easily be resolved by making the top bar smaller, but at the same time, the top bar cannot be too small, as the information must remain easily readable from the operator's position to ensure its usability. Moreover, different screen aspect ratios were not considered during the design process. As previously mentioned, the interface was developed for a 22" display with a 16:9 aspect ratio. If, for instance, the interface was to be used on a 4:3 display, some functions might need to be adjusted. This is particularly relevant for the Autopilot banner, which may take up a significant portion of the chart in the *Driving* sequence view, especially if the operator also wants to view engine data in two separate gauges. A logical next step in the design development could be to focus on improving scalability and adaptability to better support a wider range of display types, thereby aligning more closely with the goal of compatibility across various multi-functional displays.

11.8 Ethical Aspects

When designing an interface for boat displays, it is important to prioritize inclusivity to ensure accessibility for a diverse user base. This has been achieved by incorporating universally recognized icons and language, for instance by combining symbols with text for the different gauges and data. However, some aspects of the design are not fully accessible to all users. This applies in particular to the choice of colors used to indicate the port and starboard sides, which are not adapted for individuals with color blindness. In the marine environment, it is common knowledge that red color indicates port, and green color indicates starboard. In some design solutions, these colors are used alongside each other, for instance in the combined gauge where a red needle and a green needle are displayed next to each other. Due to space constraints in the combined gauge, the labels 'Port' and 'Starboard' were not included. This feature may pose challenges for individuals with color blindness, who may have difficulty distinguishing the values of the engines, negatively affecting both usability and inclusiveness. For future design development, it would be worthwhile to explore ways to address this, ensuring the information is easily distinguishable for all individuals, including people with color blindness.

Moreover, ethical considerations have been taken into account in the handling of personal data. All data was managed in accordance with Volvo's GDPR guidelines, and with the explicit consent of the individuals involved. This included obtaining approval for activities such as recording interviews, taking photos, and/or filming videos. Adhering to these guidelines ensured ethical data management and safeguards individuals' privacy.

11.9 Sustainability

Considering the environmental changes the planet is facing; designers have a responsibility to promote sustainable behaviors with their designs. A well-designed interface in a boat display can promote sustainable boating practices by encouraging fuel efficiency and reducing emissions. This aspect has been partially addressed through the *Trim Summary* feature, which provides drivers with information about their journey and the impact of their driving by displaying data such as average fuel flow. A further improvement could involve providing real-time feedback within different driving modes, using indicators, such as green or red, to reflect whether the driving behavior is considered sustainable or not. However, it is unclear whether users would appreciate this type of feedback, as it could be perceived as distracting, overwhelming or even intrusive. Therefore, this is a topic that may be worth exploring further with users, especially since the project involves large boats with engines that generate substantial emissions.

11.10 Future Work

While this project successfully met its defined purpose and objectives, there are still areas that could be further developed. Due to time constraints, not all design elements, such as the updated scroll menu in the *My Profile* feature, were thoroughly evaluated by users. A critical next step is to conduct additional rounds of user testing, ideally with a broader and more diverse group of boat operators, including more recreational users and female participants. It would also be valuable to include individuals with no prior affiliation or connection to Volvo Penta, as they are less likely to be influenced by bias. This would provide deeper insights and validate design decisions across a wider range of preferences and use cases.

There is also a strong interest in evaluating the interface's long-term usability and performance to ensure it remains effective and user-friendly over time. Conducting field tests across extended periods and in varying environmental conditions, such as nighttime operation, limited visibility, and rough sea, would provide valuable insights into how the system functions in real-world scenarios. These tests could help identify any usability challenges that may arise during prolonged use and guide improvements to critical features such as alerts, gauge readability, and the effectiveness of night mode under different lighting and operational conditions.

To further evaluate the usability of the interface, future development should allow users to interact with the system firsthand. Direct interaction offers more meaningful insights into how intuitive and user-friendly the interface is perceived, potentially uncovering issues, misunderstandings, or inefficiencies that may not emerge through observation or verbal feedback alone. Hands-on testing also enables assessment of how effectively users can navigate the system, perform key tasks, and respond to alerts or changing conditions, providing a more complete understanding of the interface's real-world performance and overall user experience.

The study highlights the importance of critically evaluating which engine and navigational data are essential to display in different views. A key insight was the psychological reassurance operators derive from being able to glance at engine data, even if they do not actively monitor it. Future work should explore alternative ways to provide this sense of reassurance, without continuously occupying screen space. Additionally, now that the *System Check* and *Trip Summary* features are included in the design, the redundancy of displaying certain data, such as fuel level, across multiple views suggests a need for further user evaluation. Similarly, the relevance of displaying rudder angle alongside the Assisted Docking banner should be reconsidered, as the AD function already provides visual feedback on the boat's movement. Moving forward, gathering further feedback on where and when data is most valuable could inform a more streamlined and user-friendly interface, minimizing visual clutter while still supporting the cognitive and operational needs of the operators.

To summarize, the project successfully fulfilled its objectives by developing a user-centered, fully digital interface that integrates Volvo Penta's EVC system into a multi-functional display. While some design elements need further testing and refinement, such as data prioritization, scalability, and user interaction in real-world scenarios, the outcome provides a solid base for future development and aligns well with Volvo Penta's vision.

12. CONCLUSIONS

The objective of the project was to develop a concept of a digital Human Machine Interface that integrates Volvo Penta's EVC system into a multi-functional display. The concept should provide the skipper of a yacht with essential information, features, and functions that ensure an enjoyable and safe passage at sea while also enhancing the overall boating experience.

From the empirical studies it can be concluded that the most essential and relevant information and functions for boat operators vary significantly between individuals. While certain operators consider specific types of engine data to be critical, others report never having consulted them. This diversity in user preferences underscores the challenge of designing a Human Machine Interface that suits all operators.

To address this and further conclude, a future Human Machine Interface in yachts should be designed with a strong user-centered approach. Usability and safety are the most important factors to consider, forming the foundation of a safe and enjoyable navigation experience. The interface should emphasize clarity, prioritize critical information, and allow for customization to accommodate the varied needs of different operators. By following these principles, Volvo Penta's goal of creating safe and enjoyable passages at sea, while enhancing the overall boating experience, can be realized.

13. REFERENCES

AB Volvo. (2025). Volvo Experience System. Retrieved May 13th, 2025, from https://www.volvogroup.com/experiencesystem/en/

AB Volvo Penta. (2024a). Volvopenta.com. Retrieved November 26th, 2024, from https://www.volvopenta.com/

AB Volvo Penta. (2024b). *Marine*. Retrieved December 13th, 2024, from https://www.volvopenta.com/marine/

AB Volvo Penta. (2024c). *Leisure boating*. Retrieved December 18th, 2024, from https://www.volvopenta.com/marine/leisure-boating/

AB Volvo Penta. (2024d). *Marine commercial*. Retrieved December 13th, 2024, from https://www.volvopenta.com/marine/marine-commercial/

AB Volvo Penta. (2025a). *History & Innovation*. volvopenta.com. Retrieved January 21st, 2025, from https://www.volvopenta.com/about-us/history-innovation/

AB Volvo Penta. (2025b). *Volvo Penta IPS*. volvopenta.com. Retrieved February 3rd, 2025, from https://www.volvopenta.com/en-us/marine/leisure-boating/volvo-penta-ips/

AB Volvo Penta. (2025c). *Electronic vessel control (EVC)*. volvopenta.com. Retrieved January 25th, 2025, from https://www.volvopenta.com/en-us/marine/accessories/electronic-vessel-control-evc/

AB Volvo Penta. (2025d). *EVC compatibility list*. volvopenta.com. Retrieved February 4th, 2025, from https://www.volvopenta.com/en-us/marine/accessories/evc-compatibility-list/

AB Volvo Penta. (2025e). *Glass cockpit*. volvopenta.com. Retrieved January 24th, 2025, from https://www.volvopenta.com/en-us/marine/accessories/glass-cockpit/

AB Volvo Penta. (2025f). *Marine accessories*. volvopenta.com. Retrieved January 22nd, 2025, from https://www.volvopenta.com/en-us/marine/accessories/

AB Volvo Penta. (2025g). *Joystick Control*. volvopenta.com. Retrieved February 7th, 2025, from https://www.volvopenta.com/marine/accessories/joystick-control/

AB Volvo Penta. (2025h). *Assisted docking*. Volvopenta.com. Retrieved February 7th, 2025, from https://www.volvopenta.com/marine/accessories/assisted-docking/

B&G. (2024). *B&G Glossary*. Retrieved February 12th, 2025, from https://www.bandg.com/glossary/

Bligård, L.O. (2015). *ACD3 Utvecklingsprocessen ur ett människa-maskinperspektiv*. Chalmers Tekniska Högskola. http://www.acd3.se/assets/files/ACD3%20-%20Utvecklingsprocessen%20ur%20ett%20manniska-maskinperspektiv%202.1.pdf

D'Ambrosio, L. (2023). *Yacht: modern meaning of the term and types of boats*. Yachting News. Retrieved May 7th, 2025, from https://www.yachtingnews.com/yacht/

Denscombe, M., & Larson, P. (2018). *The research handbook: For small-scale research projects in the social sciences* (4th ed.). Studentlitteratur.

Flanders, C. (2023). The Impact of Haptic Feedback in UI/UX: Engaging Users through Touch Sensations. *Bootcamp*. Retrieved January 28th, 2025 from The Impact of Haptic Feedback in UI/UX: Engaging Users through Touch Sensations | by Carol Flanders | Bootcamp | Medium

Garmin. (n.d.-a) *Traditionellt ekolod*. Retrieved February 26th, 2025, from https://www.garmin.com/sv-SE/garmin-technology/marine-technology/sonar/traditional-sonar/

Garmin. (n.d.-b). *Grundläggande användning*. Retrieved February 26th, 2025, from https://www.garmin.com/sv-SE/garmin-technology/marine-technology/radar/fundamentals-of-operation/

Guimaraes, F. (2021). *Benchmarking: How to conduct one*. Aela. Retrieved February 18th, 2025, from https://www.aela.io/en/blog/all/benchmarking-how-to-conduct-one

ISO. (2013). *Usability* (ISO 9241-11). The International Organization for Standardization. Retrieved February 19th, 2025 from https://www.iso.org/obp/ui/#iso:std:iso:ts:20282:-2:ed-2:v1:en

Jordan, P. W. (2002). *An Introduction to Usability*. Taylor & Francis Group. https://doi.org/10.1201/9781003062769

Nagy, V. et al (2023). Testing Road Vehicle User Interfaces Concerning the Driver's Cognitive Load. Infrastructures, 8(3), 49. Retrieved January 27th, 2025 from https://doi.org/10.3390/infrastructures8030049

National Geographic Education. (n.d.). *GPS*. Retrieved February 12th, 2025, from https://education.nationalgeographic.org/resource/gps/

Norman, D. & Nielsen, J. (1998). *The Definition of User Experience (UX)*. Nielsen Norman Group. Retrieved February 19th, 2025, from https://www.nngroup.com/articles/definition-user-experience/

Norman, D. (2013). *The Design of Everyday Things*. Basic Books. Retrieved February 4th, 2025 from https://ia902800.us.archive.org/3/items/thedesignofeverydaythingsbydonnorman/The%20Design%20of%20Everyday%20Things%20by%20Don%20Norman.pdf

Novazaki, F. (2023). *Introduction to Cognitive Ergonomics* [Power-Point Presentation]. Canvas.com. Retrieved February 3rd, 2025 from https://chalmers.instructure.com/courses/26309/files/2997554?module_item_id=419205

Patel, R., & Davidson, B. (2019). *The Fundamentals of Research Methodology: Planning, Conducting, and Reporting a Study* (5th edition). Studentlitteratur.

Reich, G. (2025). *Motorboat types: Powerboat terms, uses, and definitions*. Boats.com. Retrieved May 7th, 2025, from https://www.boats.com/how-to/motorboat-terms-different-powerboat-types-uses-and-definitions/

Simonsen, E. (2023). *Mental Workload* [Power-Point Presentation]. Canvas.com. Retrieved January 27th, 2025 from https://chalmers.instructure.com/courses/26309/files/3027113?module_item_id=423508

Simrad. (2024). *SOG versus STW*. Retrieved February 26th, 2025, from https://www.simrad-yachting.com/zh-cn/world-of-simrad/technology/sog-versus-stw/

Svensk Båtutbildning AB. (2025). *Nautisk mil, sjömil, distansminut & bågminut, vad betyder de olika begreppen?* Retrieved February 12th, 2025, from https://batutbildning.se/fragor-svar/nautisk-mil-sjomil-distansminut-bagminut-vad-betyder-de-olika-begreppen/

Sweboat. (n.d.). *Ordlista*. Retrieved February 4th, 2025, from https://www.sweboat.se/batordlista

Unmanned Systems Technology. (n.d.). *Measuring GPS Heading & Course Over Ground*. Retrieved February 26th, 2025, from https://www.unmannedsystemstechnology.com/feature/measuring-gps-heading-course-over-ground/

Volvo Penta. (2024). *Master Thesis: Contribute to easy boating*. annonsportal.chalmers.se. Retrieved December 13th, 2024, from https://annonsportal.chalmers.se/CareerServices/en/Ads/Details/2603

Yadav. A. (2023). Cognitive ergonomics: enhancing mental workload management and decision-making processes through ergonomic interventions. In *Essentials of Ergonomics* (pp 50-56). Dominant

Publishers & Distributors Pvt Ltd. ISBN: 978-93-82007-08. Retrieved February 6th, 2025 from http://www.wisdompress.co.in/wp-content/uploads/2023/10/Essentials-of-Ergonomics.pdf#page=56

Wickens, C. D., Hollands, J. G., Banbury, S., & Parasuraman, R. (2016). *Engineering psychology and human performance* (4th ed). Pearson. ISBN: 9780205021987. Retrieved February 26th, 2025 from https://ebookcentral.proquest.com/lib/chalmers/reader.action?docID=3570443&ppg=3#

Wikberg Nilsson, Å. Ericson, Å., & Törlind, P. (2015). *Design: process och metod*. Studentlitteratur AB, Lund.

Wikström, L. (2002). *Produktens budskap: metoder för värdering av produkters semantiska funktioner ur ett användarperspektiv*. [Doktorsavhandling, Chalmers Tekniska Högskola]. Chalmers Research. https://research.chalmers.se/publication/182408

Zippia. (2025). *Boat Driver demographics and statistics in the US*. Retrieved May 7th, 2025, from https://www.zippia.com/boat-driver-jobs/demographics/

A

Appendix A – The Project Brief

This appendix contains the original project brief provided by Volvo Penta for the master thesis titled ‘Contribute to Easy Boating’.

Master Thesis: Contribute to easy boating

Volvo Penta *Gothenburg, Sweden*

Transport is at the core of modern society. Imagine using your expertise to shape sustainable transport solutions for the future? If you seek to make a difference on a global scale, working with next-gen technologies and the sharpest collaborative teams, then we could be a perfect match.

Thesis work objective

The Vehicle Interface department at Volvo Penta is determined to develop more user-friendly HMIs, including displays and controls. We are focusing on creating seamless user experiences for our marine and industrial customers. Therefore, it is important that we stay at the forefront of our development to be able to challenge the market and meet the user needs of the future.

We want to explore the future of marine display solutions. Displays that shall provide the skipper with all important information, functions, and features for safe and enjoyable passages at sea while also elevating the boating experience.

Qualifications and Personal Profile

Master students within Product Development, Industrial Design, Interaction Design or similar.

Starting time: January 2025
Duration: approx. 5-6 months
Number of students: 2
Language: English
Thesis level: Master, 30 ECTS

You should possess these qualifications:

Knowledge in any of the following fields or related disciplines

- Human centered design methodology
- Cognitive ergonomics
- Human machine interaction/Human computer interaction
- Proficient in tools such as Figma, Adobe XD, or sketch
- Skilled in creating real-life prototypes to test and prove your concepts
- Interested in boats and marine vessels

B

Appendix B – Interview Questions Context Dependent Interview (in Swedish)

This appendix contains the interview template used in the empirical studies with boat operators. The template was tailored for a context-specific interview where participants responded to questions about specific driving scenarios. If the interview was conducted onboard a boat, the driver was also asked to demonstrate the interaction on the screen.

The interviews followed a semi-structured format, with the **bold questions** given priority. Additional questions are asked as needed, depending on the flow of the interview and the participants' responses.

[Swedish]

Uppvärmningsfrågor:

- Vad har du för båt?
    - Hur länge har du haft denna båt?
- Berätta om lite kort om hur du använder din båt?
- Har du mycket erfarenhet av att köra båt?
    - Antal år?
- Har du erfarenhet av några andra typer av båtar? Om ja, vilka?
- Vad är det bästa och sämsta med att köra båt?
- Har du några intyg? Förarintyg eller skepparexamen? Eller annat?
- Beskriv din förarhytt och vad din båt har för funktioner
    - Fysiska reglage
    - Digitala skärmar

Skärmrelaterade frågor:

- Vad är det för märke på din/a display/er?
    - Exempelvis SIMRAD, Garmin, B&G, osv.
- Storlek: hur många tum är din/a display/er?
- Vad för typ av display är det?
    - MFD, kartplotter, radar?
- **Vi kommer nu ge exempel på några vanliga funktioner eller information som man kan se på multifunktionella displayer i båtar. Vänligen välj ut några av de du tycker är viktigast och som du alltid, eller väldigt snabbt, vill kunna komma åt:**
    - Sjökort
    - Radar
    - Ekolod
    - Autopilot
    - Assisterad docking
    - Motordata
    - Kamera vid för och akter
    - Media (musik och video)
- **Vi kommer nu ge exempel på motordata som är vanligt förekommande i båtdisplayer, vänligen rangordna de du tycker är viktigast och välj ut några som du alltid, eller väldigt snabbt, vill kunna se data på:**
    - Varvtal [rpm] (Engine speed)
    - Motorbelastning [%] (Engine load)
    - Motortimmar [h] (Engine hours)
    - Kylvätska temperatur [°C] (Coolant temperature)
    - Motor oljetryck [kPa] (Engine oil pressure)
    - Motor oljetemperatur [°C] (Engine oil temperature)
    - Transmission oljetryck [kPa] (Transmission oil pressure)
    - Transmission oljetemperatur [°C] (Transmission oil temperature)
    - Batteri spänning [V] (Battery Voltage)
    - Bränsle kvar [% or l] (Remaining fuel/Fuel level)
    - Bränsleförbrukning [l/h] (Fuel consumption/flow)
    - Bränsleekonomi [nm/l] (Fuel economy)
    - Räckvidd [nm/km] (Range)
- **Vi kommer nu ge exempel på båtrelaterad data som är vanligt förekommande i båtdisplayer, vänligen rangordna de du tycker är viktigast och välj ut några som du alltid, eller väldigt snabbt, vill kunna se data på:**
    - Position [koordinater, lat/long]
    - Båtfart [kn] (Boat speed)
        - SOG (Speed over ground, hastighet relaterat till jordens yta) eller STW (Speed through water, hastighet relaterat till vattnet).

  - Målhastighet [kn] (Target speed)
  - Vattentemperatur [°C] (Sea water temperature)
  - Lufttemperatur [°C] (Air temperature)
  - Vindhastighet [kn or m/s] (Wind speed)
  - Vindriktning [°] (Wind direction)
  - Lufttryck [hPa] (Barometric pressure)
  - Färskvattennivå [% or l] (Fresh water level)
  - Rodervinkel [°] (Rudder angle)
  - Djup [m] (Depth)
  - Riktning [°] (Heading)
  - Trimnivå [%] (Trim level)
- **Om du fick rangordna de fyra viktigaste funktionerna som skulle vara i en standard-layout, vilka skulle det vara då?**
- **Vilka funktioner är de viktigaste, sett ur ett säkerhetsperspektiv? Varför?**
  - Vilka av dessa funktioner kan du se eller styra via displayen?
- **Vilka funktioner använder du mest, oavsett användningsscenario? Varför?**
  - Vilka av dessa funktioner kan du se eller styra via displayen?
- Kan du berätta om en funktion du tycker om att använda? Vad är det du gillar med den? Är det enkel, tydlig, pålitlig?
- Kan du berätta om en funktion du inte gillar att använda eller som du upplever bristfällig? Vad är det som gör den dålig? Är den svår, otydlig, opålitlig?

Olika körningssekvenser:

Start/kasta loss:

- Tänk dig att du ska starta båten och kasta loss från en brygga, hur går du till väga? Visa gärna hur du interagerar med gränssnittet i förarhytten.
- **Vilken information vill du ta del av när du startar och kastar loss från bryggan? Varför just denna information?**
  - Visa hur du får fram den informationen
    - Ex. sjökort, motordata, havsdjup etc.
- **Är det några funktioner du brukar använda i detta moment? Varför använder du dessa?**
    - Ex. autopilot, kameror, etc.
- Om du får varningar när du kastar loss, vad vill du få varningar på – alltså vilken information?
  - Var på displayen vill du att dessa varningar ska dyka upp?
  - Föredrar du om varningarna kommer som bilder/text, ljud eller via känseln?

Målkörning, kör mot waypoint:

- Tänk dig att du ska bestämma en rutt mot en destination, hur går du till väga? Visa gärna hur du interagerar med gränssnittet i förarhytten.
- **Vilken information vill du ta del av när du kör mot ett mål? Varför just denna information?**
  - Visa hur du får fram den informationen
    - Ex. sjökort, motordata, trimplan etc.
  - Varierar detta beroende på några yttre faktorer, som exempelvis väder, passagerare, erfarenhet?
- **Är det några funktioner du brukar använda i detta moment? Varför använder du dessa?**
    - Ex. autopilot, autotrim, etc.
- Om du får varningar när du kör, vad vill du få varningar på – alltså vilken information?
  - Var på displayen vill du att dessa varningar ska dyka upp?
  - Föredrar du om varningarna kommer som bilder/text, ljud eller via känseln?

Lägga till vid en brygga:

- Tänk dig att du ska lägga till vid en brygga, hur går du då till väga? Visa gärna hur du interagerar med gränssnittet i förarhytten.
- **Vilken information vill du ta del av när du lägger till? Varför just denna information?**
  - Visa hur du får fram den informationen
    - Ex. motordata, havsdjup etc.

  - **Är det någon information du känner att du saknar?**
- **Är det några funktioner du brukar använda i detta moment? Varför använder du dessa?**
    - Ex. assisted docking, autopilot, kameror etc.
- Om du får varningar när du ska lägga till, vad vill du få varningar på – alltså vilken information?
  - Var på displayen vill du att dessa varningar ska dyka upp?
  - Föredrar du om varningarna kommer visuellt som bilder/text, via ljud eller via känseln?

Generella reflektioner:

- **Nu när vi har kollat på olika delar av gränssnittet, hur upplever du interaktionen i stort? Enkelt, roligt, utmanande, frustrerande?**
- Finns det några funktioner du hade velat addera i displayen för att underlätta i de olika användningsscenarierna?
- Om det finns fysiska knappar på displayen:
    - Använder du de fysiska knapparna? Tycker du att de tillför något i interaktionen? Varför/varför inte?
    - Är det några fysiska knappar du hade velat ändra utformning på? På vilket sätt i sådant fall? Motivera gärna varför.
    - Finns det några knappar du hade velat lägga till?
    - Litar du mer på dessa fysiska knappar än på de digitala knapparna i displayen?
- Gällande de digitala knapparna samt information i displayen:
    - Är det några knappar du hade velat ändra utformning eller placering på? På vilket sätt i sådant fall? Motivera gärna varför.
    - Finns det några knappar du hade velat lägga till?
- **Vill du känna att det är ett visst varumärke när du interagerar med skärmen?**
    - Är val leverantör av displayen viktigt för dig? Exempelvis. Om det är en SIMRAD, Raymarine, GARMIN, B&G, osv.
    - Varför/varför inte?
- Vad vill du ha för känsla av gränssnittet?
        - Lyxigt? Tekniskt? Minimalistiskt?
- **Visualiseras information i båten på ett effektivt sätt?**
    - Hade du velat få informationen presenterad på något annorlunda sätt? I sådant fall hur? Exempelvis staplar, analoga mätare, siffror, symboler.
    - Är det någon information du känner att du saknar i dagsläget?
- Vad gör att du känner dig säker på havet?
- Vad i båten gör att det känns enkelt för dig att färdas på havet?
- Hur vet du att du gjort rätt i din interaktion med båten?
    - Hur vill du få feedback på att du gjort rätt/fel?
- Någon övrig åsikt som du vill yttra eller som du tänkt på under vårt samtal?

Tusen tack för att du ställde upp på en intervju, dina svar kommer vara till stor hjälp i vårt arbete.

Kan du tänka dig att vara med på framtida användarstudier när vi har skapat koncept som vi vill utvärdera med användare?

C

Appendix C – Interview Questions Context Independent Interview (in Swedish)

This appendix contains the interview template used in the empirical studies with boat operators. This template was adapted for a context-independent interview conducted via phone or in a meeting room, without access to a boat display for the respondents to demonstrate the interaction.

The interviews followed a semi-structured format, with the **bold questions** given priority. Additional questions are asked as needed, depending on the flow of the interview and the participants' responses.

[Swedish]

Uppvärmningsfrågor:

- Vad har du för båt?
  - Hur länge har du haft denna båt?
- Berätta om lite kort om hur du använder din båt?
- Har du mycket erfarenhet av att köra båt?
  - Antal år?
- Har du erfarenhet av några andra typer av båtar? Om ja, vilka?
- Vad är det bästa och sämsta med att köra båt?
- Har du några intyg? Förarintyg eller skepparexamen? Eller annat?
- Beskriv din förarhytt och vad din båt har för funktioner
  - Fysiska reglage
  - Digitala skärmar

Skärmrelaterade frågor:

- Vad är det för märke på din/a display/er? Exempelvis SIMRAD, Garmin, B&G, osv.
- Storlek: hur många tum är din/a display/er?
- Vad för typ av display är det? MFD, kartplotter, radar, fishfinder?
- **Vi kommer nu ge exempel på några vanliga funktioner eller information som man kan se på multifunktionella displayer i båtar. Vänligen välj ut några av de du tycker är viktigast och som du alltid, eller väldigt snabbt, vill kunna komma åt:**
  - Sjökort
  - Radar
  - Ekolod
  - Autopilot
  - Assisterad docking
  - Motordata
  - Kamera vid för och akter
  - Media (musik och video)
- **Vi kommer nu ge exempel på motordata som är vanligt förekommande i båtdisplayer, vänligen rangordna de du tycker är viktigast och välj ut några som du alltid, eller väldigt snabbt, vill kunna se data på:**
  - Varvtal [rpm] (Engine speed)
  - Motorbelastning [%] (Engine load)
  - Motortimmar [h] (Engine hours)
  - Kylvätska temperatur [°C] (Coolant temperature)
  - Motor oljetryck [kPa] (Engine oil pressure)
  - Motor oljetemperatur [°C] (Engine oil temperature)
  - Transmission oljetryck [kPa] (Transmission oil pressure)
  - Transmission oljetemperatur [°C] (Transmission oil temperature)
  - Batteri spänning [V] (Battery Voltage)
  - Bränsle kvar [% or l] (Remaining fuel/Fuel level)
  - Bränsleförbrukning [l/h] (Fuel consumption/flow)
  - Bränsleekonomi [nm/l] (Fuel economy)
  - Räckvidd [nm/km] (Range)
- **Vi kommer nu ge exempel på båtrelaterad data som är vanligt förekommande i båtdisplayer, vänligen rangordna de du tycker är viktigast och välj ut några som du alltid, eller väldigt snabbt, vill kunna se data på:**
  - Position [koordinater, lat/long]
  - Båtfart [kn] (Boat speed)
    - SOG (Speed over ground, hastighet relaterat till jordens yta) eller STW (Speed through water, hastighet relaterat till vattnet).
  - Målhastighet [kn] (Target speed)
  - Vattentemperatur [°C] (Sea water temperature)
  - Lufttemperatur [°C] (Air temperature)

    - Vindhastighet [kn or m/s] (Wind speed)
    - Vindriktning [°] (Wind direction)
    - Lufttryck [hPa] (Barometric pressure)
    - Färskvattennivå [% or l] (Fresh water level)
    - Rodervinkel [°] (Rudder angle)
    - Djup [m] (Depth)
    - Riktning [°] (Heading)
    - Trimnivå [%] (Trim level)
- **Om du fick rangordna de fyra viktigaste funktionerna/informationen som skulle vara i en standard-layout, vilka skulle det vara då?**
- **Vilka funktioner är de viktigaste, sett ur ett säkerhetsperspektiv? Varför?**
    - Vilka av dessa funktioner kan du se eller styra via displayen?
- **Vilka funktioner använder du mest, oavsett användningsscenario? Varför?**
    - Vilka av dessa funktioner kan du se eller styra via displayen?
- Kan du berätta om en funktion du tycker om att använda? Vad är det du gillar med den? Är det enkel, tydlig, pålitlig?
- Kan du berätta om en funktion du inte gillar att använda eller som du upplever bristfällig? Vad är det som gör den dålig? Är den svår, otydlig, opålitlig?
- Finns det några funktioner du hade velat addera i displayen för att underlätta båtkörningen? Ex. autopilot, assisted docking, varningar, radar, trimdata osv.
- Om det finns fysiska knappar på displayen:
    - Använder du de fysiska knapparna? Tycker du att de tillför något i interaktionen? Varför/varför inte?
    - Är det några fysiska knappar du hade velat ändra utformning på? På vilket sätt i sådant fall? Motivera gärna varför.
    - Finns det några knappar du hade velat lägga till?
    - Vilka knappar litar du mest på i displayen, de fysiska eller digitala?
- Gällande de digitala knapparna samt information i displayen:
    - Är det några knappar du hade velat ändra utformning eller placering på? På vilket sätt i sådant fall? Motivera gärna varför.
    - Finns det några knappar du hade velat lägga till?

Generella reflektioner:

- **Vill du känna att det är ett visst varumärke när du interagerar med skärmen?**
- Är val leverantör av displayen viktigt för dig?
        - Exempelvis. Om det är en SIMRAD, Raymarine, GARMIN, B&G, osv.
    - Varför?
- Vad vill du ha för känsla av gränssnittet?
        - Lyxigt? Tekniskt? Minimalistiskt?
- **Visualiseras information i båten på ett effektivt sätt?**
    - Hade du velat få informationen presenterad på något annorlunda sätt? I sådant fall hur? Tex staplar, analogt, siffror, symboler
    - Är det någon information du känner att du saknar i dagsläget?
- Vad gör att du känner dig säker på havet?
- Vad i båten gör att det känns enkelt för dig att färdas på havet?
- Hur vet du att du gjort rätt i din interaktion med båten?
- Hur vill du få feedback på att du gjort rätt/fel?
- Någon övrig åsikt som du vill yttra eller som du tänkt på under vårt samtal?

Tusen tack för att du ställde upp på en intervju, dina svar kommer vara till stor hjälp i vårt arbete.

Kan du tänka dig att vara med på framtida användarstudier när vi har skapat koncept som vi vill utvärdera med användare?

D

Appendix D – Table of Interviewed Boat Operators in the Empirical Study

This appendix contains a list of boat operators who participated in interviews for the empirical study

---

Table of interviewed boat operators' experience, gender, occupation, type of interview, and location where the interview was conducted.

	Boating experience	**Gender**	**Occupation**	**Type of interview**	**Location of interview**
Respondent 1	+10 years	Male	Student	Pilot	Conference room
Respondent 2	+30 years	Male	Volvo Penta employee	Context-independent	Distance, video call
Respondent 3	6 months	Male	Volvo Penta test driver	Context-independent	Stationary boat
Respondent 4	+30 years	Male	Volvo Penta test driver	Context-independent	Conference room
Respondent 5	3 years	Male	Volvo Penta test driver	Context-dependent	Boat in motion
Respondent 6	+10 years	Male	Volvo Penta test driver	Context-dependent	Boat in motion
Respondent 7	38 years	Male	Volvo Penta employee	Context-independent	Distance, video call
Respondent 8	37 years	Male	Technical engineer	Context-independent	Distance, video call
Respondent 9	+20 years	Male	Volvo Penta employee	Context-independent	Distance, video call
Respondent 10	+20 years	Male	Volvo Penta employee	Context-dependent	Distance, video call
Respondent 11	50 years	Male	Boat dealer	Context-dependent	Distance, video call
Respondent 12	30 years	Female	Boat dealer	Context-dependent	Distance, video call

E

Appendix E – Survey Questions Empirical Studies

This appendix contains the survey used in the empirical study to gather insights into the types of information and functions boat operators want in their displays. The survey was conducted in English and distributed to Volvo Penta's reference group, while an identical version in Swedish was shared across various boating forums on Facebook.

What type of boat do you have?
For example, sailboat, motorboat, yacht etc. Model name?

For what purpose do you use your boat?
For example for fishing, water sports, as a transport, for fun, or other?

Select the features you consider most important when driving your boat.

- ○ Nautical chart
- ○ Radar
- ○ Sonar
- ○ Autopilot
- ○ Assisted Docking
- ○ Engine data
- ○ Camera at the bow and stern
- ○ Media (music and video)

Why are these features particularly important?

Select the engine data points you think are most important to monitor when driving your boat.

- ○ Engine speed [rpm]
- ○ Engine load [%]
- ○ Engine hours [h]
- ○ Coolant temperature [°C]
- ○ Engine oil pressure [kPa]
- ○ Engine oil temperature [°C]
- ○ Transmission oil pressure [kPa]
- ○ Transmission oil temperature [°C]
- ○ Battery Voltage [V]
- ○ Fuel level [% or l]
- ○ Fuel flow [l/h]
- ○ Fuel economy [nm/l]
- ○ Fuel range [nm]

Why are these features particularly important?

Select the other data points you think are most important to monitor when driving your boat.

- ○ Position [coordinates, lat/long]
- ○ Boat speed [kt]
- ○ Target speed [kt]
- ○ Sea water temperature [°C]
- ○ Air temperature [°C]
- ○ Wind speed [kt or m/s]
- ○ Wind direction [°]
- ○ Barometric pressure [hPa]
- ○ Fresh water level [% or l]
- ○ Rudder angle [°]
- ○ Depth [m]
- ○ Heading [°]
- ○ Trim level [%]

Why are these features particularly important?

Imagine you have a 22" screen in your helm, similar to the display above.

If you were to rank the most important functions/data to be displayed in a standard layout, what would they be? Why?

F

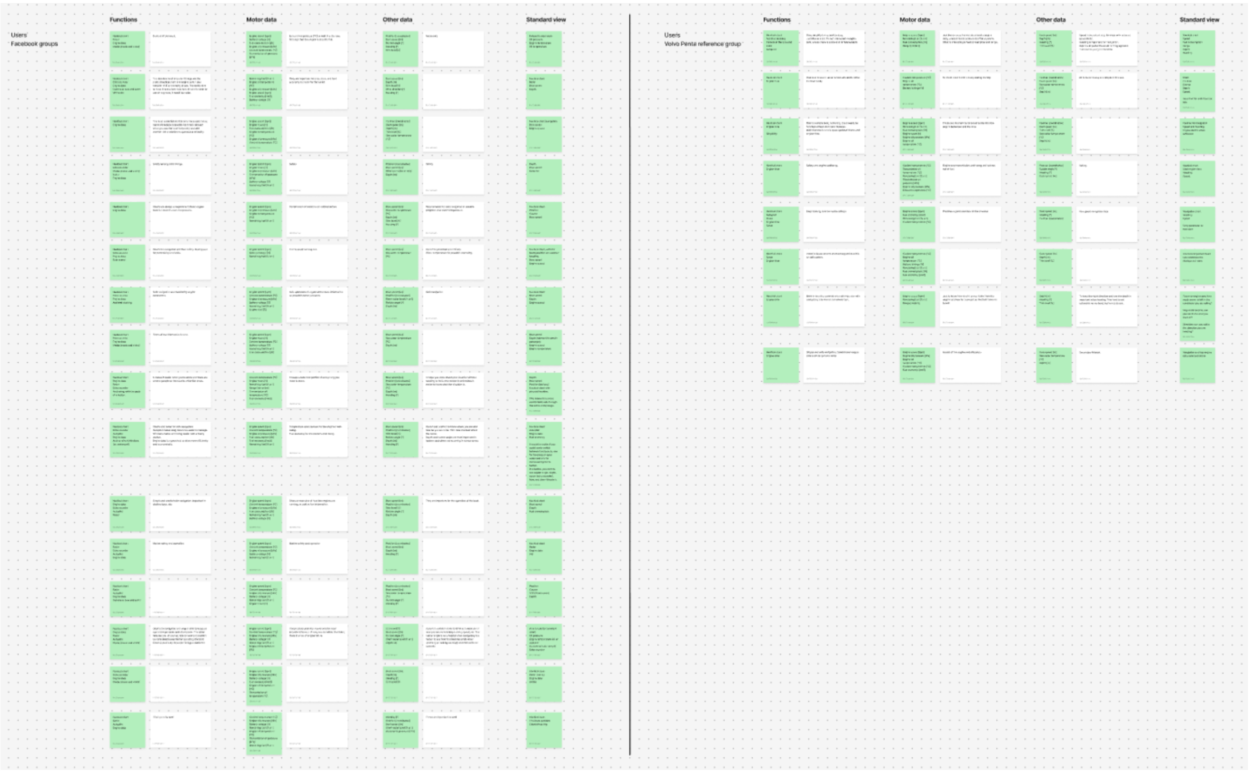
Appendix F – Structure of KJ-Analysis

This appendix presents the results of the KJ-analysis, compiled from the data gathered in the empirical study. The analysis was organized into three sections, each corresponding to different subsets of the data examined.

Structure of the analysis of the three recurring questions.

Structure of the KJ-analysis for the remaining interview questions.

Structure of the KJ-analysis for the survey.



G

Appendix G – Table of Interviewed Boat Operators in the Concept Evaluation

This appendix contains a list of boat operators who participated in interviews for the evaluation of concepts.

Table of interviewed boat operators' experience, gender, occupation, and location where the interview was conducted.

	Boating experience	Gender	Occupation	Location of interview
Respondent 1	+10 years	Male	Student	Conference room
Respondent 7	38 years	Male	Volvo Penta employee	Distance, video call
Respondent 8	37 years	Male	Technical engineer	Distance, video call
Respondent 11	50 years	Male	Boat dealer	Distance, video call

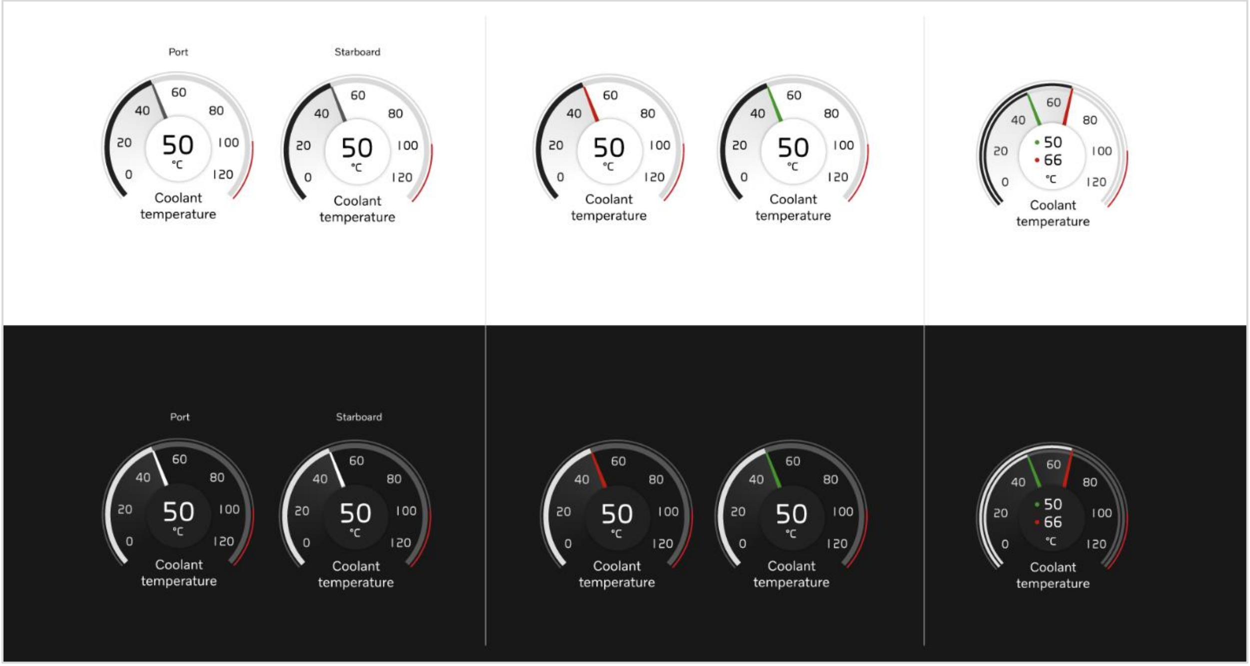
H

Appendix H – Survey Questions Concept Evaluation

This appendix contains the questionnaire that was sent out to Volvo Penta's reference group for the evaluation of the concepts.

When displaying engine data from two different engines, how would you prefer to see it - using two separate gauges or combined into a single one?

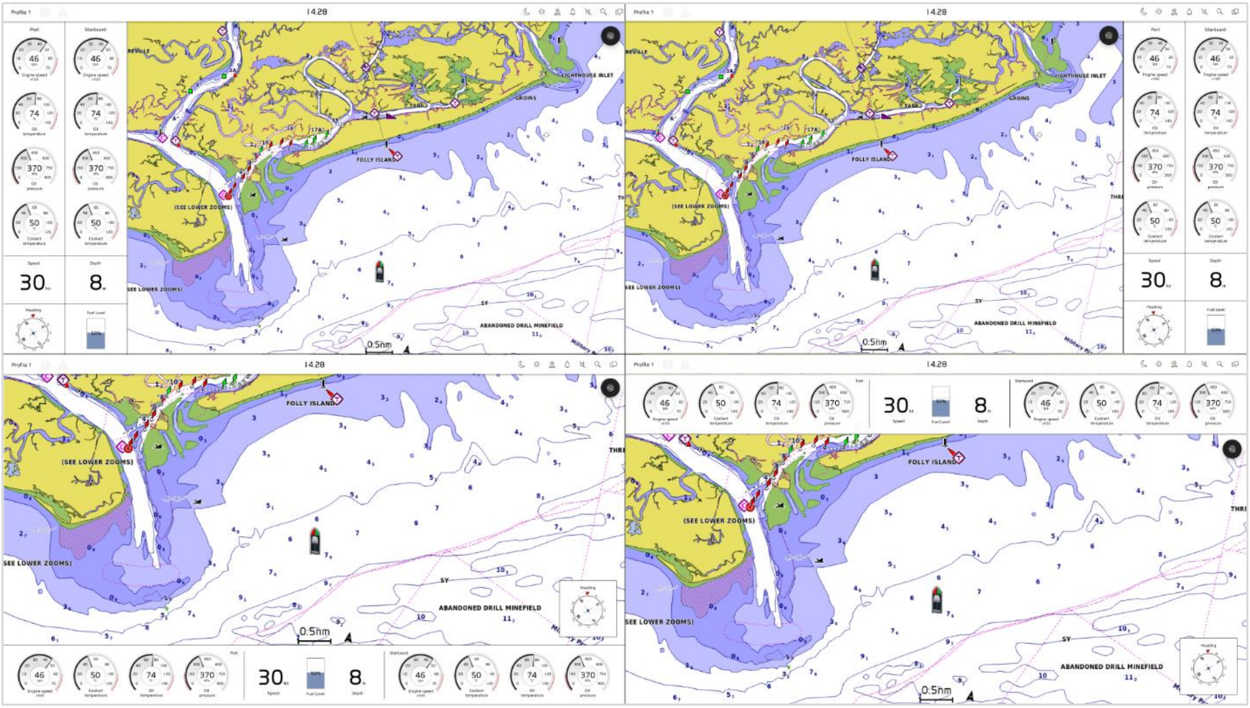
If the data is shown separately, would you rather have labels like 'Port' and 'Starboard', or distinguish the engines using different needle colors, such as red and green?
See image for comparison.



- ○ Two separate gauges with "Port" and "Starboard" labels
- ○ Two separate gauges with red and green needles
- ○ One combined gauge

Why do you want to see it this way? If you would prefer it differently, please feel free to explain how and why.

Imagine you're navigating on open water with a nautical chart and some engine data displayed. Where would you prefer to see the data – in a panel on the left, right, at the bottom, or at the top of the screen?
See image for comparison.

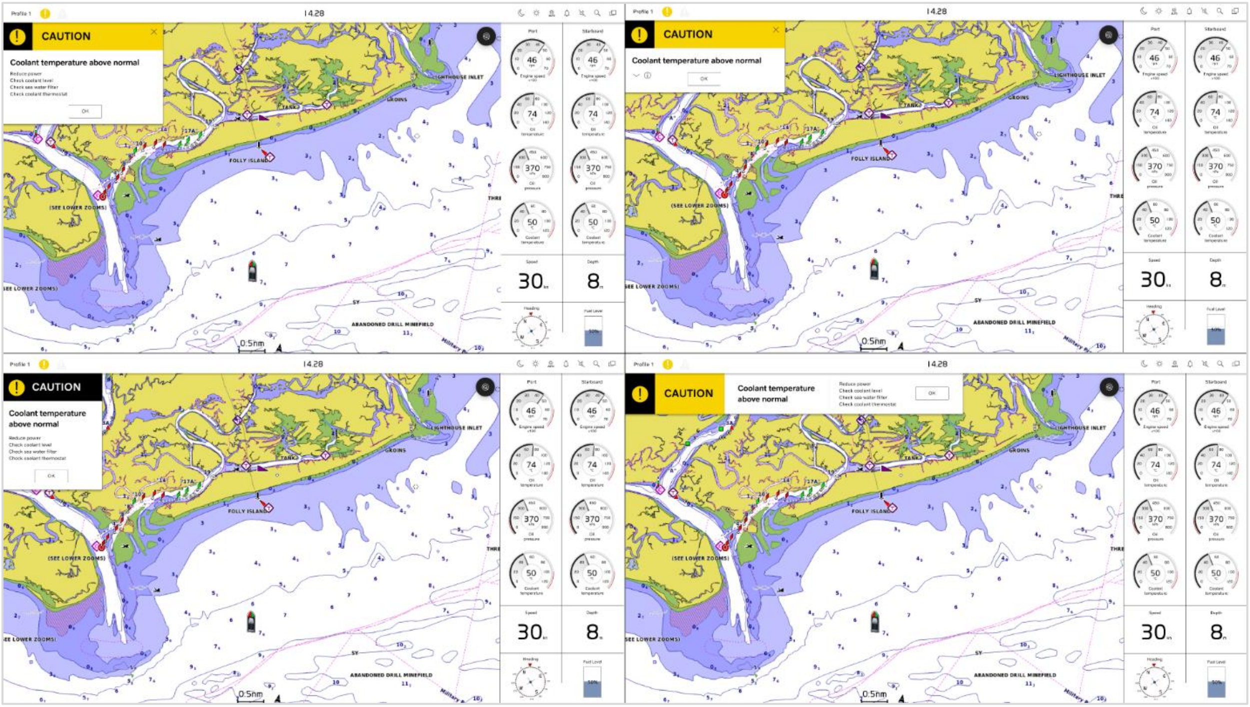


- ○ To the left
- ○ To the right
- ○ At the bottom
- ○ At the top

Why do you want to see it this way? If you would prefer it differently, please feel free to explain how and why.

Let's say you receive a warning about high coolant temperature. The warning includes information on how you, as the driver, should act to reduce the coolant temperature.

How would you prefer this warning to be visualized – a wide box, a wide box with the action plan hidden, a narrow box, or a horizontal banner?
See image for comparison.



CAUTION

Coolant temperature above normal

Reduce power
Check coolant level
Check sea water filter
Check coolant thermostat

OK

CAUTION

Coolant temperature above normal

OK

CAUTION

Coolant temperature above normal

Reduce power
Check coolant level
Check sea water filter
Check coolant thermostat

OK

CAUTION

Coolant temperature above normal

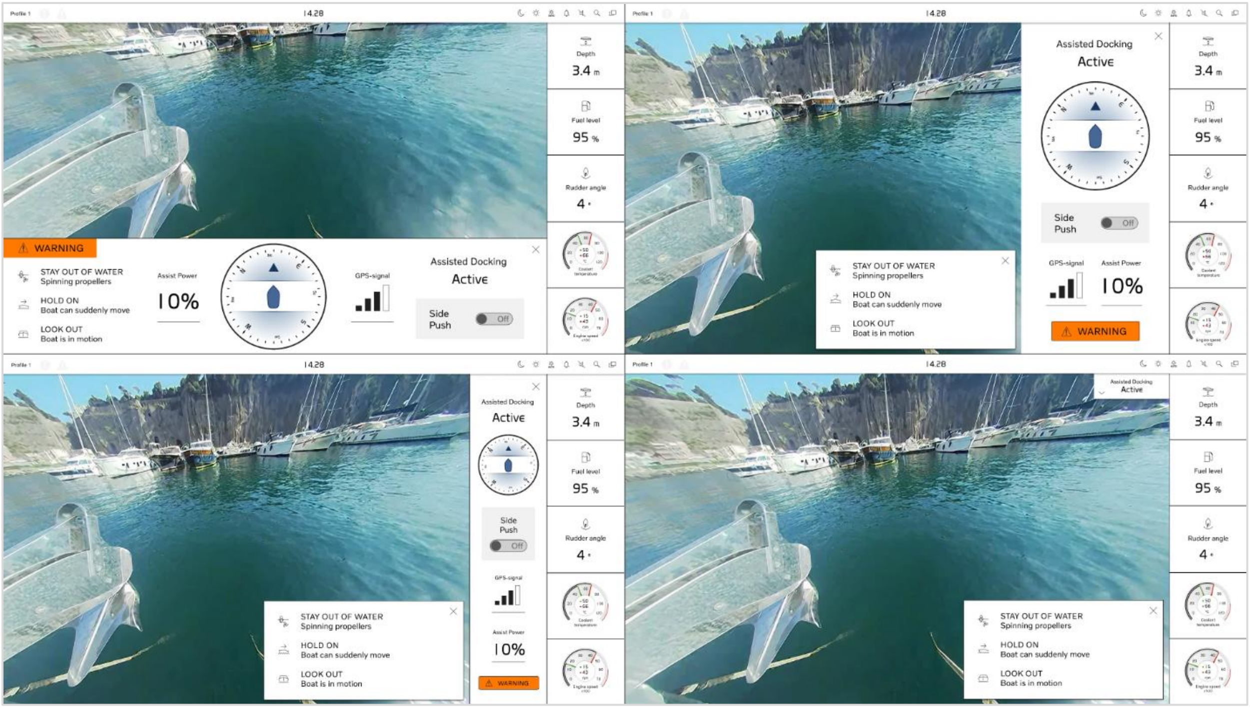
Reduce power
Check coolant level
Check sea water filter
Check coolant thermostat

OK

- ○ Wide box with action plan displayed
- ○ Wide box with action plan hidden
- ○ Narrow box with action plan displayed
- ○ Horizontal banner with action plan displayed

Why do you want to see it this way? If you would prefer the warning to be visualized differently, feel free to explain how and why.

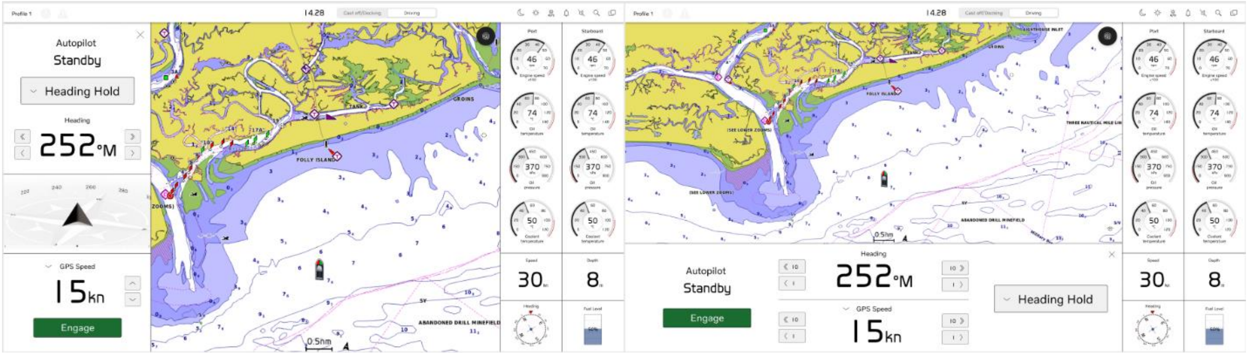
How would you like Assisted Docking to be visualized on the screen – a horizontal banner, a wide vertical banner, a narrow vertical banner, or just a small status box in the corner?
See image for comparison.



- ○ Horizontal banner
- ○ Wide vertical banner
- ○ Narrow vertical banner
- ○ Status box in corner

Why do you want to see it this way? If you would prefer it differently, please feel free to explain how and why.

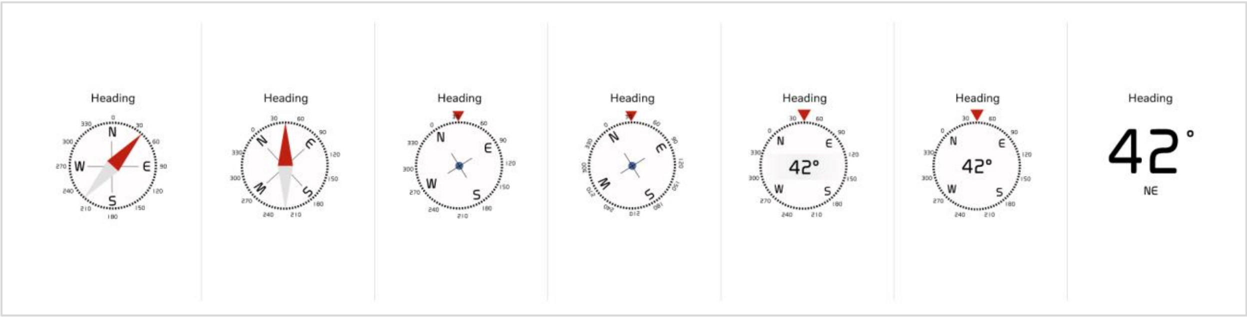
How would you like the Autopilot to be visualized – as a vertical banner on the side or as a horizontal banner at the bottom?
See image for comparison.



- ○ Vertical banner on the side
- ○ Horizontal banner at the bottom

Why do you want to see it this way? If you would prefer it differently, please feel free to explain how and why.

When it comes to how the heading should be visualized, we have a few compass designs to choose from. Select the design you prefer.
See image for comparison.

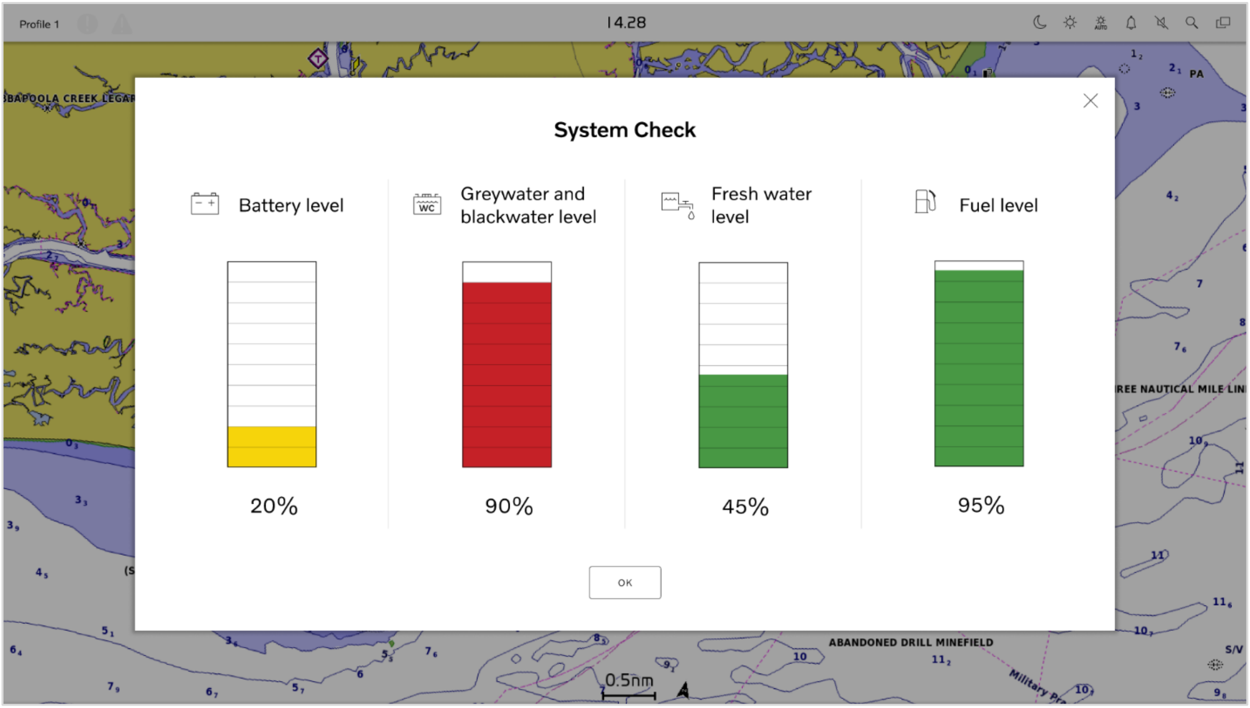


○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7

Please motivate your choice of compass. If you have any additional suggestions or preferences for the heading, we'd love to hear them.

When you start the engine and the boat's display, a system check appears showing the status of the boat's tanks — including black water, grey water, fresh water, fuel — as well as battery levels. This window disappears automatically after a short time but can also be closed manually, and it only appears at startup.

On a scale from 1 to 10, how unnecessary or useful do you consider this feature to be?
See image for visualization of System Check.



System Check

Battery level	Greywater and blackwater level	Fresh water level	Fuel level
20%	90%	45%	95%

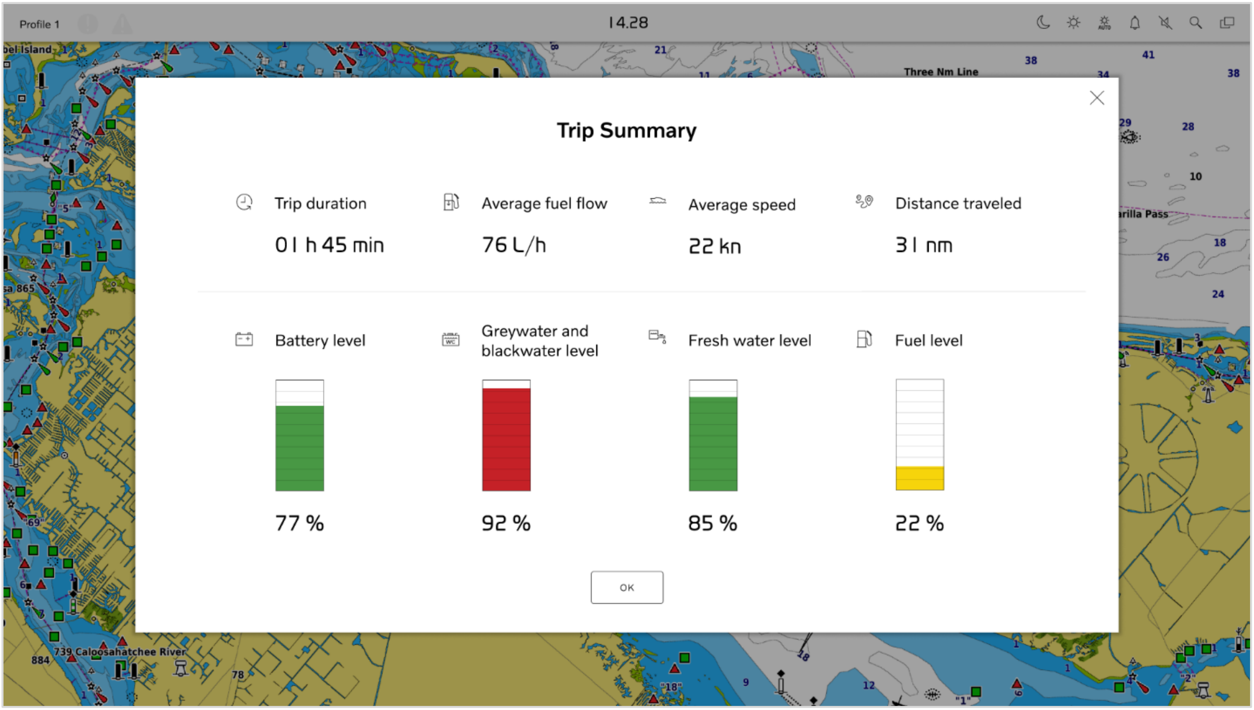
OK

○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10

Please briefly explain why you feel that way.
Is there any information you feel is missing or would like to add to this view?.

After some time out on the water, you dock at a harbor and shut off the engine. At that moment, a window appears on the screen displaying a trip summary. It shows the status of the boat's tanks, along with key trip details such as engine runtime, average speed, average fuel flow, and distance traveled.

On a scale from 1 to 10, how unnecessary or useful do you consider this feature to be?
See image for visualization of Trip Summary.



Trip Summary

Trip duration: 01 h 45 min

Average fuel flow: 76 L/h

Average speed: 22 kn

Distance traveled: 31 nm

Battery level: 77 %

Greywater and blackwater level: 92 %

Fresh water level: 85 %

Fuel level: 22 %

○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10

Please briefly explain why you feel that way.
Is there any information you feel is missing or would like to add to this view?.

DEPARTMENT OF INDUSTRIAL AND MATERIALS SCIENCE
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2025
www.chalmers.se

CHALMERS
UNIVERSITY OF TECHNOLOGY