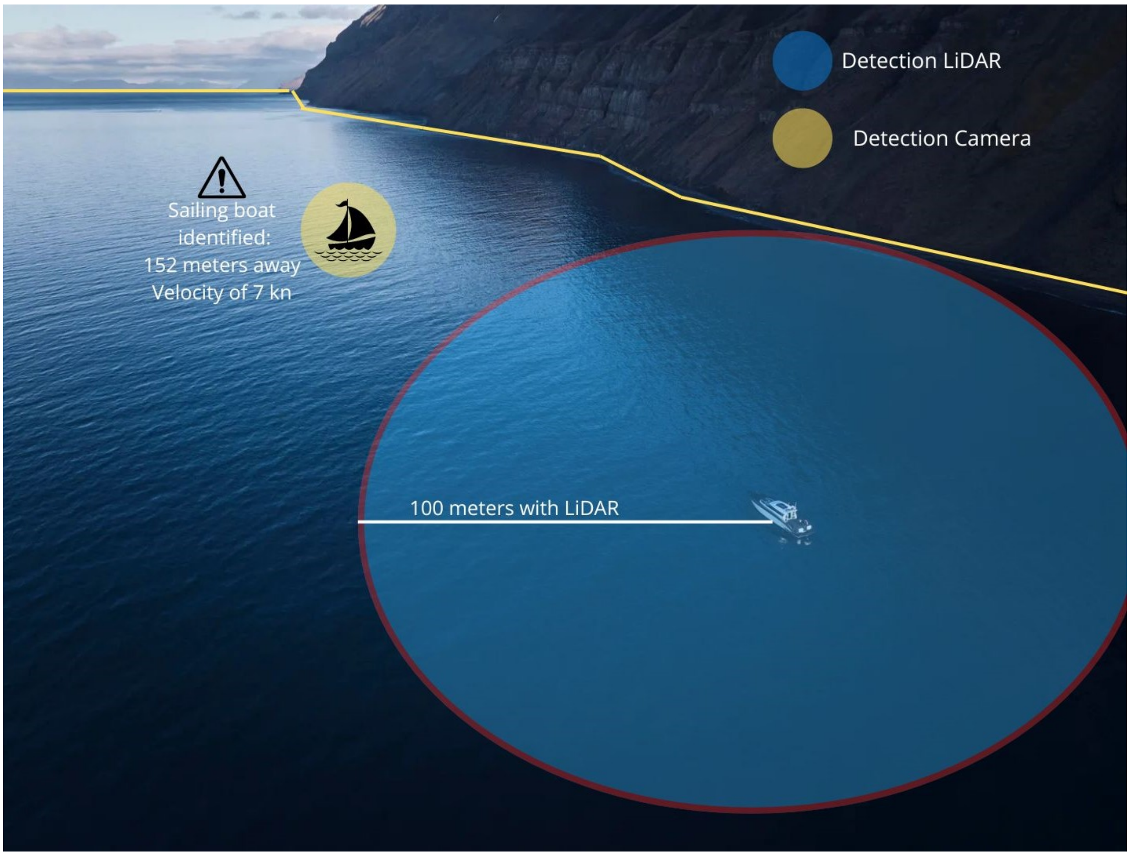

Customer Needs Identification and Concept Development in the evolving marine market

Future boat abilities developed with Volvo Penta

Master's thesis in Product Development

WILHELM JONSSON
ERIK HVIDBERG

DEPARTMENT OF TECHNOLOGY MANAGEMENT AND ECONOMICS
Division of Innovation and R&D Management
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2024
www.chalmers.se

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Supervisor: Cassandra Köbbel, Volvo Penta
Supervisor/Examiner: Lars Trygg, Department of Technology Management and Economics

Master's Thesis 2024
Department of Technology Management and Economics
Division of Innovation and R&D Management
Chalmers University of Technology
SE-412 96 Gothenburg
Telephone +46 31 772 1000

Cover: The developed concept visualized for a vessel at sea

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Abstract

In August 2023, an internal fair was held at Volvo Penta to explore opportunities for continuous update of their product portfolio. Here, stakeholders and internal R&D presented innovations for future abilities that could be implemented in the Volvo Penta offering. Many novel abilities were presented, but the fair lacked coherence and the customer needs were never addressed. The thesis aims to identify and develop desired abilities for Volvo Penta's future offerings.

The first step of the methodology was based on interviews with customers and market research. Through the identification, analysis, and structuring of customer statements, the customer needs could be formed. Both needs and market opportunities were used as a basis to generate future abilities. The most promising abilities were then selected through a three-step screening process. These abilities were then developed in further detail to prove the technical feasibility and functionality. A business case was also created to highlight the financial outlook of the abilities.

19 abilities were generated based on the information collected. After the screening process, two of the abilities remained as they were considered to be the most promising. They are the Automatic Light Guidance (ALG) and the Penta Environment Detection (PED). The PED analyzes the environment and detects hazards through camera and LiDAR sensors. The ability can detect hazards such as other vessels on collision course and objects floating in the water. The ALG utilizes the PED sensor data, to direct a spotlight which enhances safety and awareness in low visibility conditions. These two abilities were chosen to be combined as one concept, as they are highly dependent on each other. The financial outlook for the concept was considered promising, based on the high sales margins.

In conclusion, the developed abilities have high customer satisfaction, promising market opportunities, and a strong financial outlook. Based on these factors, Volvo Penta is recommended to include these abilities in their future offerings.

Keywords: Customer needs, Market Research, Idea Generation, Screening, Abilities, Technical Development, Sensor technology, Business case.

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We extend our gratitude to the individuals who participated in the interviews for customer needs identification, generously contributing their time and insights to enhance our research.

Lastly, we would like to extend our thanks to our families and friends for their support throughout this journey.

This thesis would not have been possible without the mentioned people above. Thank you!

JONSSON & HVIDBERG, GOTHENBURG, MAY 2024

List of Acronyms

Below is the list of acronyms that have been used throughout this thesis listed in alphabetical order:

AI	Artificial Intelligence
ALG	Automatic Lightning Guidance
AR	Augmented Reality
CPU	Central Processing Unit
EVC	Electronic Vessel Control
FOV	Field Of View
GPU	Graphics Processing Unit
LiDAR	Light and Detection Ranging
PED	Penta Environment Detection
SEK	Swedish Krona
UX	User Experience
VMM	Vessel Main Module

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Introduction

1.1 Background

In the market of boating and yachabilities presented.mpany Volvo Penta is pioneering in both the propulsion systeregulationsing mechanisms. Volvo Penta is a joint company within the Volvo Group that focuses on delivering power solutions for both marine and industrial applications. This has led to innovations with respect to sustainability and reliability in the propulsion segment. The current communication system for the marine segment, EVC 2 (electronic vessel control), enables the hardware in the steering mechanism to connect to the engines that propel the vessel. The EVC 2 system connects the engine, control systems and instruments to be able to exchange information, which means that the system runs all the way from the propeller (prop) to the Helm. The Helm refers to the entire steering mechanism for the boat, including the steering wheel and associated hardware such as throttle control, joystick, and screens.

Volvo Penta does not build boats on its own, but instead boat builders can integrate this system into their boats. Since the EVC 2 system spans all the way from the prop to the Helm, it can be divided into different subsections. In the figure 1.1 presented by Volvo Penta [33], a visualization of the EVC 2 and its subsystems can be seen. The Helm is the subsystem that includes components for maneuvering the boat. The maneuvers taken at the Helm will affect the rest of the subsystems. Moving down from the Helm, there is the engine control system, which ensures that the engine runs efficiently. Furthermore, there is the transmission control that controls the power and steering for the propulsion. Under the heading 'VMM', the vessel main module subsystem is presented. In simple terms, the VMM is a central node that connects all different subsystems together and will be used for aftermarket changes and as a diagnostic tool. In addition to the main EVC 2 subsystems, optional controls can also be added, such as the corrosion protection module.

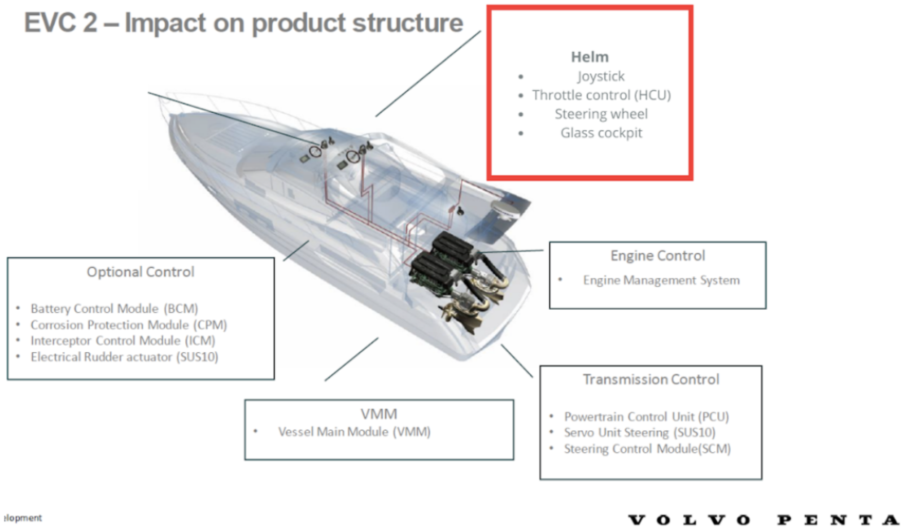


Figure 1.1: EVC 2, Volvo Penta product offerings in sub systems

The figure presented by Volvo Penta (see figure 1.2) outlines the main hardware components of the Helm of EVC 2 [33]. It consists of a joystick control, used primarily to steer the boat while docking. The throttle control, used for adjusting the power output of the engine(s) and other settings such as autopilot. The glass cockpit are the screens used for navigation and presentation of other data such as engine oil temperature and RPM (revs per minute) of the engine. Finally, the steering wheel is used to steer the vessel, mainly at higher speeds. As indicated by the name, EVC 2 is the second generation of the EVC system, where the technical internal system has changed over the course of the development. With regard to the Helm, it is clear from the market that Volvo Penta can be considered as a market leader. However, it should be noted that the Helm hardware has remained mostly the same for 18 years [32], so it is due for an update.

Figure 1.2: EVC 2, Current Helm offering

When the Helm is integrated into a manufacturer's boat, it is integrated into the cockpit. The cockpit is the area where the crew sits and operates the vessel [32]. Currently, the EVC 2 offering is integrated into the cockpit, oftentimes with many different systems from many manufacturers. An example could be navigation systems, which can come from manufacturers other than Volvo Penta and the boat builder. The integration of the Helm to the cockpit will be different based on the components requested by the customer. Thus, the cockpit will be affected by what type of Helm customers want integrated into their boats.

The EVC 2, including all of the subsystems, does not only offer simple maneuverability. As the EVC 2 system is based on information exchanged by different parts of the vessel, it enables the vessel to perform specific tasks, or so-called abilities. These abilities are a major part of the value given to the customer and is one reason why customers choose Volvo Penta over competitors. An example of an ability is the ability to propel the vessel in any direction. To do this, the Helm joystick is used to operate the engine in a specific way. This exchange of information enables maneuvering in all directions.

All of the abilities currently offered in EVC 2 are presented in Figure 1.3. Since the release of the first generation of the EVC, new abilities have been continuously added to offer the customer an 'easy boating experience' [33]. Easy boating is a common vision at Volvo Penta, which means that it should be easy for everyone to use a boat [32]. One must understand and be aware of the current abilities and features of the system to develop a future Helm in a way that will be considered better compared to EVC 2.

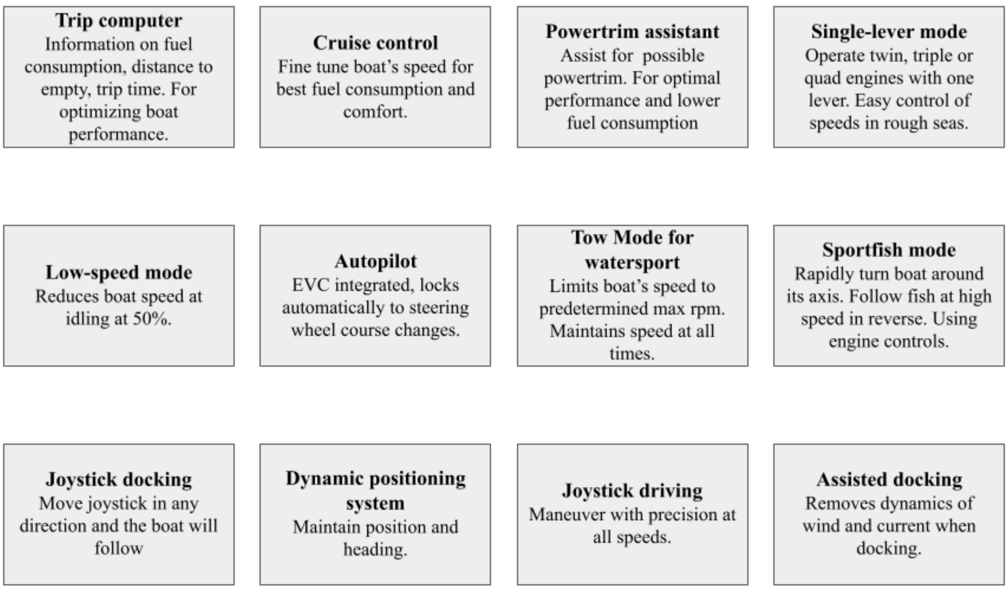


Figure 1.3: Abilities of the EVC 2

As a way of exploring the opportunities for the future, a fair was held internally at Volvo Penta in August 2023. Here, suppliers, partners and internal R&D presented many new futuristic abilities and functions that a vessel could have. For example, adopting augmented reality (AR) for determining distances to objects and surround sound used to enhance the user experience (UX). Consequently, it was presented how these abilities were integrated into the Helm and even the cockpit of the vessel. Even if the fair presented innovative abilities, it was still apparent that there is still no common vision for the future abilities. Furthermore, according to Volvo Penta, it is not possible to integrate new abilities into the current EVC 2 system [32]. Thus, to be able to integrate new abilities, there has to be a change from the current EVC 2 system.

To solve future integration problems of the EVC 2, a next-generation EVC update with code name 'next-generation Helm' is planned for release in the near future. Without disclosing confidential information, it can be stated that there are no major differences to the current Helm components or offering. In the article on *the influence of time-to-market*, written by Nunes and Braga, they argue that keeping the product portfolio continuously updated is important to stay ahead of competitors and sustain and develop the market share [3]. Therefore, a major update of the EVC is important.

Today, boat builders choose different manufacturers for different parts of the Helm, resulting in a cluttered cockpit. During the fair, senior management also presented a change in the Volvo Penta business strategy, which addressed this situation. The strategy is to focus on delivering a comprehensive solution for the marine segment, where the Helm and cockpit will be a significant part of the offer compared to today. This shows potential for the major update to the Helm, which will allow the integration of new abilities. The timeline of this system update is between 5-10 years in the future. Looking back at the fair, many new innovative abilities and implementations at the Helm were presented, but a common theme in the presented abilities is lacking [32]. Thus, a question remains to be asked:

What abilities do the Volvo Penta customers want integrated into the Helm?

Identifying these customer needs and designing the new abilities in-line with them will lead to a more successful offering and possibly a broader market share. A customer needs study can also give insight into possible abilities not presented during the fair. Furthermore, focusing development on what customers want reduces the risk of costly R&D mistakes.

To clarify the development, a timeline can be seen in Figure 4. As stated above, the next-generation Helm only has minor updates in terms of functionality, which limits the possibilities of implementation of these new abilities and features. These new abilities will therefore be integrated in 5-10 years, and they will be a part of future Helm vision.

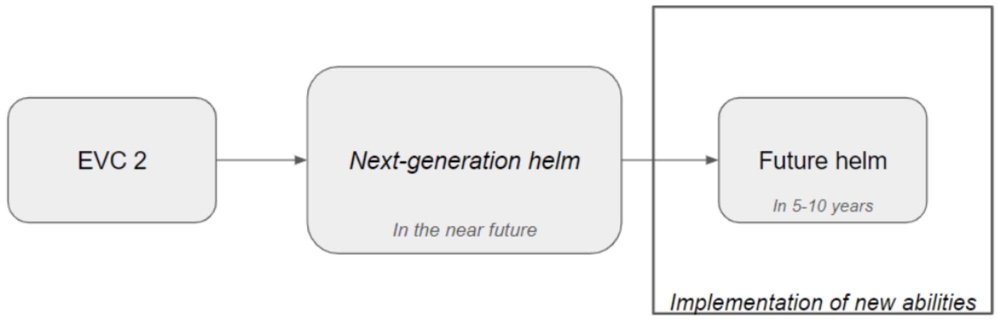


Figure 1.4: Timeline of the Helm offering

In summary, Volvo Penta has the EVC 2 system for controlling and steering the boat, and it is reaching the maximum capacity to develop against future needs. To stay ahead on the marine market, a continuous update of the product portfolio is immensely important [3]. The importance of updating and developing the system has been stated by the senior management; however, there lies an uncertainty in what future abilities should be integrated.

1.2 Aim

The aim of the thesis is to identify and develop desired abilities for Volvo Penta's future offerings of the EVC system and future Helm.

1.3 Limitations

To set a direction for the thesis, limitations have to be defined. The limitations will be presented in an order which first looks at the main focus of the development and successively goes towards a more detailed.

Firstly, Volvo Penta operates in various segments from land to sea, as described in the background. This thesis will focus on the marine segment. Thus, disregarding development in the land segment which is based on the engines for different kinds of construction vehicles. Although the marine segment is chosen, there are still limitations to be set. The Volvo Penta marine segment consists of marine commercial and marine leisure [33]. The thesis will not address the marine commercial segment due to more strict regulations, which differ from the leisure segment. Taking these regulations into account would increase the time and scope of the thesis.

In the marine leisure segment, there are sub-categories; sailboating, powerboating (20-50 feet), yachts (50-80 feet) and superyachts (80+ feet). The category of sailboats will not be taken into account in the development. Sailboats are not chosen on the basis of the different layout and type of systems, such as propulsion and steering mechanisms. The design of the cockpit of the sailboat differs from most powerboats and yachts, having a larger steering wheel and different controls layout.

Another area that needs to be restricted is the technological depth of the analysis and the outcome of the concept. As stated earlier, the thesis has its main focus on desired abilities for the future Helm. The technological analysis will not cover the full future system architecture for the implementation of the abilities but rather focus on what components need to be included, and how they interact.

When it comes to the customer needs identification process, the methodology was inspired by the methods presented by Ulrich and Eppinger [30]. These methods are specifically catered to product development, and since the the thesis outlines the development of abilities, the method could not be followed exactly as presented. Thus, the thesis had to adjust or skip certain steps of the Ulrich and Eppinger methodology.

Although efforts were made to incorporate relevant financial data in the business case, the depth of analysis may be limited, and certain parts may not have been fully specified. This stems from the financial aspects not being the focus of the thesis. To base the business case on relevant data, a project manager at Volvo Penta was consulted to specify relevant information. As a result, the financial implications presented in this thesis should be interpreted as an overview of profitability and not a comprehensive financial analysis.

Furthermore, the thesis will not cover the ethical or legal implications of the new abilities developed.

1.4 Specification of the issue being investigated

To specify the issue being investigated, the purpose and main objectives will be specified. The result will answer the research questions that will guide the research and development.

1.4.1 Research Questions

The research questions have been formulated based on the background, limitations and purpose.

RQ1: *What abilities do the customers of Volvo Penta want integrated into the future Helm?*

RQ2: *How does the most promising abilities, according to the customers, function from a technical point of view?*

RQ3: *What is the financial outlook for the chosen abilities?*

2
Methods

The second chapter clarifies the method used in the thesis. This includes research design and strategy, as well as the methods employed. The methods are structured in a four-step road map.

2.1 Research Strategy

The research strategy, as defined by Merriam and Tisdell [21], is related to the approach used to conduct the study. There are two main types of approaches described by Merriam and Tisdell, quantitative and qualitative strategies [21]. The quantitative research strategy is numerical in nature, to describe facts and characteristics or relationships between events. Furthermore, according to Bell and Bryman, quantitative research is defined by deductive reasoning, where a researcher first formulates a hypothesis and conducts a research to test the hypotheses [7]. Qualitative research is based around uncovering the meaning of a phenomenon, how people interpret experiences, construct their worlds, and the meaning they attribute to their experiences. The qualitative approach uses inductive research to identify patterns and hypotheses to make meaning of the data. Based on this information, Merriam and Tisdell [21] support the choice of qualitative research, because of the focus on the customer needs study.

2.2 Research Design

As defined by Bell and Bryman in 2022, the research design is a framework for collecting evidence for research questions, as well as analyzing the data [7]. Aligning the research questions and the purpose, the chosen framework is the single case study. The framework makes conclusions based on Volvo Penta, the single case presented. A single case provides in-depth context and information, which is useful when designing a specific product or part [7]. Although the case is based on Volvo Penta systems, the thesis includes external research to enrich the study. Thus, making the thesis replicable to other cases.

As Bell and Bryman have described in their 2022 book, a research design serves as a structured approach to collect evidence relevant to the research questions, as well as to analyze the collected data [7]. In line with the research questions and the purpose, this study adopted a single case study framework, focusing on Volvo Penta as the case under investigation. Using a single case study allows for an in-depth context [7], particularly valuable in the context of developing future abilities for Volvo Penta. While the case study analyzes Volvo Penta's systems, external research will be incorporated to enhance the depth and breadth of the study, thereby increasing its applicability to other similar cases.

The single case framework is structured into four distinct phases, illustrated in Figure 2.1.

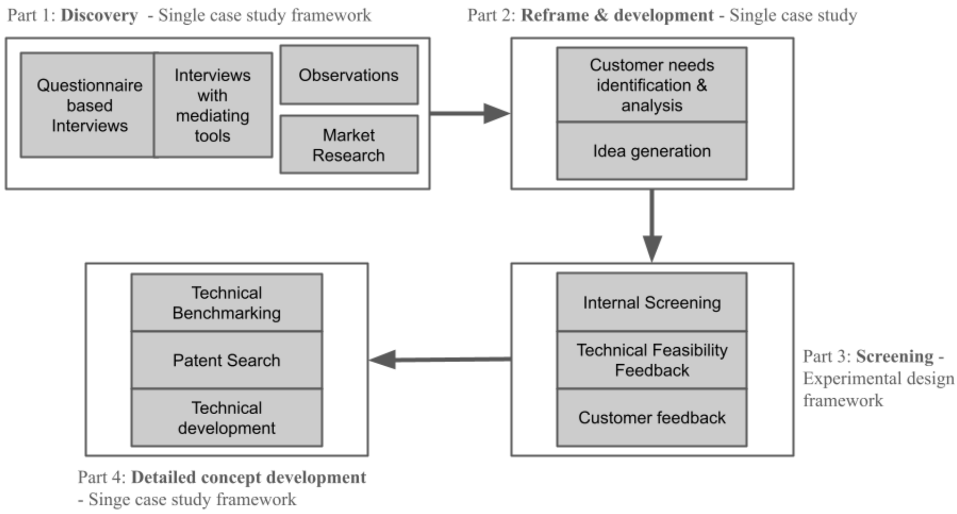


Figure 2.1: Roadmap of thesis

The first phase focuses on data collection aimed at collecting customer and market data.

The second phase involves a reframe and development stage, leveraging Ulrich & Eppinger's methodology [30] for identifying customer needs, analyzing and presenting new abilities through idea generation.

In contrast to traditional single case studies, the third phase introduces an experimental design framework. As described by Merriam and Tisdell [21], experimental research is used to draw conclusions from specific hypotheses; these hypotheses relate to the abilities generated through the generation of ideas. This phase includes internal screening, technical feasibility assessments, and customer feedback. The internal screening process involves taking the abilities through the development funnel as outlined by Ulrich & Eppinger [30]. Technical feasibility feedback requires presenting the developed concepts to technical experts to evaluate their feasibility. In addition, customer feedback is sought to ensure that the screened abilities align with their initial customer needs. In the following, the four steps presented in the research design are described in further detail.

The methods employed throughout the thesis are based on the methods presented by Ulrich & Eppinger in their book Product Design and Development [30]. Since the thesis aims to develop future abilities rather than products, the methods presented by Ulrich & Eppinger will be used when applicable. Ulrich & Eppinger presents methods for product development, and therefore alterations were made to accommodate the development of abilities. The major differences between products and abilities were seen as the lack of clear boundaries of abilities. Abilities cover different parts of the vehicle, including multiple functions. Products, on the other hand, are more structured and include one function which can be broken down into clear sub-funcitons.

2.3 Discovery

In Section 2.3, the data collection methodology is described, structured around the four steps depicted in Figure 2.1. Keeping the qualitative research approach, the data was collected from market research, interviews, and observational studies. Continuous research of internal Volvo Penta resources was used to mitigate the risk of reinventing the wheel.

2.3.1 Market Research

Ulrich and Eppinger's product design and development framework emphasizes the importance of market research in benchmarking current technologies and trends [30]. Developing an understanding of the market dynamics of the boat world provides a valuable direction in developing abilities for the thesis.

This approach serves dual purposes: firstly, facilitating a comprehensive exploration of competitors and their strengths and weaknesses, thereby identifying market gaps for targeted product development initiatives. Secondly, it serves as a wellspring of inspiration for the ongoing refinement and enhancement of the Volvo Penta offering. The project team conducted market research within the marine sector, while also examining trends within the automotive industry, which, given its progress in technological innovation, has been largely driven by a more competitive market landscape. This cross-industry analysis not only enriched the ideation phase but also provided valuable insight into future prospects and capabilities within the marine industry.

2.3.2 Interviews

Interviews were the main source of data collection, as they are suitable for collecting empirical data [7]. The structure of the interviews was based on the theory presented by Ulrich and Eppinger in 2020. Each interview session was scheduled for one hour and the structure of these interviews was divided up into two parts;

1. Questionnaire-based with semi-constructed questions exploring the needs of the customers.
2. Using mediating tools to discuss the current EVC 2 system, competitor solutions and cockpits from other segments.

The first part of the interviews was semi-structured. A semi-structured interview is an interview where there are a few predefined questions to guide the conversation but with flexibility to explore new topics. In general, semi-structured interviews are valuable in qualitative research, particularly when seeking to understand the subjective experiences and perspectives of the participants [11]. Consequently, it was useful when seeking to understand boat-owner's needs.

The second part of the interview included mediating tools. According to Ulrich and Eppinger, mediating tools are used to enrich data by increasing engagement and clarity of content [30]. For this study, visual tools in the form of pictures of the EVC 2 were utilized.

In terms of sampling methodology, nonprobability sampling was employed, given its use in qualitative research contexts [21]. Specifically, purposeful sampling was used to select participants from whom maximum insight could be obtained [21]. To expand the pool of participants, snowball sampling was adopted to find individuals within the boating and yachting communities. This approach facilitated a more extensive and diverse sample, particularly given the niche nature of the customer base interested in larger boats and yachts.

Looking at customers needs, it can be stated that customers mainly operate the vessels but there are instances where the customers do not operate the vessel themselves. Thus, to capture the needs, customers can be divided into different types of users who operate the vessels. Participants were classified into five distinct groups according to the Ulrich and Eppinger theory [30]: primary users, experts, stakeholders, and lead users. Thus, when referring to customers, all the users presented will be included. These user types capture the customer needs. Users will also be used to describe when customers or other users operate the vessels. Table 3.1 below delineates these user categories, along with the types of user found by purposeful sampling.

Based on the research presented by Griffin and Hauser, 98% of the customer requirements are identified after the 20 interviews [30]. In the actual sample size of the study, 14 interviews were conducted due to time restrictions.

The main focus of the interviews was to engage with primary users, as they have a lot of experience driving vessels that have Volvo Penta systems installed. The interviews were mainly conducted in a digital meeting format, since some users are not located in the Gothenburg region. An interview was conducted in person at the institution of management and economics of innovation at Chalmers University of Technology. Since the interviews were held in pairs, one person was able to focus on

Table 2.1: User Categories and Types of Users

Type of User	**User Category**
Primary user	Customers of the power boats
Primary user	Customers of the yachts
Experts, stakeholders	Internal experts at Volvo regarding the current system EVC 2
Experts	Boat builders
Stakeholders	Service personnel at Volvo - Observation
Lead users	Captains of boats and yachts
Lead users	Boat instructor

interacting with the interviewee, and the other was able to take notes. Note taking was the chosen method for documenting the interviews. The interview guide for all of the user types can be found in Appendix 2.

2.3.3 Observations

In alignment with the thesis roadmap, the first phase also involved observing the functionality of the current system. As suggested by Merriam and Tisdell, ethnographic methods will be used for this purpose [21]. Ethnographic observational studies were conducted to capture latent needs that may not have been articulated during the interviews. Latent needs can offer insight into unconscious behaviors [30]. Observations were conducted in collaboration with an internal Volvo Penta expert, where observations were made with the person interacting with the existing EVC 2 Helm in real-life conditions. The observational study was documented by taking pictures and videos, as well as keeping notes throughout the interaction.

2.4 Reframe and development

The reframe and development phase included the customer needs identification & analysis followed by the generation of ideas.

2.4.1 Customer needs identification & analysis

In the customer needs identification and analysis stage, the methodology employed is rooted in an approach to identify customer needs and establish target specifications by Ulrich and Eppinger [30]. However, the scope of this thesis diverges from that of Ulrich and Eppinger's work.

2.4.1.1 Ulrich and Eppingers method for identifying customer needs

Traditionally, the method for identifying customer needs is a five-step process, where the third step includes "organizing the needs into a hierarchy of primary and secondary needs". This is done to facilitate working with a large number of needs. Working with fewer needs led to handling the needs as one, thus eliminating the third step. This leads to a four-step process:

1. Data collection from customers.
2. Interpret the raw data in terms of customer needs.
3. Establish the relative importance of the needs.
4. Reflect on the results and the process.

Data collection from customers

During the discovery phase, raw data were gathered and documented by taking notes. To interpret data in subsequent stages, this raw data was structured using a template, as depicted in Figure 2.2, which was used consistently in all interviews. Organizing customer statements into the categories presented in the interview guide helped to organize the statements in a systematic way. The collected needs were further interpreted into the underlying needs, which will be discussed further in the following chapter.

Person being interviewed	Category	Customer statement	Interpreted need
User being interviewed	Drivining expierience		
	Digital vs traditional helm		
	User experience		
	Ergonomics		
	Suggested improvements for their vessel		

Figure 2.2: Template for data collection

Interpret the raw data in terms of customer needs

According to Ulrich and Eppinger, establishing customer needs involves interpreting the raw data collected from interviews and observations [30]. Ulrich and Eppinger also further discuss Griffin and Hauser's findings, where interpretation of customer needs varies from person to person. Therefore, the interpretation was made in a group of two. Furthermore, Ulrich and Eppinger's five guidelines for interpreting needs were followed:

- "What" not "How"
- Specificity
- Positive not negative
- An attribute of the product
- Avoid "must" and "should"

Establish the relative importance of the needs

Ulrich and Eppinger propose a survey to establish the relative importance of the needs identified in previous stages [30]. Because of time constraints, surveys will not be used as a way to establish the relative importance. Instead, the importance of the needs will be based on the occurrence of the needs in the interviews, as many customers shared similar needs. Since customers formulate themselves differently from each other during the interviews, the needs were interpreted slightly differently for each interviewee. When establishing the importance of the needs through the occurrence, the needs with a similar formulation were grouped as the same need.

Reflect on the results and the process

The last step in the customer needs identification process was reflecting on the process. Ulrich and Eppinger provide questions for reflection; below are two questions used in the process:

1. Are there any areas of inquiry we should pursue in follow-up interviews or surveys?

2. Have we interacted with all types of customers in our target market?

These questions were handled not only in the end but also throughout the customer needs study, to ensure that the study included all the needed data.

After the needs have been identified, Personas can be created. Creating personas is a way to communicate and better understand the identified needs [5].

2.4.1.2 Ulrich and Eppingers method for establishing target specifications

After the importance of the needs has been established, the target specifications are set. The target specifications facilitate the design and engineering of a specific product [30] or, in this case, an ability.

The target specifications are measurable specifications that outline what the ability should do. The setting of target specifications was done before generating abilities from the needs. In the case of developing the abilities, the target specification was used to compare abilities in the screening process.

Prepare the set of metrics The metrics were established by considering each need to consider the precise measurable characteristic that the ability has to perform. These metrics reflect the degree to which the ability will satisfy the customer's need.

The metrics were structured in the form of a needs-metrics matrix. A needs-metrics matrix is structured with two axis. A column for the needs identified in earlier stages and a row for the metrics defined. To fill out the matrix, each need is analyzed to define an attributed metric. Since some needs might be difficult to describe with one single metric, needs can have more than one metric associated with them. However, ideally, each need corresponds to one metric, since metrics should be "complete" [30]. The matrix created empty cells, where dots were placed in the cells if the need corresponded to the metric.

Target specification The final target specification was made up of 5 columns. The structure of the target specification was altered from the original structure proposed by Ulrich and Eppinger. Ulrich and Eppinger propose defining the importance, units, marginal, and ideal value for each metric. This is suitable for the development of products. To fit the development of abilities and the scope of the thesis, the structure was changed from that of Ulrich and Eppinger. The target specification included the metric, importance, and units. The importance was based on the importance of the needs established in the earlier steps. Units were established by defining how each metric is measured. In this stage, other general target metrics were added, inspired by the needs presented in the book Product Design and Development by Ulrich and Eppinger [30].

2.4.2 Idea generation

Because of time constraints, the generation of ideas was based on the most occurring needs. The most occurring need had eight occurrences, while the lowest is one. The chosen needs had an occurrence of five or more. Ideally, all needs would have been included, but since this is a future development of abilities rather than a specific product, some differences were made. The idea generation resulted in abilities that solved the needs of the customers.

Ulrich and Eppinger's method for concept generation presents a five-step process from which concepts can be derived.

1. *Clarify the problem*
2. *Search externally*
3. *Search internally*
4. *Explore systematically*
5. *Reflect on the solutions and the process*

This approach for product development is well suited for developing specific components or products with defined borders. In contrast, the thesis covers development of abilities with less defined borders. Thus, the idea generation diverges from that of Ulrich and Eppinger. The steps used for the generation of ideas were;

1. Market research
2. Brainstorming from customer needs

Market research was outlined in the discovery phase, and using the information gathered from the market develops the understanding of the market dynamics and trends, which can prove valuable when brainstorming future abilities.

Brainstorming was used to generate ideas. The needs of the customers were the focus to guide the brainstorming. The session lasted over one hour, where ideas were written and sketched. The brainstorming took inspiration from the market research performed in the discovery phase, as well as the top five customer needs that occur. Ulrich and Eppinger propose guidelines for brainstorming [30]:

- Suspend judgement
- Generate a lot of ideas
- Welcome ideas that might be infeasible
- Make plenty of sketches
- Build sketch models.

The sketch model building was not used because the materials needed to build the models were not available at the Volvo Penta office.

After the ideation phase, the generated concepts were structured using a matrix. Ulrich and Eppinger propose to use a morphological matrix [30]. The morphological matrix is based on an idea generation based on subfunctions. The idea is to propose solutions to subfunctions of a problem [30]. This serves as a structured framework where all identified solutions are systematically organized for each subfunction. Each solution is also associated with a corresponding sketch to enhance understanding. Subsequently, the morphological matrix is utilized to identify and merge similar solutions, as well as combining the different solutions to the subfunctions to create many different concepts. The concepts are therefore unique in the type of solutions they are based on. These concepts can later be eliminated using different methods.

As the thesis focuses on development of abilities and not products, it was not possible to create sub-functions based on the needs. Therefore, the morphological matrix was not the method chosen to structure the abilities generated. Instead, the abilities generated were structured in an "ability matrix" with the needs on the y axis and the corresponding abilities on the x axis. This creates a list of abilities for each need. Since the ability matrix is not based on sub-functions, no combination of many possible concepts was made. Instead, the abilities are eliminated directly.

In conclusion, the reframe and development stage of the method took the customer statements from the discovery phase and identified the needs within them. With the needs identified, future abilities could be generated through idea generation by brainstorming the customer needs, as well as market analysis. The next step is to screen these abilities through internal and external screening, as well as customer feedback. The screening is used to choose the most promising abilities.

2.5 Screening

The screening part of the method is about reducing the number of abilities and choosing to focus the detailed development on the most promising ones.

The screening was divided into three different parts. Firstly, an internal screening of the abilities was performed using a Pugh matrix. Secondly, the abilities that passed the first screening were evaluated together with technical experts at Volvo Penta, where technological feasibility was the focus. Lastly, abilities that passed the technological feasibility screening were evaluated with customers, where customer satisfaction was highlighted, ultimately guiding what ability / abilities to focus the further detailed development on.

2.5.1 Internal screening

The process of internal screening includes assessment and elimination of abilities from the ideation phase. This evaluation is guided by the metric criteria from the needs-metric matrix and general criteria from the target specification. Abilities that do not meet the metrics sufficiently are systematically excluded from further consideration. The criteria were added to a Pugh matrix. The technique was created by Stuart Pugh and has become a standard part of Six Sigma methodology and is a common tool for decision-making among concepts in product development [30]. The Pugh matrix is a criteria-based decision matrix used to determine which of several potential abilities should be screened by comparing them with each other. An arbitrary ability was chosen as the reference, and the other abilities were then compared with the reference following the set criteria. If an ability was considered better than the reference, a +1 was assigned, if equal a 0 was assigned, and if worse, a -1. In the end, this led to a total score of each ability. The abilities satisfying the worst criteria were screened and removed for continued screening.

2.5.2 Technical feasibility feedback

Also included in the screening, is the technical feasibility feedback. Here, technical experts at Volvo Penta gave insight if the concepts could be technically feasible. Feedback sessions were performed with the use of mediating tools. These were visual representations and technical descriptions of the abilities left after the internal screening. Feedback sessions were held for one hour and feasibility in terms of material cost, technological components, manufacturing, internal development, and general performance was discussed for each of the concepts. A total of two sessions were held with one technical expert per session was attending.

A success of a "concept" is dependent on the customer satisfaction; however, the concept must also be technically feasible. According to Ullrich & Eppinger [30], technical feasibility is a vital part to take into account when choosing which "concepts" to focus on. Since there is a limitation in the technical depth of the thesis, experts were needed to evaluate and screen the abilities effectively in terms of feasibility.

2.5.3 Customer feedback

In this phase, the abilities were tested and evaluated by the primary users interviewed. This phase involves experimental research, which tests the abilities developed to draw conclusions about development [21]. The experimental research was performed with mediating tools, such as drawings, virtual prototypes, and technical descriptions of the abilities.

This method is primarily of a confirmative nature, where the customers indicated their agreement or disagreement with the abilities. In addition, there were discussions of potential improvements and design alterations. Engaging customers in both the design and the screening processes proves to be an effective strategy to ensure the success of an ability [30]. Often, there exists a disparity between a customer's expressed preferences and how engineers interpret those preferences in a concept. Therefore, revisiting the customer's feedback after the concept generation phase is crucial. This iterative step not only provides valuable information on the strengths and weaknesses of each concept, but also enables the elimination of unfeasible concepts and the implementation of design changes to improve the overall quality of the concepts [30].

2.6 Detailed concept development

The detailed concept development is the last step of the method. In this part, the chosen abilities left from the screening part were further developed in terms of:

- A visual representation of the abilities
- A technical specification of the components needed for the ability
- Business case with financial calculations

Before being able to present the detailed development as stated above, two steps were taken to gain an understanding of the technology and competitors.

- Technical benchmarking
- Patent search

These steps were the basis for the final technical development. A benchmarking for similar products on the market was used to understand the technical and financial aspects. It also provided insights into how the abilities can work technically. A patent search was also performed as an inspiration source for development, but also to highlight legal constraints when developing the abilities. From technical benchmarking and patent search, the final specification could be set. Although much of the technical development is seen as a black box, a technical expert was consulted to review the development and give technical insights to further enrich the development.

2.6.1 Technical benchmarking

The initial stage of the detailed concept development involved conducting a comprehensive technical benchmarking analysis of similar products available within the market. This analysis was carried out with the primary objective of providing Volvo Penta with a comprehensive insight into the competitive environment, addressing technological specifications, associated costs, and the degree to which these offerings align with abilities.

Benchmarking not only facilitated a complete understanding of market dynamics, but also empowered an analysis of the strengths and weaknesses of competitors, thereby enabling the identification of potential market gaps. [30]

Subsequently, a selection of five distinct products on the market was chosen for in-depth analysis with respect to each ability. Relevant product attributes were extracted from the respective company websites and systematically compared with each other within a comparative matrix. This systematic comparison allowed the identification of optimal performance attributes with cost considerations, facilitating informed decision-making in the pursuit of product development objectives.

2.6.2 Patent search

A patent search was performed as an inspiration source for the set of technical specifications, but also as a constraint on the designs that were already patented and should be avoided. The patent search method was performed following the multistep US patent search strategy of the United States Patent and Trademark Office as the following:

1. Brainstorm terms that describe the invention. Here, alternative words describing the concepts were collected to expand the patent search.

2. Conduct a keyword search using the patent public search. This was first performed in a broader sense and later also refined for patents found. Patents were reviewed and irrelevant ones were eliminated.

3. Conduct an in-depth review of the documents found in the patent search. The patents were reviewed in detail, both looking at the descriptions, statements, and drawings.

4. Expand the search with relevant CPC classifications. As an expansion of the keyword search, analysis of relevant classifications for the concepts was also performed.

5. Review of cited references. The patent includes a section of cited references; these references were analyzed to find more information about the patents.[24]

The last step of the method includes performing similar analyses in other foreign patent databases. Due to a time constraint, this was not performed. The Epacenet webpage, which was used for the patent search, provides to some extent patent globally, making it suitable for the patent search.

2.6.3 Technical development

With the technical benchmarking and patent search as a basis, a technical specification and system architecture were established, describing the technical components needed, as well as how these components work together in a simple system architecture.

As a way of approving that the project group chose an appropriate and feasible technical specification for the chosen abilities, an expert within sensor technology systems at Volvo Penta was involved in the decision and approved the technological specification in a one-hour meeting where smaller details that were missed by the project group were added that created the final technical specification and functional scheme.

When the technical specification was established, a visual representation showing the abilities and financial calculations for the business case could be started. The total cost for all components was calculated by researching components that met the target specification, and the components with the highest performance for the lowest cost were chosen. The project group followed the method of absorption costing from the literature Industriell ekonomi - Grundläggande ekonomisk analysis by Lantz, Löfsten, & Isaksson [9] for the financial calculation because it is an efficient way of creating a perception if a product or project is worth investing in, that also Volvo Penta had prior knowledge working with.

3
Results

This chapter presents the result of the development of abilities for Volvo Penta.

3.1 Discovery

As highlighted in the method chapter, the discovery phase includes market research, interviews, and observations. The results of these steps are outlined in this subchapter.

3.1.1 Market Research - Competitor benchmarking

In this subchapter, the results of the competitor benchmarking are presented. The key features and abilities with different systems are highlighted to gain an understanding of Volvo Penta's competition. The aim of competitor benchmarking is to highlight the competitor technology as a baseline for the specification of the requirement, find their strengths and weaknesses, and to be an inspiration source for concept generation.

The three main competitors of Volvo Penta are:
1. Yamaha Motor Corporation
2. Mercury Marine
3. Honda Marine

Yamaha - Helm Master EX
Yamaha Motor Co.is a Japanese mobility manufacturer that produces motorcycles, motorboats, outboard motors, and other motorized products. The company was established in the year 1955 upon separation from Nippon Gakki Co., Ltd. (currently Yamaha Corporation) and is headquartered in Iwata, Shizuoka, Japan. In the marine segment, they offer marine engines and the Helm Master EX. The Helm master ex is an engine control system for steering vessels, but the system also integrates many abilities into the Helm. These abilities will be analyzed for competitor benchmarking.

The joystick of the Helm master ex has three buttons in the middle that all have different abilities. *StayPoint* is a feature that automatically fixes the boat in one position, maintaining both heading and position.*FishPoint* is an ability for fishing with the boat, similarly to *StayPoint*, it maintains the position of the boat, but not the heading. Furthermore, it uses minimal RPM for the engines to not scare the fish while fishing. Lastly, *DriftPoint* maintains heading only and allows natural drift from wind or current, which is used for example drift fishing or kite fishing.

The throttle control, or as Yamaha calls it, DEC (digital electronic control) also has an innovative ability worth analyzing. The ability is called *SpeedControl* which allows the user to fine-tune the exact speed of the vessel. The *SpeedControl* is also available at lower speeds, where the system through the usage of *PattermShift* which automatically sets the engine in and out of gear, enables the vessel to operate smoothly at lower speeds. This ability is therefore useful for docking.

In the autopilot keypad on the Helm master ex there are four abilities associated with steering the boat. These are called *Heading hold*, *Course hold. Track point* and *Pattern steer*. *Heading hold* and *Course hold* works similarly, where the *Course hold* follows a set course by the user and the *Heading hold* follows a compass setting, adjusting the boat to follow its order. *Track point* takes it one step further and lets the user set a route with different points on the display which the boat then automatically follows. This ability allows the user to plan the route in advance. Lastly, the *Pattern steer* allows the user to choose among pre-set patterns such as 'zigzag' which the boat will automatically perform [34].

As a result of the benchmarking on Yamaha, it can be stated that they are similar in the abilities they offer. Most of the abilities that Yamaha offers are also present in the current EVC 2 system. Yamaha seems to have a more diversified positioning system, which allows the users to stay in the exact same heading and position or keep only the heading. But in conclusion, the Yamaha Helm master ex has no major differences in abilities or a competitive advantage over Volvo Penta.

Mercury Smartcraft

Mercury Marine is a marine engine division of Brunswick Corporation headquartered in Fond du Lac, Wisconsin. The main product line is outboard engines. They also produce the MerCruiser line of sterndrives and inboard engines, as well as associated electronics for steering and controlling the engines and its features.

Similarly to the Volvo Penta EVC 2, and the Yamaha Helm Master Ex, the hardware for controlling and steering the boat consists of a display, throttle control, and a joystick. Looking at the innovative abilities this system offers, SmartCraft seems to be their main competitive advantage. The SmartCraft can be seen as the connection that enables the user to interact with the engine and allows the engine to display data to the user electronically. The *VesselView* is one display that works with the SmartCraft, so the user gets access to full engine performance, but also other parts of the vessel such as GPS-chart, sound system, radar, etc. This can also be seen on smartphones through an application.

The joystick has some innovative abilities. It operates from a steering perspective equal to the Volvo Penta, but has features integrated into the buttons, such as for Yamaha. *Heading* is a feature in which the use of an integrated digital compass automatically maintains the course of the boat. *Bowhook*, similarly to heading, holds a direction, but it does so also with respect to wind and or currents.*Skyhook* is another feature where the boat maintains its position and direction, so the boat is automatically anchored with the push of a button. Similarly to Yamaha's *Trackpoint*, the *Route* feature navigates the vessel to an active way-point or route on the chart. Lastly, the *Drift* hook feature holds the direction but unlocks the position, allowing the wind and currents to carry the boat along - when you want to drift in a controlled way.[20]

As can be seen, many of the abilities of the Mercury system are similar to those of the EVC 2 system.

Honda Marine IST
Honda Marine is an American company headquartered in Alpharetta, Georgia who designs and produces boat engines. Honda Marine is part of the "Honda's Power Products" division that manufactures other products such as cars and motorcycles. When it comes to the marine segment, Honda's system to control the vessel is called Intelligent Shift & Throttle® (IST). It consists of a steering wheel, throttle control, joystick, and screens,similar to the competitors.
The IST system does not have any new innovative abilities. Rather, the system has a focus on being able to retrofit, i.e. be installed on older engines, be simple to install. An ability provided by IST is the ability to trim all engines simultaneously or fine-tune the individual engines. Trimming is the action of adjusting the engine(s) so that the bow (front) of the boat finds the correct place. Looking at these abilities that are presented as the main on their official Web homepage,

Their most modern and up-to-date technology in their Helm is their joystick, the *Dometic Optimus 360 Joystick*. The joystick is developed by Dometic, not Honda themselves, and includes the regular feature of joysticks to steer and rotate the vessel in all directions, and also via collaboration with *SeaStar GPS system*, being able to maintain a fixed position or heading. The joystick is used at lower speeds and also has a sensitive touch function for high-precision response. It is also compatible with third-party autopilot systems.

In September 2021, Honda released their connectivity system called *HondaLink Marine*. This system puts smart boating in the hands of boat owners. The new, integrated smartphone application provides owners with complete remote monitoring capability and ownership information for boats anytime from anywhere with information like boat engine health and boat tracking. This technology takes Honda to the next level in technology and connectivity. [19]

For many years, Honda has seemed to have focused more on offering customers a traditional and robust system than pioneering with innovative technology. As presented above, they have moved more towards connectivity, which is something Volvo Penta are also doing. This highlights the possibility of future development with regard to connectivity. Therefore, connectivity will be taken into account when developing abilities.

Synthesis of competitor benchmarking

As seen through market research, Yamaha, Mercury, Honda and Volvo Penta all offer similar abilities in their systems. But there is a trend leaning towards connectivity and being more aware of the surroundings. This was kept in mind for further development.

3.1.2 Market Research - Automotive industry

As an inspiration source for the idea generation phase, the automotive industry was further analyzed. The automotive industry is generally under higher pressure to innovate, resulting in a further progress in innovation and technology development compared to the marine industry [29]. This makes it interesting to analyze. The car manufacturers Mercedes, Tesla, and Volkswagen were chosen because of the study made by *Center of automotive management*, where they ranked these manufacturers with the highest innovation score. [10]

Mercedes Benz
Mercedes-Benz is a German luxury and commercial vehicle automotive brand established in 1926 in Stuttgart, Baden-Württemberg [8]. The most relevant features for the marine industry are collected under what Mercedes are referring to as *Intelligent Drive* found on their official webpage [8]. It consists of the subcategories of: Driving assistance and safety, Parking, Lighting and visibility, and Chassi. The most interesting abilities are presented below:

The ability *Active Lane Keeping Assist* works as an attentive observer. If the user unintentionally leaves the lane or gets too close to other road users, the system can bring the user back into the lane by means of a steering intervention. An additional warning will also follow in the form of a steering wheel vibration.

Blind Spot Assist keeps a close eye on blind spots via sensors. The system can warn the user of side collisions stemming from the blind spot. After your trip, the system remains alerts and warns the user if the door is opened the door at the wrong time. This is a particularly important protective measure, especially for cyclists.
The *Active Parking Assist* ability with *PARKTRONIC* finds a suitable parking space and parks the vehicle conveniently and automatically with the touch of a button. The system can also assists when exiting the parking space. The parking feature also includes 360 degree cameras that through several cameras enables the user to see the vehicle from above, which increases the awareness of the environment while parking.
Lastly, the *adaptive highbeam assist plus* is considered interesting. With this ability, the user can keep high beams on at all times without dazzling other road users. The intelligent system excludes oncoming traffic or vehicles in front with highly precise LEDs: This means that the user does not have to constantly switch to the low beam

and can better recognize the carriageway and hazards due to the high range of the headlamps. [8]

Tesla Inc.
Tesla, Inc. is an American multinational automotive and clean energy company headquartered in Austin, Texas, which designs, manufactures and sells electric vehicles, stationary battery energy storage devices from home to grid-scale, solar panels and solar shingles, and related products and services[28].

The first ability that was found to be innovative and novel was Tesla's different 'mode' abilities. There is a mode called the 'sentry mode', which will start recording from outside cameras and alert the user if it is damaged.

Tesla also has a unique advanced sensor coverage that is used for several features called *Tesla Vision*[28]. The sensors range a maximum distance of 250 meters with its main focus on the forward sensors. Sensors are used as a warning system that warns the user if the car is going to be hit by other cars, or if an object is in the way, in all directions.

Navigate on Autopilot is also an ability within Tesla Vision that suggests lane changes to optimize the route, and makes adjustments so that the user doesn't get stuck behind slow cars or trucks. When active, *Navigate on Autopilot* will also automatically steer the vehicle toward highway interchanges and exits based on your destination.

With *Smart Summon*, the car will navigate more complex environments and parking spaces by itself, maneuvering around objects to find you in a parking lot. This ability is possible because of Tesla's connectivity [28].

Volkswagen
Volkswagen is a German automobile manufacturer headquartered in Wolfsburg, Lower Saxony, Germany that was founded in 1937. Volkswagen is part of the Volkswagen group, which in 2017 was the largest car manufacturer in the world in terms of sales[28].

Upon analysis of the abilities and features of Volkswagen cars, the *Augmented reality head-up display* was considered to be innovative. *Augmented reality head-up display* is a technology that projects text, images, and even 3D animations onto the windscreen. It allows the user to easily glance at useful information, allowing the user to access information efficiently.

Another ability available to Mercedes and Tesla is adaptive cruise control. The *adaptive cruise control ACC* allows the car to keep a set speed and a distance to the car in front. It is performed using sensors.

Emergency Assist is a feature that detects that the driver is not paying attention.

This triggers an alarm in a safety program. The brake is activated to create a more jerky ride, while audible signals and hazard lights warn the driver, passengers and surrounding traffic. If the system receives no response from the driver, the car brakes and stops at the side of the road, with the warning lights still on [31].

Synthesis of automotive industry

In summary, the research of the automotive industry gave inspiration to the idea generation phase for future abilities in the marine sector. Sensor technology was an aspect that all car brands had. Sensors are connected to parking, autopilot, adaptive cruise control, and warning systems. Furthermore, some car manufacturers appeared to have advanced lighting abilities connected to sensors, such as the one from Mercedes. This is an innovation that has not yet been adapted in the marine industry and, therefore, will be used as inspiration in the idea generation phase.

3.1.3 Interviews and observations

As stated in the method, the interviews were conducted as semi-constructed interviews exploring the needs of the customers, as well as including mediating tools in the form of pictures. In addition, an observation was made with service personnel from Volvo Penta. In total, 13 interviews and an observation were conducted to explore customer needs, with different types and categories of users. The specific number of interviews for each type and category is presented in table 3.1.

Table 3.1: User Categories and Types of Users

Type of User	User Category	Number of interviews
Primary user	Customers of the power boats	1
Primary user	Customers of the yachts	5
Experts, stakeholders	Internal experts at Volvo regarding the current system EVC 2	3
Experts	Boat builders	1
Stakeholders	Service personnel at Volvo - Observation	1
Lead users	Captains of boats and yachts	2
Lead users	Boat instructor	1

As stated in the method, the main focus of the interviews was the primary users in the category of power boat and yacht customers. This can be seen because roughly 43% of the collected data came from the primary users. Through note taking during interviews and observation, customer statements were collected, as seen in Appendix 3. Most of the interviewees from the primary user group have many years of experience on sea, thus, an interview was also conducted with an inexperienced user. Interviewing an inexperienced user gave a broader view of the study. In addition to that, an interview was held with a boat instructor whose teaching experience broadened the understanding of inexperienced users. The analysis and interpretation of these statements will be presented in the subsequent reframe and development chapter.

3.2 Reframe and development

3.2.1 Customer needs identification & analysis

In the next section, the results of the customer need identification and analysis is presented. It includes identifying the needs by interpreting the customer statements, creating personas based on the data, establishing the importance of the needs, and finally setting a target specification.

3.2.1.1 Interpretation of customer statements

Based on the data collected in the discovery phase, the customer statements were interpreted as needs. The interpreted needs along with the customer statements are found in Appendix 3. Three personas were created to clarify the needs and different users. These include a professional user who uses vessels regularly for work and an experienced user who has used vessels seasonally for many years. Lastly, the inexperienced user, who has less experience on sea. These are presented below:

Figure 3.1: Persona 1: The professional user

The experienced user

About:
Age: 52
Job: Middle manager in the industry
Driving experience: More than 15 years
Boat: 45 feet yacht from 2010

Motivations:
Thinks that the whole boating experience is great and a part of their identity. When looking at how the boating experience could be improved, he looks more into <u>efficiency</u>, how the already existing way of steering the boat could be improved, via for instance making functions more easily accessible.

Needs:

- Not to let go of steering equipment to change settings on screen
- Make important functions easily accessible
- Better adjustment of driving position
- Steering hardware should feel robust

Figure 3.2: Persona 2: The experienced user

The inexperienced user

About:
Age: 43
Job: Marketing specialist
Driving experience: None, passenger only
Boat: 42 feet yacht from 2011

Motivations:
Thinks that there lies a stress in steering and controlling the vessel, especially in the docking situation. Looks more into <u>effectiveness,</u> new innovative ways that makes the boating experience easier for everyone via for instance automatic docking technology.

Needs:

- Simplify control of the vessel
- Easier to dock vessel
- Be aware of other vessels and hazards in the nearby area
- Increase connectivity

Figure 3.3: Persona 3: The inexperienced user

3.2.1.2 Establishing importance of needs

As seen in Appendix 3, the process of identifying customer needs created multiple needs that had similar formulations. Needs with similar formulations were treated as the same. The importance was determined by the number of times the needs occurred in the discovery phase. The importance/occurrence is structured in descending order, showing the most important needs first. Understanding the importance of needs was valuable to determine which needs to focus on when abilities were developed.

Need	Occurence/ Importance
Not to let go of steering equipment to change settings on screen	8
Make important functions easily accessible	8
Adjusting driving position	6
Be aware of other vessels and hazards in the nearby area	6
Increase perception of forces in the vessel environment	5
Enhance focus on environment	5
Easier to dock vessel	5
Identifying errors in the system	4
Assist in solving errors in system	4
Show relevant information to the user	3
Size of steering hardware should fit a wider user range	3
Standardized layout of controls	2
Coherent design of the helm	2
Helm offering should be compact	2
In case of failure, have redundancy for all systems	2
See screen and hardware lights in sunlight	2
Vessel should assist in operating smoothly	2
Make steering hardware more responsive	2
Make steering hardware respond to inputs smoothly	2
Steering hardware should feel robust	2
Increase connectivity	2
Better entertainment system	1
Have a choice to deactive tech.	1
Easier to install EVC system	1
Simplify contol of the vessel	1

Figure 3.4: Establishing importance of needs

3.2.1.3 Target Specification

The next step of the Ulrich and Eppinger methodology is to establish the target specification [30]. The first step was to create a needs-metric matrix. The full matrix can be found in Appendix 4. The matrix resulted in 26 different metrics related to the identified needs. The desired result was one metric per need, but in the end only 13 of the 24 needs were associated with one metric. The other needs were described by two or more metrics.

Taking the metrics from the needs-metric matrix, a target specification could be established. The target specification can be found in Appendix 5. The matrix resulted in a visualization of the importance and units of the different metrics. The target specification also includes general metrics as stated in Ulrich and Eppinger [30], the single case presented implied adding metrics such as handling mechanical loads, handling salt/freshwater and minimizing production cost.

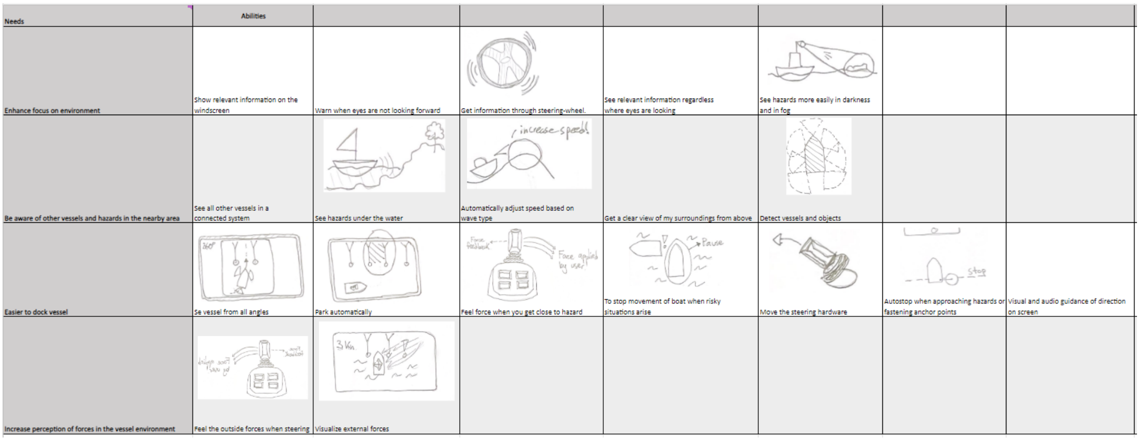
3.2.2 Idea Generation

After the needs had been identified and the target specification set, the generation of abilities was carried out. Before starting the process, a discussion regarding the results of the customer needs identification was held with a product range manager at Volvo Penta. The result of the discussion was that many of the hardware and steering related needs were now taken care of in the next-generation Helm. In figure 3.4, it is clear that the needs related to the steering have a higher importance; however, because of the new information that came to light and not reinventing the wheel, the needs related to the hardware were not considered.

Furthermore, because of time constraints, there were still too many needs to take into account when ideating the abilities. Thus, only the most important needs from the previous sections were used in the idea generation stage. Consequently, only the needs that had an occurrence of five or more were considered in the ideation phase. In summary, disregarding hardware related needs and not ideating the needs with an occurrence below five resulted in a list of four needs.

1. *The need to:* enhance focus on the environment.
2. *The need to:* be aware of other vessels and hazards in the nearby area.
3. *The need to:* dock the vessel in an easier way.
4. *The need to:* increase perception of forces in the vessel environment.

These needs were the basis of the idea generation to establish the abilities. Based on the method presented for idea generation, the abilities were brainstormed for each of the four needs. The brainstorming was based on previous market research and customer statements. The result of the idea generation gave 19 abilities. These were organized into the "ability matrix". The structure of the matrix is shown below in figure 3.5. A larger scaled ability matrix is found in Appendix 6.



Needs	Abilities						
Enhance focus on environment	Show relevant information on the windscreen	Warn when eyes are not looking forward	Get information through steering-wheel.	See relevant information regardless where eyes are looking	See hazards more easily in darkness and in fog		
Be aware of other vessels and hazards in the nearby area	See all other vessels in a connected system	See hazards under the water	Automatically adjust speed based on wave type	Get a clear view of my surroundings from above	Detect vessels and objects		
Easier to dock vessel	Se vessel from all angles	Park automatically	Feel force when you get close to hazard	To stop movement of boat when risky situations arise	Move the steering hardware	Autostop when approaching hazards or fastening anchor points	Visual and audio guidance of direction on screen
Increase perception of forces in the vessel environment	Feel the outside forces when steering	Visualize external forces					

Figure 3.5: Ability-matrix

3.2.2.1 Enhance focus on the environment

Ability 1.1 - See relevant information on windscreen
The ability to "see relevant information on screen" is based around the idea that the information the user wants to see is projected on the windscreen, to minimize attention downward to the Helm. The information presented on the windscreen would include the information available in the current Helm, as well as information that might be included in the future (5-10 years). An example of this would be distance visualization, visualization of route. Furthermore, since all users have different needs, the information presented must be selectable by the users themselves. This idea was inspired by research of the automotive industry. The technology used today by the automotive industry is a heads-up display. As presented in market research, Volkswagen has released a heads-up display with implemented augmented reality (AR); this could also be a viable option for the future.

Ability 1.2 - Warn when eyes are not looking forward
The ability warns the user when they are not looking forward. This would be implemented by tracking eye movement and a warning system. This lets the user know when they are not paying attention and increases safety. Inspiration was also taken from the automotive industry, when cars tell you to take a break or to keep the eyes forward.

Ability 1.3 - Get information through the steering wheel
Also taking inspiration from the automotive industry, this ability also takes inspiration from biology. Getting information through the steering wheel through, for instance, vibration is a way to use the sense of physical touch to inform the user to keep the eyes focus on the environment.

Ability 1.4 - See relevant information regardless of where eyes are looking
Getting the information needed regardless which direction a person looks could be solved by using augmented reality glasses (AR). This was taken as inspiration from a presentation on AR at Volvo Penta [32]. AR allows the user to get relevant infor-

mation regardless of where they are looking. Thus, the user would not have to look down at the Helm when operating the vessel.

Ability 1.5 - See hazards more easily in darkness and in fog
An automatic lightning system connected to a system that analyzes the environment creates an ability that could lead the way for the user in both darkness and fog with light. In addition to leading the way, an automatic adjusting lightning system can highlight hazards and other objects in the water. The inspiration was from customers who discussed difficulty navigating in the dark. During navigation, they would have their attention down at the radar, and not forward. This ability enhances the focus on the environment during darkness or fog.

3.2.2.2 Be aware of other vessels and hazards in the nearby area

Ability 2.1 - See all other vessels in a connected system
With this ability, a more developed navigation system is established, where the vessels are connected to the same system and visible on the screen using wifi, 5G/4G. Inspiration for brainstorming came from certain car navigation apps. The system can give suggestions on other routes to take or warn if a vessel approaches at high speed close to the user. Furthermore, since vessels are connected, warnings can also be sent in case of hazards. Thus, implementing this ability solves the need to be aware of other vessels and hazards in the nearby area.

Ability 2.2 - See hazards under the water
Relating to the need of being aware of vessels and hazards in the nearby area, this ability looks below water in the form of an improved sonar. The customers interviewed wished to improve the detection of underwater hazards more clearly, especially in front of the vessel when approaching docking situations.

Ability 2.3 - Automatically adjust speed based on wave type
When operating a vessel, larger waves are also considered as hazards by the customers. Thus, with technology that analyzes wave size and automatically adjusts the speed, satisfaction and safety for customers. Furthermore, recognizing and adjusting the speed based on the size of the wave makes a smoother ride, because the current generation autopilot does not adjust speed [32]. The idea was inspired by a discussion with an expert from Volvo Penta [32].

Ability 2.4 - Get a clear view of my surroundings from above
Increasing the perception the environment can also be solved by introducing the ability of get a view from above. The inspiration for the ability came from an internal presentation at Volvo Penta, where they mentioned that they had patents for use of drones. Exactly how drones were supposed to be used was never specified, therefore using the drone patent was the basis for the ability.

Ability 2.5 - Detect vessels and objects
Similar to ability 2.1, this ability is based on being aware and sense other vessels or hazards in the nearby area. This ability diverges because one does not use a connected system where all vessels are connected. It is based on using other technology, such as a sensor system of some kind that can detect other vessels and hazards. Taking it one step further, it would also be able to give warnings to avoid collisions. This is also an idea inspired by the automotive industry.

3.2.2.3 Easier to dock

Ability 3.1 - Se vessel from all angles
The need of vessels being easier to dock could be solved by implementing the ability of seeing the vessel from all angles. Seeing the vessel from all angles would make docking easier because of the increased perception of where the vessel is. This ability is prominent in the automotive market, as seen in market research.

Ability 3.2 - Park automatically
The easiest method of docking would be to dock or "park" automatically. This is the end goal of making docking easier. It would function through gaining a picture of the environment in the harbor through, for instance, sensor technology or drones and deciding the desired spot to dock at.

Ability 3.3 - Feel force when you get close to hazard
As described in the background, the current EVC system has an ability called "assisted docking" which makes use of the joystick to move in all directions. One thing that was noticed during the observation phase is that it is impossible to feel when you get close to an object. An addition to this that would improve the current ability is to add force feedback, which is feeling a force in the steering equipment when you get close to objects. It would increase awareness and make docking easier.

Ability 3.4 - To stop movement of boat when risky situations arise
One difficulty that inexperienced users felt when docking is that everything moves on the ocean. It is not like a car, where you press the break and stop, the environment affects the vessel much more. With this in mind, the ability to stop the movement of the vessel was reexamined. It should be noted that the existing ability "assisted docking" has a positioning feature which allows the users to hold the vessel in one place, with minimal deviation. Furthermore, the positioning system only works if the assisted docking ability is activated and assisted docking is only available with the joystick. Ability 3.4 takes assisted docking one step further by working with both the joystick and steering wheel, as well as by working without having to engage another ability first. Performing a stop motion should be performed without unnecessary steps, and that is what Ability 3.4 solves.

Ability 3.5 - Move the steering hardware
One ability that is missing from the Volvo Penta product portfolio is the ability to move the steering hardware [33]. Moving the hardware could increase comfort by allowing adjusting of seating position, but also being able to get closer to objects for maximum precision when docking.

Ability 3.6 - Auto-stop when approaching hazards or fastening anchor points
Auto-stopping when approaching hazards or fastening anchor points takes a different spin on ability 3.4. Unlike in 3.4, here the stop of movement occurs automatically. The vessel should be able to feel when it is close to objects, including buoys where fastening anchor points are needed when docking. Thus, not only does this ability auto-stop for hazards, but also stops to assist the driver in difficult or stressful docking scenarios.

Ability 3.7 - Visual and audio guidance of direction on screen
Like parking a modern car, this ability uses visual and audio guidance to give directions and warnings when docking. The ability increases the perception of the environment alongside the guidance for direction.

3.2.2.4 Increase perception of forces in the vessel environment

Ability 4.1 - Feel the outside forces when steering When it comes to increasing the perception of forces in the vessel environment, a similar ability can be used as in 3.3. Here, feeling the forces from the vessel environment can be implemented into the steering equipment in the form of vibrations or force feedback. This ability increases perception by providing an input to the human sense of touch.

Ability 4.2 - Visualize external forces
Looking at sight, visually displaying the outside forces on the screen would increase the perception of the vessel environment.

3.3 Screening

To decrease the amount of abilities and to focus the development on the most promising ones. Some of the abilities have to be eliminated by using different screening methods.

3.3.1 Internal Screening

The internal screening process was performed according to the Pugh matrix. The different abilities were compared against a reference ability according to criteria from the metric-needs matrix and the target specification. Throughout the internal screening process, the number of abilities was reduced from 19 to 12. Decreasing the number of abilities facilitated future screening together with technical experts and customers.

The screening process was organized according to the different customer needs and their respective abilities. Thus, only abilities within the same needs were compared. The abilities were evaluated based on the metric criteria presented in the target specification, as well as four common criteria from the target specification. These four common criteria were:

1. Cost of implementation
2. Technical complexity to implement
3. Performance
4. Innovation level

"Cost of implementation" referred to the financial aspect of both the technical components necessary to fictionalize the ability, as well as considering development cost internally at Volvo Penta. Secondly, the "technical complexity to implement" assessed the technical advancement of the ability and how difficult it would be to implement. The assessment was based on looking at the current EVC 2 and it's technology. Thus, the less technological components and changes that the current system needs for the new ability, the higher the score given in the matrix.

Performance criteria considered how well the ability meets the customer's need in general. Lastly, the innovation level assessed how novel the ability is compared to what already exists on the market, both in the marine and automotive industry. The innovation level was discussed with Volvo Penta as a desire to aim the abilities for 5-10 years ahead.

Enhance focus on environment	1.1 See relevant information on windscreen (ref.)	1.2 Warn when eyes not looking forward	1.3 Get Information through steeringwheel	1.4 See relevant information regardless where eyes are looking	1.5 See hazards more easily in darkness or in fog
Minimize time spent looking at the helm	0	-1	-1	0	1
Cost of implementation	0	-1	1	-1	-1
Technical complexity to implement	0	0	1	-1	0
Performance	0	-1	-1	1	1
Innovation level	0	0	-1	1	1
SUM	**0**	**-3**	**-1**	**0**	**2**
Pass	Yes	No	No	Yes	Yes

Figure 3.6: Enhance focus on environment

In figure 3.6, the 5 different abilities for the customer need "Enhance focus on environment" were evaluated. This customer need relates to the desire for drivers to maintain focus on the surroundings of the vessel without having to look down at the Helm while driving. From this process, the ability 1.2, "Get warned when I am not looking forward" and 1.3, "Get information through steering wheel" were removed due to performing worse in performance, and the innovation level being considered lower since they are both seen in the automotive industry currently. The most promising ability was 1.5, where an automatic spotlight will be used to illuminate hazards during darkness and fog with the help of sensors analyzing the environment. This ability had a high performance because the driver could keep his eyes on the environment without having to look down at the plotter or radar. The innovation level was also considered high since this kind of concept has not yet been seen on the market.

Be aware of other vessels and hazards in the nearby area	2.1 See other vessels in a connected system(ref.)	2.2 See hazards under the water	2.3 Automatically adjust speed based on wave type	2.4 Get a clear view of my surronding from above	2.5 Detect vessels and objects
Maximize input from outside enviroment	0	1	1	1	1
Cost of implementation	0	-1	-1	0	-1
Technical complexity to implement	0	-1	-1	-1	-1
Performance	0	1	1	0	1
Innovation level	0	0	1	1	1
SUM	**0**	**0**	**1**	**1**	**1**
Pass	Yes	No	Yes	Yes	Yes

Figure 3.7: Be aware of other vessels..

Figure 3.7 outlines the Pugh matrix for the customer need "Be aware of other vessels and hazards in the nearby area. This customer needs to consider the possibility of crashing into other vessels, objects, and or shallows, and the abilities present ways of enhancing awareness of the environment. From this screening, only ability 2.2 was screened due to its high cost and advanced implementation technology. The ability would most likely include some type of sonar, which is far from Volvo Penta's core business and an area where other companies such as Garmin and Echopilot have come far in development. The other abilities were still considered relevant from this step of the screening process.

Easier to dock vessel	3.1 Se vessel from all angles (ref.)	3.2 Park Automatically	3.3 Feel force when you get close to hazard	3.4 To stop movement of boat when risky situations arise	3.5 Move the steering hardware	3.6 Autostop when approaching hazards or fastening anchorpoints	3.7 Visual and audio guidance of direction on screen
Maximize input from outside envirome	0	0	0	-1	-1	1	1
Minimize steps by user when docking	0	1	0	1	-1	1	1
Minimize time spent docking	0	1	0	0	1	0	1
Cost of implementation	0	-1	-1	-1	-1	-1	-1
Technical complexity to implement	0	-1	-1	-1	-1	-1	-1
Performance	0	1	0	1	0	1	1
Innovation level	0	1	1	0	-1	1	1
SUM	**0**	**2**	**-1**	**-1**	**-4**	**2**	**3**
Pass	Yes	Yes	No	No	No	Yes	Yes

Figure 3.8: Easier to dock vessel

"Easier to dock vessel" was the third customer need. It refers to solving the problems associated with docking the vessel, making it easier in some way. In figure 3.8, 7 different abilities are visible that solve the need of the customer. After the screening, abilities number 3.3, 3.4, and 3.5 were eliminated, mainly due to cost of implementation and technological complexity. The most promising concept was ability number 3.7, which idea was built on using visual and audio *guidance* with the potential use of 360 cameras and sensors, not seen as a concept in the marine or automotive industry yet, making it novel.

Increase perception of forces in the vessel environment	4.1 Feel the outside forces when steering (ref)	4.2 Visualize external forces
Maximize input from outside enviroment	0	0
Cost of implementation	0	1
Technical complexity to implement	0	1
Performance	0	-1
Innovation level	0	0
SUM	**0**	**1**
Pass	No	Yes

Figure 3.9: Increase perception of forces in the vessel environment

The customer need "Increase perception of forces in the vessel environment" was a customer need mainly expressed by the lead users - the captains. The need has been expressed while discussing critical situations in a boat environment, where the forces of wind, waves, and currents make it difficult to operate the vessel. The abilities of being able to physically feel and visually see the forces were generated as abilities to the need. Ability number one was screened during this process due to its higher cost of implementation and technical complexity, since electric motors and or vibration units have to be implemented to the Helm to make the driver physically feel the forces. Therefore, visualization of forces on a screen was considered a more efficient solution.

3.3.2 Technical Feasibility Feedback

According to Ulrich and Eppinger, there are several ways to choose what concepts to eliminate. The previous internal screening through a Pugh matrix is one way. External decisions, where concepts are handed over to customers, clients, or some other entity for selection, are another way. As described in the method, the second step is to perform a technical feasibility feedback. These external decisions can be organized into a list of pros and cons according to Ulrich and Eppinger [30]. A pros and cons list based on technical feedback given from experts was chosen as the second way to eliminate the generated abilities. In Appendix 9, the result of the screening from technical experts is visible.

The pros and cons list is organized into the different customer needs and their respective abilities. The goal of the pros and cons method is to check whether the abilities are technical feasible. In the far right column of the figure, the decision is presented to proceed with the respective ability or not.

Based on this screening session, the customer need for "Easier to dock vessel" was eliminated, along with the abilities. The reason was the extensive resources currently being put into development for docking. Therefore, experts highlighted that focusing on the further development of other areas in addition to docking would bring more value to the thesis and Volvo Penta.

From this screening, the number of abilities went from 12 to 5. These five abilities are then taken to the customers for the final screening. The most promising ability according to the technical feasibility feedback was the ability 2.5 due to its many features that it brings to the user. The usage of some kind of sensors for analyzing the environment is necessary for implementing a "collision avoidance system", which warns the user of other vessels and hazards. It is also necessary for autopilot, auto parking, and other abilities that have been developed. Ability 1.5 is an example where sensor data is needed to determine where to direct the lightning system. Ability 2.3 is also an ability that needs sensor data to be able to analyze the wave height, making it a central node for adding other abilities in the future.

3.3.3 Customer Feedback

Table 3.2: Customer feedback

Abilities	Customer satisfaction
1.1 See relevant information on windscreen	No
1.5 See hazards more easily in darkness or in fog	Yes
2.3 Automatically adjust speed based on wave type	No
2.4 Get a clear view of my surrounding from above	No
2.5 Detect vessels and objects	Yes

In table 3.2 the results of the discussions of the abilities with two customers are visible. From the top of the table, the ability 1.1 was eliminated due to its limited value-addting aspect in other parts of the vessel in addition to presenting information on the windscreen. Furthermore, its main purpose is to present information, which was considered to have a lower importance from the customers compared to the other abilities. It was described by a customer as something that is "nice to have but not need to have". Ability 1.5 was appreciated by customers due to its safety purpose and the aspect of increasing awareness of the environment. Furthermore, the system is automatic, which means that customers do not have to interact with it to be functional. This is apparent in the current lightning systems, where it is controlled via remote control. The negative aspect highlighted with the ability was that the user could lose night vision when exposed to light during use.

Ability 2.3 was also eliminated. One of the customers in the yacht segment expressed that this type of system would not make sense to have for a larger yacht. When there are waves, it would be better to increase the speed rather than decreasing the speed and regulating it for a smooth ride. The reason for this was that yachts (over 40 feet) "breaks" the waves more efficiently in higher speeds, resulting in a smoother ride for the passengers, without needing to decrease the speed. Therefore, investing in this type of system for a 40 + feet vessel would not be an efficient solution of achieving a smooth ride but rather would be more suitable for smaller vessels. Since larger vessels correspond to a larger share for Volvo Penta, the ability is eliminated.

Ability 2.4, which uses a drone to achieve a clear view of the surrounding from above, was discussed and compared with ability 2.5. Due to drone regulations, noise pollution, and limitation in the amount of additional features that could be implemented with the ability, it was decided that usage of some kind of sensors such as ability 2.5 would be superior. As mentioned in the Technical Feasibility feedback, Ability 2.5 has a wide possibility of adding multiple valuable features. One customer said: "Ability 1.1 is nice to have, but ability 2.5 is a need to have, to increase the general safety and awareness of my surroundings."

In summary, after completing the 3 stages of screening, including internal screening, two one-hour meetings with technical experts following a pros and cons list method, and two half-hour meetings with customers, it was decided to perform detail development of ability 1.5 and 2.5 due to their novelty, and value-addling ideas. They have also not been seen on the market yet and the customer satisfaction level was considered to be high.

3.3.4 Synthesis of screening

From the screening process, the abilities 1.5 and 2.5 were chosen as the most promising abilities for a continuous detailed development. Although these were considered most promising for future development, the ideas regarding the other abilities and the collected customer needs are still valuable for Volvo Penta, and may be used for other future projects.

Since ability 1.5 is highly dependent on ability 2.5 with its sensor technology, the abilities were formulated as a single combined concept. In addition to calling the entity a concept, names were also given to communicate the concept in a clear way. Ability 1.5 was named Automatic Lightning Guidance (ALG), and ability 2.5 was named Penta Environment Detection (PED), which will be used in the following chapter. Thus, when referring to the concept, both ALG and PED are included.

To clarify the concept for further development, a bullet point list of functions that the concept can perform is outlined below:

Object identification:
The concept will be able to identify objects in both daylight and night time of for instance other vessels, sea marks and visible shallows, making the user more aware of the environment.

Distance detection
The concept will calculate distances from objects that are able to be detected. It could be both the distance to land and also other vessels and objects in the sea.

Velocity detection
Other than identifying an object and calculating the distance, the concept will also be able to calculate the velocity of an object. This is useful to create a clearer perception of other vessels at sea.

Collision avoidance
With information regarding what type of objects are around the vessel, at what distances and what velocity they have, the concept will use that information to send out a warning to the user, if it determines that a collision could occur. This significantly increases user safety and awareness.

Light up - Objects

With the connection between the detection and lighting functions, the concept will be able to light up objects such as shallows, logs or kayaks during driving in darkness or fog to prevent a collision. It can also light up sea marks for the driver.

Lightning assistance
Other than lightning up objects, it can be used to assist the captain, in situations where a person falls in the sea during darkness and or fog. It can also assist with lights while working on the boat by following the user with lights. Lightning assistance could also be used while leaving or entering the vessel, where the lightning system can light up the way for the user on land.

3.4 Detailed concept development

The detailed concept development is based on the ALG and PED system. To scientifically develop these abilities, competitive research in the form of technical benchmarking and a patent search was carried out. From these steps, the final technical development was described. To structure the development, the two abilities (ALG, PED) will be analyzed separately before combining in the end. Since the concept is based on two different abilities, these will be analyzed separately.

3.4.1 Technical Benchmarking

The first step in the development of the detailed concept is technical benchmarking, in which competitors are analyzed to define their technical specifications and pricing.

Company & product	Sea machines AI-RIS COMPUTER VISION SENSOR	Sea.AI SENTRY	Sea.AI Offshore one	BSB AI & Sea.AI OSCAR 320	Ouster OS1-128 LiDAR
Price	321 138 SEK	544 381 SEK	127 357 SEK	317 274 SEK	79 657 SEK
Sensor technology	1x Optical Camera, 4K (3840×2160)	2x thermal: 640×512 px 2x lowlight: 2592×1944 px	2x thermal: 320×256 px 1x lowlight: 2592×1944 px	2x thermal: 320×256 px 1x RGB: 1920×1080 px	Class 1 eye-safe per IEC/EN x 512 @ 10 Hz or 20 Hz • x 1024 @ 10 Hz or 20 Hz • x 2048 @ 10 Hz
Identifaction	AI/ML model, built on a database of imagery (Computer vision)	Computer vision	Computer vision	Computer vision	LiDAR
Field of view	Horizontal: 90° Vertical: 49°	Horizontal: 360° Vertical: 20°	No tilt, Horizontal: 50°	Horizontal: 110° (daytime) No tilt	Vertical: 45° (+22.5° to -22.5°) Horizontal: 360°
Range	500 meters	Smaller objects: 700 meters Larger boats: 7500 meters	Smaller objects: 100 meters Larger boats: 1000 meters	Smaller objects: 100 meters Larger boats: 1300 meters	Max 200 meters
Components	External AI-RIS Processing Module AI-RIS Camera (User Interface Display - Teguar 15.6″ LCD Sunlight Readable Touch Display)	Vision unit (2 thermal cam. & 2 low light cam) Integrated processing unit	Vision unit (2 thermal cam. & 1 low light cam) Integrated processing unit	Vision unit (2 thermal cam. & 1 RGB cam.) External processing unit	LiDAR component
Features	Can record an event, detect, track, classify and geolocate surface targets, collision avoidance	Collision avoidance, Object tracking Perimeter surveillance, Manual control of cameras UI in Onboard computers, tablets & smartphones (iOS & Android)	Identify objects, track course, distance information, collision warnings UI: iOS, Android, PC, B&G, Furuno, Garmin, Raymarine, Simrad	Identify objects, track course, distanceinformation, collision warnings UI: iOS, Android, PC, B&G, Furuno, Garmin, Raymarine, Simrad	Unparallel mapping capabilites Distance detection Object detection
Interface	1x Gigabit Ethernet port by Intel® I219- LM 1x Gigabit Ethernet port by Intel® I210-IT 2x Gigabit Ethernet port Intel® I350-AM2 802.3at POE+	Ethernet	Ethernet NMEA 2000 external Alarm Buzzer	2 x Ethernet – 1 x NMEA 200	Output: UDP over gigabit Ethernet Input: EEE1588 Precision

Figure 3.10: Technological Benchmarking for PED

In figure 3.10 a clipping of the most relevant part of the benchmarking is seen. The benchmarking includes products similar to the PED ability of the competitors of Seamachines [18], Sea.AI [27], Ouster [23], LOOKOUT [16], ALIA [4] and Hesai [13]. The full version is presented in Appendix 7. From the analyzed competitors, there is an apparent similarity between the products presented and the PED system. Looking at the pricing of the products, it can be stated that the mean price is 225 921 SEK. The most common technologies used for analyzing the environment are optical and thermal cameras. Some also used LiDAR (Light and Detection Ranging), which is a method to determine ranges by targeting an object or a surface with a laser and measuring the time for the reflected light to return to the receiver

The analysis provided information on the technological components necessary to achieve the function of the PED system, which would include:

- A type of sensor (either camera(s) and/or LiDAR) for analyzing the environment.

- A processing unit, connected to the sensor(s), handling the sensor data, performing computational calculations, and presenting the data to the driver visually on a screen.

- A screen, connected to the processing unit, that presents the data to the driver

As a result of the benchmarking for the PED system, it was concluded that the choice of sensor was vital for the performance of the PED system. From the analysis of the competitors' products and their performance, conclusions regarding the pros and cons with the sensor technology can be drawn. In figure 3.11, conclusions are collected from the analysis of the sensor technologies of competitors.

	Pros	Cons
Camera-based sensor technology	-Longer range of analysis. -More accurate object identification. -Can be used in multiple purposes, ex. record an event or use as a parking camera.	-Needs thermal or low light cameras to be able to analyze in fog or darkness, which are expensive. -Distance detection is not as accurate. -Computationally heavy to handle image data in high resolution -Narrower field of view
LiDAR-based sensor technology	-Are less expensive -Wider field of view -More accurate distance detection -Less computionally heavy data to handle. -Works well in darkness or fog	-Worse object identifaction -Shorter range of analysis -Not serving dual function

Figure 3.11: Pros and cons list for sensor technologies

The synthesis of the list of pros and cons is later used to develop the final concept (ALG + PED). Looking at the lightning system market, spotlights seem to be the most feasible alternative for a lightning system. It has high lighting capability, maneuverability, and being a standard in the marine industry. The next step is the analysis of the spotlight producers on the market, which were Golight [12], 1852-Marine [2] and Jabsco 180 [1]. Looking at figure 3.12, three electrically steered spotlights for the marine industry were analyzed.

Company & product	Golight - GT 20004 Searchlight remote control	1852-Marine Searchlight remote control	Jabsco 180 Searchlight - control panel
Price	SEK 11,699.00	SEK 6,299.00	SEK 21,205.00
Tilt	135 degrees	180 degrees	70 degrees
Rotation	360 degrees	360 degrees	360 degrees
Range	1475 meters	750 meters	418 meter (1 lux)
Steering	Electric	Electric	Electric (cable)
Candela	544 000	54 302 (4320 lumen)	230 000
Type of light source	10 High FLux LED	LED	Not stated
Weight	2370 gram	3840 gram	Not stated
IP code	IP56	IP65	
Voltage	2 x 12V	10-30 V	12 V / 24 V
Power	40 W	48 W	Not stated
Radio-frequency	433 MHz	Not stated	Cable, no frequency
Light spreading	8 degrees	Spot 10, Flood 90	7 inches (17,78 cm)

Figure 3.12: Technological Benchmarking for ALG

The analysis showed that no similar products to the ALG concept are available on the market. Thus, there is no system where the spotlight is connected to sensors, and with the help of a processing sends instructions to an electric engine that will rotate and tilt the spotlight to the desired spot.

No further analysis on the separate system architecture for the ALG concept was performed, since according to Volvo Penta, the spotlight would most likely be purchased by a supplier. The spotlight with motor would be purchased since lighting technology is not part of Volvo Penta's core knowledge. The novelty of the ALG system lies in being connected to the PED system, including sensors, to perform automatic movements.

3.4.2 Patent search

The patent search was performed according to the US Patent and Trademark Office. After performing both keyword searches and CPC classification searches, four different patents were determined to be similar to the ALG and PED. These patents were analyzed in depth, so the abilities developed would not violate any patent. Further analysis of the patents also enriched the technical development regarding the combination of technology, which will be presented in the next chapter. This chapter first analyzes two concepts similar to the ALG and then two concepts for the PED.

Radar Controlled Automatic Target Illumination System
In simple terms, the patent is a radar controlled automatic target illumination system for marine and other moving vessels. The patent is owned by two private people, ROBERTSON GLEN E and WEBSTER JOHN, from the United States. In figures 3.13 and 3.14, drawings showing the design are visible. Figure 3.13 shows a simple system architecture, and Figure 3.14 illustrates the system assembled on a boat, showing the different components operating to fulfill the patent function [14].

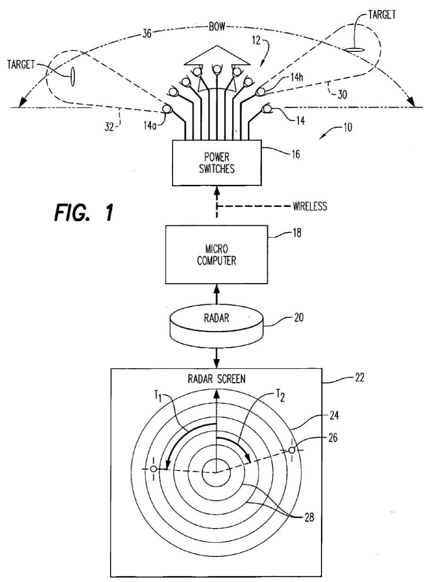


Figure 3.13: System architecture

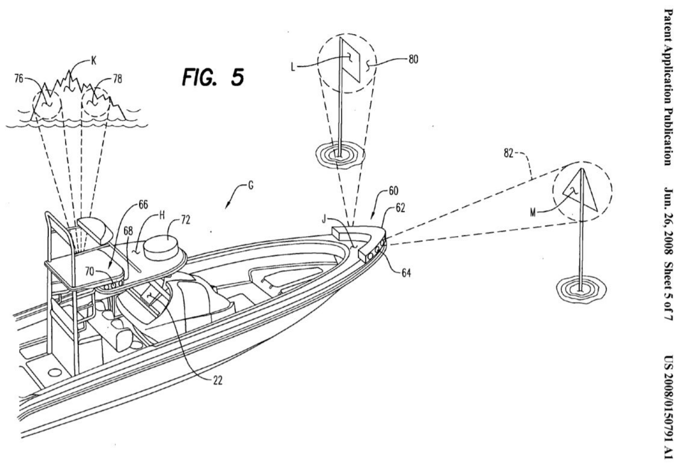


Figure 3.14: System assembled

The ALG system distinguishes itself from this patent in several ways. Firstly, the patent describes the so-called "illumination" with lights in sectors where the microcomputer decides which sector to activate via power switches. This results in illumination only possible in certain spots. On the other hand, the ALG system uses an electrically steered spotlight that can provide several functions, such as providing lighting for a person on land, rotate, and light up 360 degrees with a tilt of 135 degrees. These are examples which illustrate that the ALG system is more complex. Secondly, the patent vaguely describes the analysis of the environment and refers to the radar. The ALG concept uses the sensors provided by the PED system, which uses a different sensor technology. The patent is similar to the ALG, but the technical components and system architecture are considered to be too different and thus do not violate the patent.

Marine ranch intelligent security system

This patent discloses an intelligent security system for a marine ranch. The system consists of a master control system connected to a radar system that has the ability to activate a warning system. The warning system is activated when the radar detects objects on the surface of the water or under the water. The system then uses a strong light search for rescuing. The patent is owned by the Chinese electronic manufacturer SHANDONG ZHONGZHI JUNCHUANG ELECTRONIC TECH CO LTD. The system architecture is visible in figure 3.15: [17]

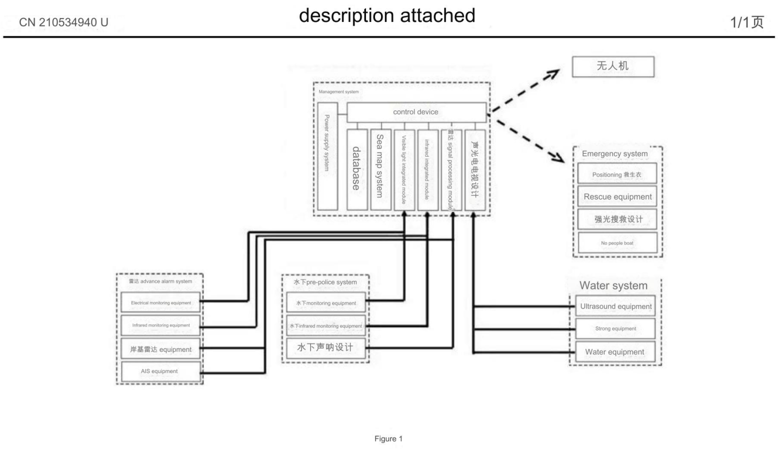


Figure 3.15: System architecture

Although this patent presents a similar concept of analyzing the environment and directing a light in rescuing situations, there are several aspects that differ from the ALG ability. The patent has a specific focus for usage in the marine ranch (fish farms) sector, whilst the ALG system is designed for leisure and/or commercial boating. The patent also differs since underwater analysis is performed. The architecture of the system of this patent gave inspiration for how ALG and PED could be connected.

In the next part, patents similar to the PED system will be analyzed. Generally, there were significantly more patents within the subject of collision avoidance, identification, detection, and radar, compared to automatic spotlights. Due to time constraints, none of the patents were analyzed, which means that further research within this area is recommended for Volvo Penta.

Collision avoidance for marine vessels
This patent is owned by the NORWEGIAN UNIV OF SCIENCE AND TECHNOLOGY and describes a collision avoidance system for a marine vessel. It consists of a tracker unit configured to track target vessels within an area around the marine vessel by determining a position and velocity of the tracked target vessels. The patent is considered comprehensive and consists of a 47-page long document with 36 different claims of what the patent owns the right to. In figure 3.16 a system architecture is outlined of how the system will work, and in figure 3.17, maneuverings performed by the boat are visible [25].

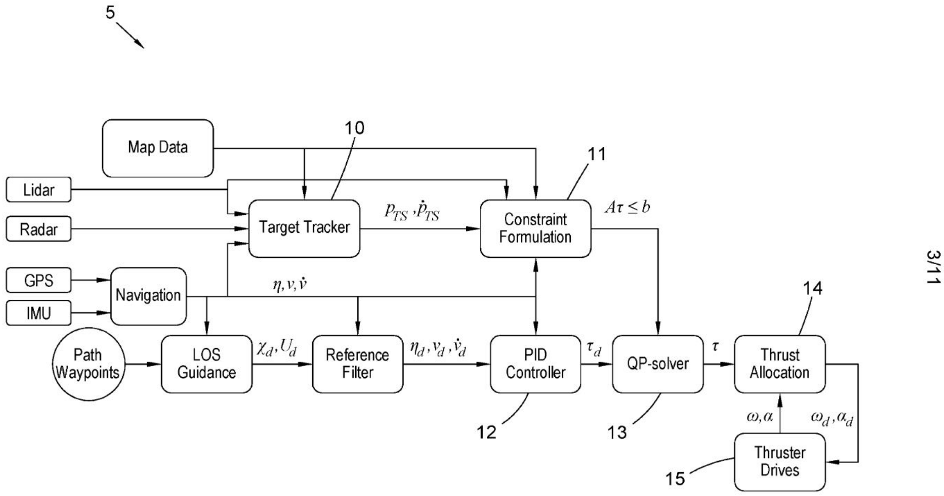


Figure 3.16: System architecture

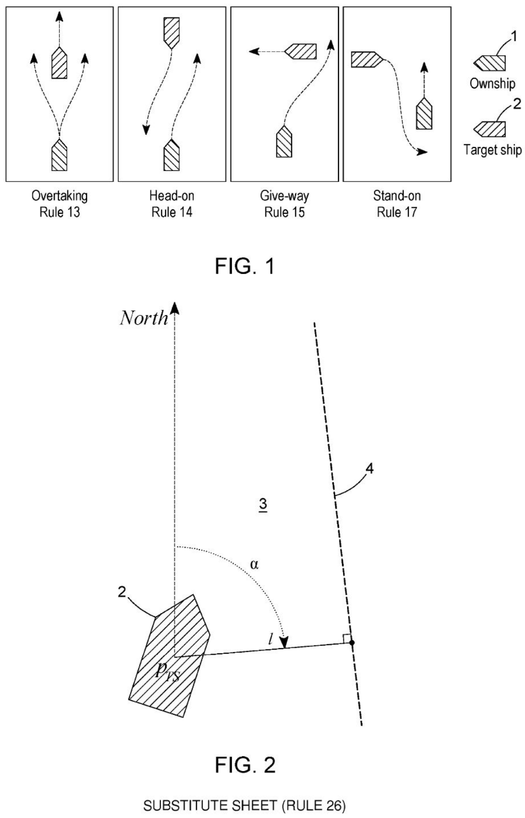


Figure 3.17: Maneuverings

The patent has a focus on the scientific, programming, and mathematical part about how the system should identify velocity and positions for a vessel. It also includes how the system should operate the vessel to avoid a potential hazard situation. The

PED system outlines the technical components, system architecture, and features that the system will include. The patent is more thorough than the PED system, as the PED does not include programming and mathematical logic. This makes it difficult to determine if the PED system violates this patent. For further development of the PED system, Volvo Penta is recommended to analyze the patent more thoroughly to ensure that the patent is not violated.

Collision avoidance assistance system
The patent owned by MIZUNO YOSHIRO from Japan outlines a system for supporting ship collision avoidance using many sensors, including a video camera, color meter, spectrometer, infrared sensor, temperature sensor, radar, LIDAR, sonar, anemometer, ship speedometer, GNSS receiver. The sensor data are analyzed by a learning unit that outputs an evaluation in the form of identification information and or collision avoidance support information. [35]

The patent is similar to PED in the aspect of sensor data analyzed by a processing unit, to present relevant information. Since the patent is vague, it speaks for itself that the PED does not violate the patent. The drawings outline a system architecture and the placement of the different sensors in a simple way. It will therefore be difficult to state that the PED system violates the patent since the patent lacks technical depth. Also, if a patent for the PED system is filed, doing it together with the ALG ability will differentiate the concept even more, since it will have a stronger focus on the lighting aspect.

However, the patent gave inspiration for the PED system, highlighting the possibility of using multiple types of sensors to analyze the environment. This has not been seen on the market yet, as seen in the competitor benchmarking. SEA.AI and Sea Machines both use thermal and optical cameras, but not any other type of sensor.

In summary, the patent search resulted in several valuable insights. Firstly, multiple ways of outlining a system architecture were seen. This gave inspiration for how to organize different technical components, to make the concept functional. The patent "Collision avoidance assistance system" by MIZUNO YOSHIRO also gave inspiration for using multiple sensor technologies to analyze the environment, potentially creating a competitive advantage over the majority of competitors that highly relies on computer vision with cameras only. The patent area of collision avoidance is extensive, and further analysis has to be performed alongside with the development of the PED to ensure that violation does not occur. From this patent search, no patent for ALG and PED combined was found, which opens the possibility for further development by Volvo Penta.

3.4.3 Technical development

Technical insights were gained from technical benchmarking and patent search. In this chapter, the final technical development is presented as a synthesis of the research carried out. Since much of the technical development was considered outside the scope of the thesis, a technical expert from Volvo Penta was consulted to confirm the technical aspects. The technical development begins with an outline of the system architecture. From the system architecture, the components needed for the system to function are presented.

3.4.3.1 System architecture

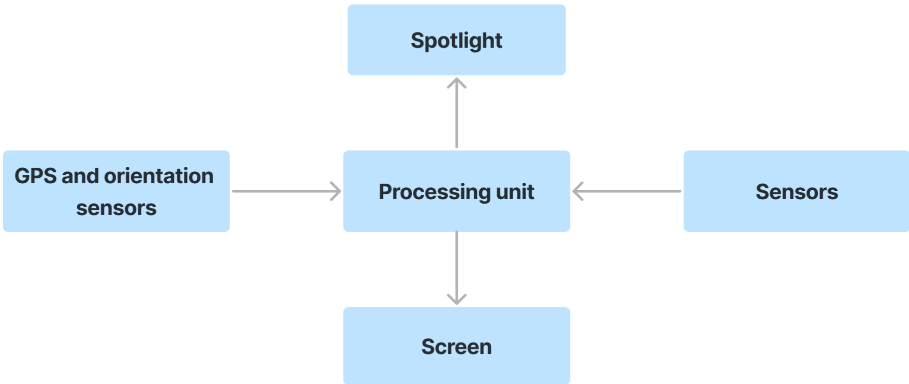


Figure 3.18: System architecture

In figure 3.18 a simple system architecture of the combined concept is presented. The inspiration for the outline came from the patent analysis, where multiple similar systems presented the systems with a system architecture. The components included in the system architecture are sensors, GPS and orientation sensors, processing unit, screen, and spotlight. These are the components included to make the ALG and PED abilities work. The anonymous technical expert from Volvo Penta was consulted and approved the structure of the system architecture.

The sensors on the right are visible to analyze the environment. Their task is to scan the environment and give the data of the environment to the processing unit. As seen in the patent search and technical benchmarking, this can be performed in multiple ways. On the left side, the GPS and orientation sensors are visible. The data they provide are currently available in the EVC 2 system, and is needed to establish the position of the vessel. To make the concept work, the two data sources are processed in a processing unit. The processing unit can then send a signal to the ALG system in the form of actions that the spotlight has to perform. The processing unit can also send information to the vessel screen, to enhance the awareness of the users. In the upcoming part, the choices for the technical components with motivations will be presented for the combined ALG and PED.

3.4.3.2 Sensors

The sensor technology analysis was performed using the pros and cons list in the technical benchmarking chapter. Combining that with inspiration from the patent "Collision avoidance assistance system" by MIZUNO YOSHIRO, a decision of moving forward with a combination of cameras and LiDAR was taken. According to the technical expert, the use of a combination of sensor technology has several advantages because they compliment each other in a cost-effective way. According to the expert, camera-based sensor technology has a wide range of analysis and accurate object identification. The LiDAR, on the other hand, has the advantage of environment detection in lower light and nighttime situations, and is less expensive than the thermal cameras used on the products of Sea.AI. The total component cost for using thermal cameras instead of LiDAR is approximately double with less Field of View (FOV).The field of view is the angular extent of the observable world that is seen at any given moment by an instrument or human. see Appendix 7.

Choice of camera:
The first component to specify is the camera. The specifications of the cameras used for the ALG & PED concept were taken from Sea.AI, as referenced in 3.10. An optical camera with a resolution of 2592x1944 px is used. An example of this type of camera is the Arducam IMX477, which is priced around 1000 SEK. Furthermore, this specific camera is also compatible with the processor unit chosen, as described in the sub-chapter below. The range of the camera varies depending on the sight of the environment. With this resolution, object identification can be made for larger vessels up to 1000 meters and 100 meters for smaller objects. This data is based on the information presented by Sea.AI.

Choice of LiDAR:
LiDARs have now been decided to be used as a second sensor type, instead of the expensive thermal cameras. When choosing LiDAR, there are two types to choose from. A traditional mechnaical LiDAR has 360 degrees horizontally in FOV and a range of around 100 meter. It relies on rotating mechanical components that are used for the mapping of the environment. Using this technology makes them accurate, although there are drawbacks. They are often larger and are prone to breakage because of the moving parts. According to the anonymous technical expert, it is possible to find one priced around 30 000 SEK. Using the LiDAR means that you can have the upside of night vision for a fraction of the price.

There is another type of LiDAR, called solid-state LiDAR. Unlike traditional mechanical LiDAR, solid-state LiDAR does not contain moving parts, making it more compact, durable, reliable, and less expensive. Instead of 360 degree FOV, it has a field of view of around 110 degrees. Solid-state LiDAR sensors are increasingly popular in automotive applications, robotics, drones, and other industries that require precise 3D environmental sensing and are estimated to cost around 10 000 SEK, according to the expert.

The benefits and drawbacks of both LiDARs are apparent. To diversify the result and give multiple ideas to Volvo Penta, two different versions of the concept are presented, one using solid-state LiDAR, and the other using mechanical. There is a clear performance difference in the FOV for the two versions. It is Volvo Penta's choice to choose which version is preferred. The first version is called "Basic", and the other one is called "Vision Plus". The plus version increases performance in terms of FOV, though for a higher cost. The differences between the two versions will be what type sensor components will be used, as they differ in amount and types of cameras/LiDARs. These versions are presented below.

	Basic	**Vision Plus**
FOV Camera (total)	156 deg.	390 deg.
Cameras	2	5
Solid state LiDAR	Yes	No
Mechanical LiDAR	No	Yes
Range LiDAR	100	100
# of LiDAR	2	1
FOV LiDAR (total)	218	360

Figure 3.19: Sensor systems

Basic
As can be seen, the Basic is made up of 2 cameras as well as two solid state LiDARs. This results in a total of 156 and 218 degrees of FOV, respectively.

Vision Plus
Secondly, the vision plus is determined to have 360 degrees of FOV with one mechanical LiDAR, and a total FOV of 390 degrees with five cameras.

Comment regarding what the sensors do:
As stated in the end of the screening chapter, the concept includes functions it can perform. The functions related to the sensors are:

- Object identification
- Distance detection
- Velocity detection

Camera technology is used for object identification. According to the technical expert, the objects can be identified by the camera because it provides color data. The color data makes it possible for the processing unit to recognize what the objects are.

When it comes to the distance and velocity detection, both the LiDAR and the camera have the possibility of gathering the data. According to the expert, the distance and velocity data are more accurate from the LiDAR, but since the camera has a longer range, it can be useful to detect distance and velocity beyond 100 meters.

3.4.3.3 Processing unit

The processing unit that was chosen was based on what is used in Sea.AI's products. Their models, Sentry and Offshore, have been proven to be functional and are currently on the market. Their processing units are based on two main components. The first component is the CPU (central processing unit), whose task is to handle the instructions of a computer program needed for the abilities. The other component is the GPU (graphic processing unit), whose task is to process the image and video graphics required by the camera [26]. Sea.AI uses the Nvidia Jetson AGX Xavier Industrial processing unit for all products in their range. The Nvidia is a powerful processing unit equipped both with a CPU and a GPU. It is designed for use on industrial products and specifically for autonomous machines [22]. This makes it suitable for use on the ALG and PED. According to the technical expert, the processing unit, such as Nvidia, has to be powerful to make the abilities fictionalize. The camera-based data are computationally heavy and need a powerful processing unit. The LiDAR does not require as much computing power. In conclusion, Nvidia is chosen as the type of processing unit, as it is proven to have the computational power required for the specific area of use.

Comment regarding what the processing unit does:
Since the processing unit handles all data that is needed for the concept to function, it is responsible for the collision avoidance aspect of the concept. The processing unit has to make decisions regarding the warning of the user based on the distance, velocity, and type of object. This information has to be presented to the user, and therefore the processing unit has to send out a signal to the screen, so the user can interpret the warning, and avoid the collision. Furthermore, it is also responsible for sending a signal to the spotlight to enable the lightning functions to operate.

3.4.3.4 Spotlight

The next component to develop is the spotlight. As stated in the technical benchmarking, the spotlight is recommended to be purchased from suppliers, rather than produced in-house. The recommended product is the Golight GT 20004. This product has a rotation of 370 degrees, 135 degrees of tilt, and the highest candela (illumination) of 544 000. This, as well as being driven by a remote control (radio frequency), makes it suitable for the concept. According to the interview with the expert at Volvo Penta, there would not be any significant alterations to the spotlight to function with the ALG system.[6]. For the ALG system to function, the processing unit would have to send a radio frequency signal to the spotlight. Since the spotlight can receive those signals, it makes the ALG system compatible with the product. Other types of connection between the spotlight and the processing unit could also be possible, such as a simple wired connection or WiFi.

Comment regarding what the spotlight does:
The signal from the processing unit allows the spotlight to guide the user when navigating at night. It also highlights hazards such as shallows, lights up objects floating on the water detected by the sensors, and lights up the deck or surrounding in docking or working conditions.

3.4.3.5 Other components

As seen in the technical benchmarking of the PED system, other components are needed to make the ability functional. Since the development is not focused on a final detailed construction of the concept, an analysis of all "other components" will not be made. These components will be taken into account in the form of waterproof casing and cabling. These are the "other components" presented by Sea.AI. More research into components is needed for the final detailed development.

3.4.3.6 Synthesis of Technical development

From the system architecture and component specification, a patent application was filled in 2024-05-29 at Volvo Penta for it being considered novel, inventive, and industrially applicable.

3.5 Presentation of the developed concept

3.5.1 Visualization

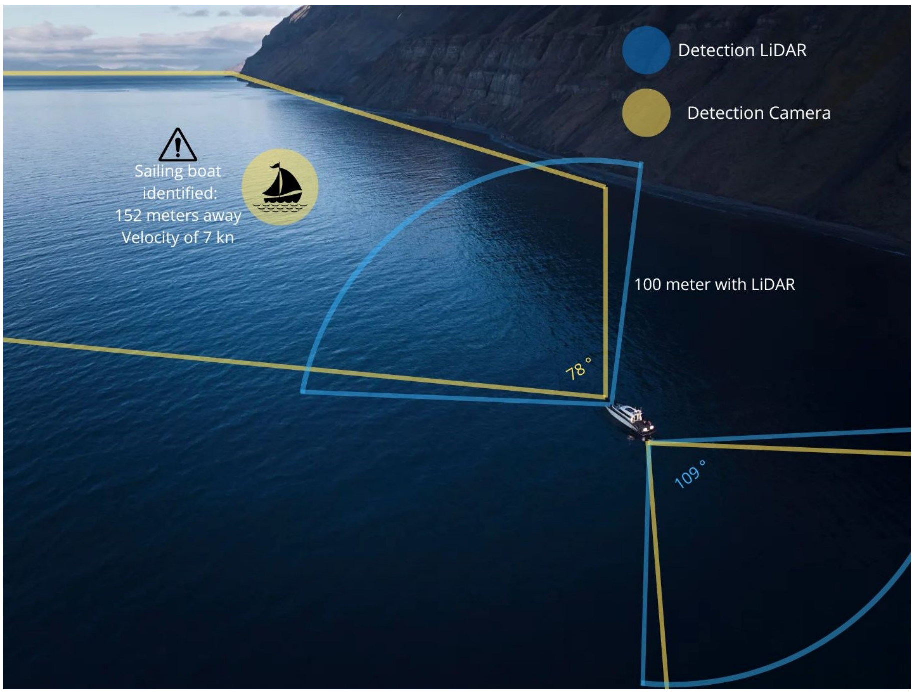


Figure 3.20: Concept Basic

In figure 3.20, the basic variant of the concept is presented. The blue arc represents the scanned area by the two solid-state LiDAR sensors, as stated earlier, it has a range of 100 meter and a total FOV of 218 degrees. The yellow area represents the area scanned by the two camera sensors, which has a total field of view of 156 degrees and a range of about 1000 meters for larger vessels. In figure 3.20, the yellow lines highlight the shoreline, to visualize the ability to detect distances to land. The cameras and the LiDARs are placed in both the bow and stern, to detect the environment in front and behind the vessel. In the upper left corner of the figure, a sailing boat is identified in the scanning environment of the camera sensor, where the distance and the velocity are calculated. Note that the figures presented in this chapter only gives a visual representation to prove the concept and are not an accurate representation.

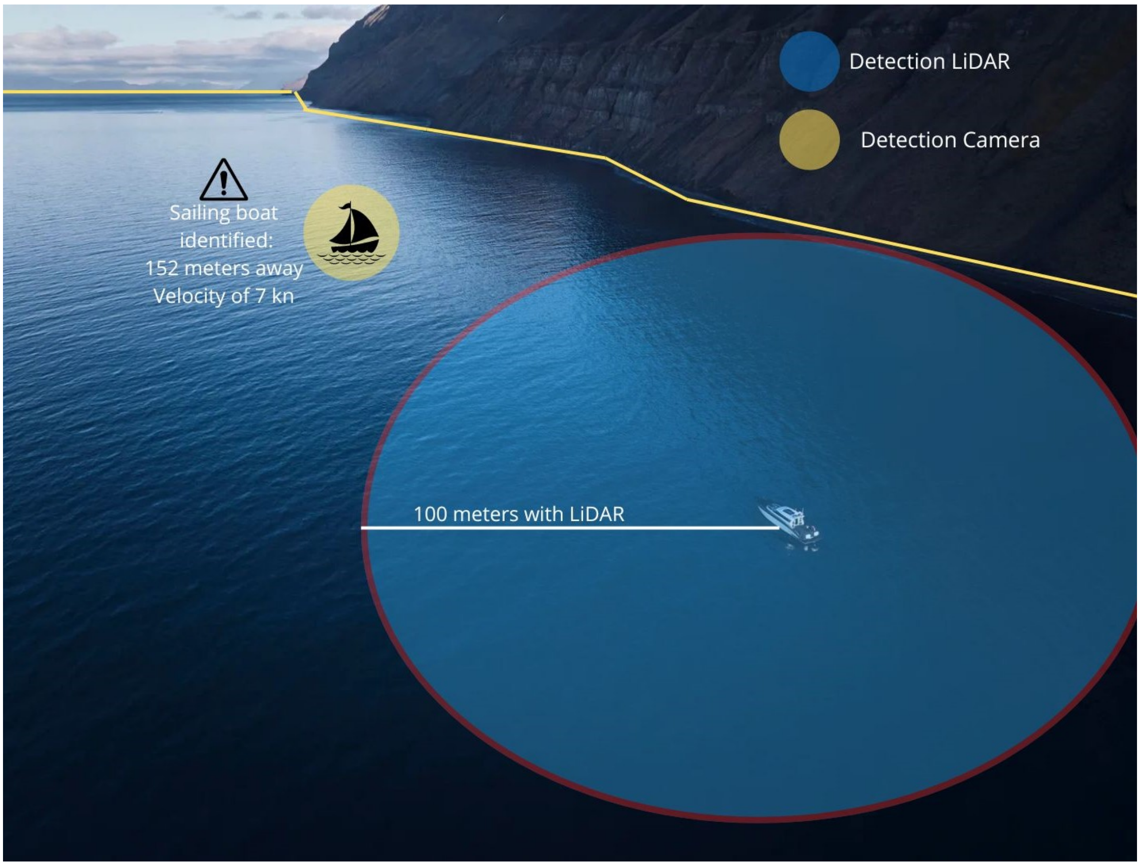


Figure 3.21: Concept Vision Plus

In figure 3.21, the vision plus variant is presented. It distinguishes itself from the basic variant in the FOV aspect. For the LiDAR sensor, it uses one mechanical LiDAR with a FOV of 360 degrees, and for the camera sensor system, it uses 5 cameras, reaching a FOV of 390 degrees. The two variants share the same functions and range, the difference between the variants lies in the FOV aspect.

Figure 3.22: Showcasing lightning system

In figure 3.22 a yacht with the spotlight system is presented. It showcases how the spotlight both lights up the way forward widely and pin points the route with more intense light to guide the user.

The lobster trip - A customer story

To highlight where value is added to the customer and how the system performs, a story of the customer journey was created [5]. The story is based around a lobster fishing trip and highlights both the ALG and PED systems separately, and together as one concept.

Setting the scene: The date is 4 October 2030 and the place is Mollösund.

Johan and his daughter Siri walk down from their house on a dark October evening to his boat to pick up lobster cages. He unlocks the boat from his phone, 100 meters away, and the boat starts to illuminate its way with its spotlight without dazzling him.

They enter the boat and Johan sets a route on the large screen to the placement of the lobster cages they put out last weekend. The boat starts and the ALG system lights up in front of the vessel, creating a thin line 40 meters ahead of the boat.

With the help of the PED system, the vessel recognizes a log that is floating relatively close to the route. This is now visible on the large screen at the Helm, the ALG system highlights the log with the spotlight, and the system makes a warning sound, making Johan aware of the hazard.

Johan and Siri arrive at their location where the lobster cages were placed last weekend. Siri goes to the stern of the boat and bends forward to catch the buoy, and as she does so, a strong wave hits the boat and Siri falls into the cold sea.

The PED system recognizes that a human is detected close to the vessel in the water, and the ALG system points the spotlight to her, making her visible in the dark water to Johan. Johan runs forward and pulls Siri up.

As Johan and Siri are pulling up the cages and checking for lobsters, the ALG system lights up the deck so that they can easily see. "Look! We got 2!"

On their way back to Mollösund, they drive through a rather narrow passage. With the help of the PED system, the distance to the rock walls is visible on the screen, which makes it clear to Johan when he is safely in the middle of the passage.

After passing the narrow passage, they drive through an area with many shallows. Normally during the day, a navigation mark which is there is easy to spot. But since it is dark, the ALG system lights it up automatically. This allows them to navigate treacherous waters without hitting the shallows.

When they arrive at their pier again, the camera from the PED system, the light from the ALG system, and LiDAR sensors create a clearer view, making it easier for Johan to dock, even in darkness.

3.5.2 Implementation of concept into Helm

To clarify how the customer will interact with the concept, a focus on implementation into the Helm will be presented. The sensors, processing unit, and spotlight will be placed outside of the system boundary of the Helm. However, a screen for presenting data collected by the sensors to the customer will be the link from the concept to the Helm. The screen could either be a separate screen dedicated to the concept, or a multi-function screen used for other purposes such as navigation. Exactly how the interaction will be performed (i.e. touch, usage of buttons or keypad) is not decided and requires additional analysis.

3.5.3 Cost calculations

The third step in the presentation of the abilities is the cost calculations for the two types of variants. These served as a base for the business case performed, as well as informing Volvo Penta about the future costs connected to these abilities.

The cost is structured by presenting a best and worst case for each price variant. To clarify, for the basic variant there is a best and worse case cost. The abilities are to be implemented in the future; therefore, the cost for the same performance in 5-10 years will be expected to decrease. The cost would decrease with time due to improved manufacturing processes and increased competition among manufacturers. Furthermore, the cost decrease can also be supported by Volvo Penta's economies of scale in case they produce PED and ALG at higher production volumes. For the costs of the technical components in the worst case, information has been taken from the companies official web page available for private customers. Volvo Penta being a company can also purchase these directly from the suppliers or wholesalers, this also decreases the price. Normally, the mark-up from wholesale to retail is 50%-30%. As a baseline, a 30% decrease is set over the given time.

Basic Figure 3.24 shows the cost calculations for the basic variant.

Components	Quantity	Price - Worst	Price - Best	Worst-case	Best-case
Processing unit - NVIDIA Jetson AGX Xavier	1	SEK 20,000.00	SEK 14,000.00	SEK 20,000.00	SEK 14,000.00
Solid state lidar	2	SEK 10,000.00	SEK 2,000.00	SEK 20,000.00	SEK 4,000.00
Camera - Arducam IMX477	2	SEK 1,000.00	SEK 700.00	SEK 2,000.00	SEK 1,400.00
Installation cables	1	SEK 2,500.00	SEK 1,750.00	SEK 2,500.00	SEK 1,750.00
Weather proof casing	1	SEK 3,000.00	SEK 3,000.00	SEK 3,000.00	SEK 3,000.00
Total for Penta Enviroment Detection				**SEK 44,500.00**	**SEK 24,150.00**
Spotlight with electric motor	1	SEK 11,699.00	SEK 11,699.00	SEK 11,699.00	SEK 11,699.00
Total cost for both systems				**SEK 56,199.00**	**SEK 35,849.00**

Figure 3.23: Cost calculations - Basic

As seen in the figure, the cost is outlined for the processing unit, solid-state LiDAR, camera, cables, casing, and the spotlight. The structure shows the cost of the PED ability first, and then as the final concept with both ALG and PED. For the final concept, it can be stated that the final cost of most of the components needed would be around 56 199 SEK for the worst case and 35 849 SEK for the best case.

Components	Quantity	Price - Worst	Price - Best	Worst-case	Best-case
Processing unit - NVIDIA Jetson AGX Xavier	1	SEK 20,000.00	SEK 14,000.00	SEK 20,000.00	SEK 14,000.00
Mechanical lidar	1	SEK 30,000.00	SEK 21,000.00	SEK 30,000.00	SEK 21,000.00
Camera - Arducam IMX477	5	SEK 1,000.00	SEK 700.00	SEK 5,000.00	SEK 3,500.00
Installation cables	1	SEK 2,500.00	SEK 1,750.00	SEK 2,500.00	SEK 1,750.00
Weather proof casing	1	SEK 3,000.00	SEK 3,000.00	SEK 3,000.00	SEK 3,000.00
Total for Penta Enviroment Detection				**SEK 57,500.00**	**SEK 43,250.00**
Spotlight with electric motor	1	SEK 11,699.00	SEK 11,699.00	SEK 11,699.00	SEK 11,699.00
Total cost for both systems				**SEK 69,199.00**	**SEK 54,949.00**

Figure 3.24: Cost calculations - Vision Plus

Vision plus The vision plus version outlines the cost for the processing unit, mechanical LiDAR, camera, cables, casing, and spotlight. The difference in number of sensors is apparent, as the vision plus includes five cameras and one more expensive mechanical LiDAR. The total cost for the worst case is 69 199 SEK, and the best case is 54 949 SEK.

3.5.4 Business case

In this subchapter, financial calculations will be performed following the method of absorption costing to discuss the business case of the concept. Both the Basic and

Vision Plus variants of the concept will be presented where the chosen parameters will be motivated and varied to show how the financial aspect changes with a specific focus on the price-volume relationship.

As a first part of the financial calculation, the initial costs were calculated. This included the development and testing cost necessary to make the concept fully functional, as well as a cost for advertising. A matrix showcasing the initial cost is visible in Figure 3.25.

Description	**SEK**	**Justification**
Development	SEK 7,080,000.00	-5 engineers -2 years of work
UX integration	SEK 2,832,000.00	-2 engineers -2 years of work
Mechanical integration	SEK 2,832,000.00	-2 engineers -2 years of work
Testing	SEK 2,880,000.00	-4 engineers -1 year of work
Components for testing	SEK 1,000,000.00	-Buffer
Other costs	SEK 500,000.00	-Buffer
Advertisment	SEK 1,000,000.00	-3 marketers -6 months
Total	**SEK 18,124,000.00**	

Figure 3.25: Initial cost calculation

In a discussion with an experienced project leader at Volvo Penta within sensor technology, the 7 different parts associated with the development of the concept were formulated. The first row in figure 3.25 outlines the development phase. It refers to the initial progress towards making the concept functional. This phase involves different steps and has a focus on back-end development with things like data management and functional logic.

After 2 years of development, a UX-integration follows. In a UX-integration, the focus lies on front-end development, which means how to steer and operate the different functions for the screen, where the concept will be visualized for the user. During UX integration, mechanical integration also occurs. It refers to the physical integration of the casing for the technical components and cabling management. Lastly, a testing phase follows that involves fine tuning the whole concept on a software level and physically testing the casing. This phase was calculated to require 4 engineers working for 1 year. Buffer costs were also added under Components for testing and Other costs, and lastly, an advertisement cost important to penetrating the market with a new product was added, resulting in a total cost of 18 124 000 SEK.

With the fixed initial cost calculated, the variable cost associated with the absorption costing was next to be determined. Following the method presented by Lantz, Löfsten, & Isaksson [9] in figure 3.26 , the sales activities associated with the sale of the product in the retailers were determined to be 15% of the selling price. Similarly, the general administration cost was also determined to be 15%, following similar examples in the literature. An additional "other costs" of the 15% percentage rate was also added to take into account the cost associated with costs related to components logistics, continuous product development, complaints and customer support. An installment cost was also calculated to be 2000 SEK per sold product, assuming that it will take one person 4 hours of work to install the whole system with a hourly pay of 500 SEK. From the subchapter "Cost calculations", the component costs for each concept variant (Basic and Vision Plus) were used, where the best and worst cases are presented in figures 3.27 and 3.28. The initial cost calculated was added but divided by over 5 years, assuming that as a minimum product life cycle.

Costs	
Components	SEK 56,199.00
Sales %	SEK 33,750.00
Administration %	SEK 33,750.00
Other costs %	SEK 33,750.00
Installment	SEK 2,000.00
Total variable cost	SEK 159,449.00

Figure 3.26: Variable cost calculation

Finally, pricing was established, following the competitor pricing strategy outlined in the literature *Pricing done right* by Smith [15]. This approach simplifies the pricing issue, ensures competitiveness in the market, and reduces the risk of entering the market with a too low or too high price. The average price of products analyzed in the "Technical Benchmarking" section was approximately 225 000 SEK, which became the price for the Basic variant. Considering that the component costs of the Vision Plus variant are roughly 23% higher than those of the Basic variant, the price for Vision Plus was set approximately 23% higher than that of the Basic variant, at 275,000 SEK.

Basic - Worst case	
Income	
Volume	56
Price (to the cust.)	SEK 225,000.00
Income	SEK 12,600,000.00
Costs	
Components	SEK 3,147,144.00
Sales %	SEK 1,890,000.00
Administration %	SEK 1,890,000.00
Other costs %	SEK 1,890,000.00
Installment	SEK 112,000.00
Initial cost	SEK 3,624,800.00
Total cost	SEK 12,553,944.00
Profit	SEK 46,056.00
Cost per sold product	SEK 159,449.00

Basic - Best case	
Income	
Volume	43
Price (to the cust.)	SEK 225,000.00
Income	SEK 9,675,000.00
Costs	
Components	SEK 1,541,507.00
Sales %	SEK 1,451,250.00
Administration %	SEK 1,451,250.00
Other costs %	SEK 1,451,250.00
Installment	SEK 86,000.00
Initial cost	SEK 3,624,800.00
Total cost	SEK 9,606,057.00
Profit	SEK 68,943.00
Cost per sold product	SEK 139,099.00

Figure 3.27: Financial calculation - Basic variant

In figure 3.27 the two financial calculations of the basic variant are presented. The difference between the two is the component cost, which is 30% lower for the best case. This component cost affects the sales volume break-even, which in the worst case is 56 units and for the best case 43, calculating with the same retail price.

Vision Plus - Worst case	
Income	
Volume	46
Price (to the cust.)	SEK 275,000.00
Income	SEK 12,650,000.00
Costs	
Components	SEK 3,183,154.00
Sales %	SEK 1,897,500.00
Administration %	SEK 1,897,500.00
Other costs %	SEK 1,897,500.00
Installment	SEK 92,000.00
Initial cost	SEK 3,624,800.00
Total cost	SEK 12,592,454.00
Profit	SEK 57,546.00
Cost per sold product	SEK 194,949.00

Vision Plus - Best case	
Income	
Volume	39
Price (to the cust.)	SEK 275,000.00
Income	SEK 10,725,000.00
Costs	
Components	SEK 2,143,011.00
Sales %	SEK 1,608,750.00
Administration %	SEK 1,608,750.00
Other costs %	SEK 1,608,750.00
Installment	SEK 78,000.00
Initial cost	SEK 3,624,800.00
Total cost	SEK 10,672,061.00
Profit	SEK 52,939.00
Cost per sold product	SEK 180,699.00

Figure 3.28: Financial calculation - Vision Plus variant

In figure 3.28 the two financial calculations of the Vision Plus variant are visible. Similarly to the Basic variant case, the difference between the two is the component cost, which is 30% lower for the best case. The sales volume break-even for the worst case was calculated to be 46 units and 39 for the best case.

4
Discussion

4.0.1 Discovery

Looking at the interview part of the discovery phase, it is clear that the most important types of customers were interviewed. Although the interviews had a wide scope, they did not cover the specific groups of primary users equally. Powerboat users had one interview, while the yacht segment had five. For further development and improvements to the thesis, more power boat users should be interviewed to discover their needs, since they might differ.

Looking at the total number of interviews, 14 were conducted. Due to time constraints, 20 interviews could not be conducted, as specified in the method. In the case of the thesis, 14 were still considered sufficient due to the observation made. What the interviews lacked in customer needs, the observation made up for, because of the latent customer needs collected. Furthermore, the interviews were also semi-constructed over one hour, which means implicit needs were able to be collected. In conclusion, obtaining implicit needs from interviews and latent needs from the observation, results in a sufficient data collection methodology.

One more limitation can be seen in the discovery phase. The observation was carried out with a service employee at Volvo Penta. To further enhance the research, it would be beneficial to make observations with the primary users interviewed. In this way, the observations could confirm the stated needs and further complement the latent needs. In the scope of the thesis, this could not be performed due to geographical and seasonal constraints. None of the primary users lived near Gothenburg, where the thesis was written. Furthermore, the customer needs identification was made during the winter months and the interviewee vessels were not in the water, due to the colder temperatures.

Analyzing the content of the interviews and observation, it could be stated that one major part included analyzing the steering equipment at the Helm, rather than only discovering the new abilities. This could have affected the results by missing opportunities and digging deeper into the abilities. However, the abilities are controlled by the Helm, and thus analyzing the Helm in the interviews provides information on the possibilities for new abilities. Although the Helm gives insight into abilities, the interviews and observation phase should have had a larger focus on abilities in general, rather than the equipment of the Helm.

Market research in the marine and automotive industry was chosen for two reasons. Firstly, the marine industry showcases the competition of Volvo Penta and shows where potential gaps lie in the market. Secondly, automotive has advanced with regard to the innovation and implementation of new technologies. Understanding this innovation shows potential where the marine industry could improve and innovate. These two reasons motivate the choice of market research in the marine and automotive industries. Furthermore, in each industry, multiple companies were analyzed, making the market research broader. One limitation with the market research of the automotive industry is the fact that the research of the automotive industry gave insights into the current abilities, and not future abilities planned for 5-10 years ahead. For further research, analyzing the abilities planned for the automotive companies would be beneficial. To understand how the innovative industry sees the future in 5-10 years. However, the abilities presented by market research do not exist in the marine industry, which makes them futuristic in terms of the abilities currently available to marine vessels. In line with futuristic market research, it would enrich the study to research other, more futuristic industries, such as the space industry or similar. In summary, market research is considered to be sufficient in terms of breadth and depth of the industries covered, but it would be beneficial to look at other industries that are more futuristic and look at future-planned abilities rather than current available ones.

4.0.2 Reframe & Development

The initial part of the reframe and development phase was to identify customer needs by interpreting customer statements. To interpret the customer statements correctly, the Ulrich and Eppinger methods were used. These gave guidelines on how to interpret the needs of customers. Furthermore, the interpretation was performed by two people, ensuring that the customer's needs were interpreted correctly. The following steps to establish importance and create the target specification were also performed by two people. To improve the understanding of the needs, personas were created. One limitation with the methodology of the customer needs identification step is when establishing the importance. The importance was established by determining the occurrence of the needs. To enhance the result, other measures to establish the importance of customer needs could have been applied. This could have been done by returning to the customers and making them rank the needs according to their individual importance.

As an interpretation of the needs, the idea generation was also based on the methods presented by Ulrich and Eppinger. From the theory presented, the ideas were inspired by market research, customer ideas, and needs. With these sources of inspiration, the idea generation was performed, resulting in the abilities presented. There are a few limitations with the idea generation phase. This phase differs most from the Ulrich and Eppinger method. Ulrich and Eppinger base their idea generation on generating solutions to subfunctions that together create one product. This was not possible for the development of abilities. To maintain a similar idea generation structure for abilities, only the most important needs were used. This was changed due to the presence of too many needs to ideate. The most important needs were those with an occurrence greater than five. Furthermore, since sub-functions were not created, the morphological matrix could not be used. There was a clear limitation with the idea generation of abilities compared to products, though the methodology was altered to fit the structure of the abilities.

4.0.3 Screening

From the three-step screening part of the method, the number of abilities went from 19 to 2 with the result that the abilities 1.5 (ALG) and 2.5 (PED) were the most promising to focus further development on.

As observed in the market research section, sensor technology plays a vital role in comfort and safety-related features such as autopilot, auto parking, cruise control, and smart lightning systems in the automotive industry. The marine industry lacks in this technological area, but there are competitors that offer expensive products with similar technologies that have not yet been implemented on a large scale, as in the automotive industry.

The market gap for this type of sensor technology in the marine industry, in combination with promising technical feasibility, positive customer feedback, and the possibility of future implementations of other abilities such as ability 1.5, 2.3, 3.2 and 3.6, resulted in the decision to continue to develop ability 2.5 (PED).

ALG solves the need to increase awareness when driving in darkness or fog. As indicated by market research and patent search, this has not yet been seen on the market. With its connection to the PED with sensor data, computer-based decisions can be made, opening up a variety of functions. With the PED system in place, implementations of the ALG is cost-effective, since motorized spotlights, available on the market, can be utilized. The earlier drawback of the ALG system from customer feedback described the loss of night vision. However, with the ALG and the PED connected, the user would suffer less fatigue, since the system helps the user analyze the environment for hazards. The argument about loss of night vision also applies to a similar situation when driving a car in darkness. In addition, it is also statutory to have a lightning system in cars. The novelty in combination with the variety of value-added functions, cost effectiveness, technical feasibility, and positive customer feedback entailed a decision of future development.

Connecting to the three different personas formulated by the customer needs study, the concept could be considered valuable for all three. The professional user highlighted the importance of safety and redundancy for the future EVC system. Looking at the concept, the safety aspects and increased awareness is prominent. The experienced user had a stronger focus on efficiency, making the already existing way of steering and controlling a vessel better. The efficiency aspect could be considered improved with the use of the concept, especially with the lightning aspect. An example could be navigation in darkness, where the concept would reduce the friction of keeping focus on the radar. Lastly, the inexperienced user stated the importance of new innovative ways to make the boating experience easier. These personas illustrate the customer satisfaction of the concept, due to novelty and its increasing functions in safety and awareness.

The result of the screening process gives Volvo Penta a guidance and recommendation on what abilities to focus their R&D on for their future Helm offering.

Looking at the limitations in the method and result for the screening process, the internal screening and technical feasibility could be considered sufficient due to the structured method and the nonbiased decisions of the screened abilities. However, customer feedback was only received with two participants, which is low considering that 20 interviews must be conducted to identify 98% customer needs in the initial identification. [30] This implies that the level of customer satisfaction and opinions are not fully covered by customer feedback sessions. The time constraint and difficulties finding participants with prior knowledge in boating were the reasons for the low number of participants. For the future development of the abilities of Volvo Penta, the level of customer satisfaction should be more thoroughly evaluated.

4.0.4 Detailed concept development

From the development phase of the detailed concept, the technical specification was set in a form of a system architecture and a component specification. With the specification of the components and the mean price of the competitors on the market, a simplified business case was created to give Volvo Penta an indication of the financial potential of the concept.

A patent search and a technical benchmarking of similar products on the market gave a broad view of similar systems. With this in mind, a system architecture was determined, which was approved by an expert in sensor technology at Volvo Penta. The system architecture outlines a unique way of utilizing a combination of the sensor technologies: cameras and LiDAR, not seen on the marine market yet. The combination entailed equal performance for a relatively low cost, while comparing with competitors, approximately half in component cost; see Appendix 8. With the system architecture determined, a component specification was established. The choice of components was based on the technical specification of the competitor SEA.AI to ensure functionality. When it comes to the choice of LiDAR, it was determined on the basis of research of the different variants of the technology (solid-state or mechanical LiDAR).

As a way of diversifying and capturing a larger customer base, two different variants - Concept Basic and Concept Vision Plus - were presented. The differences between the two were the sensor components, where the Vision Plus variant had 23% higher component cost and consequently better performance in terms of FOV. The component cost for the two variants was calculated by researching the components. This cost was used in the financial calculation for the business case.

In discussion with an experienced project leader at Volvo Penta, an initial development cost was calculated. With that set, the cost absorption method presented by Lantz,Löfsten, & Isaksson [9] was used to further calculate the business case. The price was set at the mean price of the competitors according to the economic theory of competitor pricing [15]. With the price, component cost, and other associated overhead costs determined from following similar examples from Lantz,Löfsten, & Isaksson, a result was presented. The result of the business case looks promising relating to the high sales margin associated with the low component cost of the concept.

When considering the limitations observed in the results, several aspects warrant further attention for the development of Volvo Penta. Firstly, the presented system architecture is considered correct but simplified. This establishes the need for additional analysis and research to establish a functional architecture with detailed circuit specifications. Moreover, there is a need for further examination of component specifications. Although the current approach relies on components inspired by competitors, there is a possibility that these components have excessive performance. Therefore, exploring more cost-effective alternatives, particularly for the processing unit, could potentially mitigate costs.

The main limitation with the result of the technical specification is the LiDAR sensor choice versus thermal cameras. Although the LiDAR sensor is significantly less expensive than thermal cameras, it does not offer as long range for detecting objects. SEA.AI does not state exactly how long their thermal and color cameras can detect in darkness; however, they state that "the thermal cameras will be able to perform much better than the human eye." [26]. The lack of range during darkness is the main negative aspect of the developed concept. However, 100 meters of range which the LiDAR chosen is still considered enough, especially when considering that customers drive slower during darkness and bad sight.

The concept shows an overview of the technology needed, but to further develop a functional concept, back- and front-end development has to be performed. This is needed to handle sensor data and take computational decisions. In addition, mechanical design and testing are also necessary for further development.

In the business case, there are also limitations and uncertainties that are important to highlight. Firstly, the cost absorption method is a simplified method to give a general financial view of the business case. It relies on utilizing standardized percentage rates for aspects like sales and general administration, which is suitable for simplified calculations, but might in reality differ significantly from actual costs. From the interview with the project manager, costs related to component logistics, continuous product development, complaints, and customer support were also highlighted. To account for these, they were added to "other costs", with a set rate of 15%. "Other costs" has a high uncertainty because the categories included were not presented in the cost absorption method. The reason for including "other costs" was to present a conservative financial calculation by accounting for the categories. Furthermore, there were additional costs that were not included in the cost absorption. These could be obtaining certificates, adapting to regulations, and discussions with customers about the user interface of the collision avoidance visualization on the screen.

An analysis of the size of the market is also recommended to gain an accurate perception of the sales volume. In the result, no estimation of the sales volume was performed, but instead sales volume break even was calculated for the different variants. A more accurate estimate of sales volume plays a significant role in the decision to continue developing the concept since it has a major impact on profitability in the financial calculation.

Pricing is also an aspect to be further analyzed. The price was set to the mean price of the competitors following the competitor pricing method. However, pricing strategy plays a vital role and affects sales volume and, in turn, profitability.

Lastly, the component cost needs further research and is limited. It is based on components similar to those found online for private customers. The component cost would certainly be lower, which is taken to account in the "best- and worst-case" scenarios for cost calculations due to no VAT and price reduction of bulk purchase. As stated above, the possibility of choosing components that are less expensive than the ones presented also exists, and this could further decrease the component costs.

5 Conclusion

In conclusion, it is evident that the overarching aim and the research questions have been effectively addressed and answered. The initial aim set in the Introduction was to identify and develop desired abilities for Volvo Penta's future Helm and EVC system. To achieve this aim and answer the three research questions, this thesis explored the various phases of discovery, reframing, development, screening, and detailed concept development.

Through interviews and observation, key insights have been gained regarding the customer needs, to identify and develop the desired abilities. Market research illuminated the disparities between the marine and automotive industry, highlighting the need for greater integration of sensor technology in the marine sector. Although interviews and observations provided valuable data on implicit and latent needs.

Reframing and developing ideas based on customer needs and market research led to the identification of promising abilities. The screening process further narrowed the focus to two key abilities: Automatic Light Guidance (ALG) ability and Penta Environment Detection (PED). These two abilities proved to be promising in terms of customer satisfaction, technical feasibility, and the possibility to integrate other future abilities. Thus, these are the abilities that Volvo Penta customers want integrated into their future Helm.

The detailed concept development phase provided technical specifications, system architecture, and component specifications for the abilities to function as a concept. In basic terms, the concept includes a sensor system based on LiDAR and camera technologies, which provides an analysis of the environment. Through a processing unit, this information can be sent either to the captain or to the automatic spotlight. Further development has to be made with regard to technical depth, but the detailed concept development provided a technical implementation and underlying structure needed for the abilities to function. In addition, the business case presented the promising financial outlook of the concept. The business case highlighted a high sales margin of the developed concept, and thus a low sales volume break-even point.

Despite these challenges, the thesis has provided valuable insights and recommendations for Volvo Penta's future R&D efforts. The results highlight a strategic direction for the future Helm and EVC offerings.

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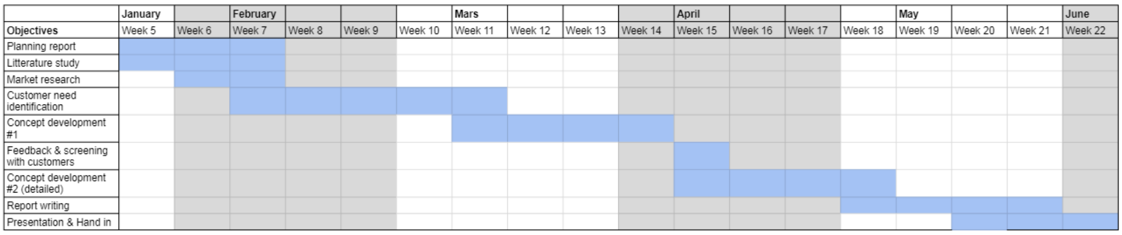
A

Appendix 1

A.1 Gantt chart



B
Appendix 2

Interview Guide - primary users

Part one - Questionnaire based, semi-constructed questions

1. **Demographics:**

Name:
Age:
Occupation:
Gender:
Relation status:
From:
Language:
Highest education:
Employment:

2. **Vessel-specific questions:**

What kind of boat do you have?
What year is it from?
What is included in your helm?
What brand(s) is the helm?
How many years of experience do you have driving a boat?

3. **Driving experience**

- Can you describe memorable or *enjoyable experiences* you've had while using the boat, and what made those experiences special?
- What is *important* for you when ***driving*** a boat?
    - Is there anything *missing* for you when driving the boat that could make the experience better? (A feature/ability)

- Can you describe any *challenges or frustrations* you've encountered while driving your boat from the cockpit (helm)?
    - Inefficient driving frustrations with regards to the helm? Unnecessary movements, etc.
    - Do you have any *weather-related frustrations*? (e.g., wind, rain, sun) Do you wish for any new features that would help mitigate these frustrations?

- How do you envision integrating modern technology, such as touchscreen displays or voice commands, into the helm and cockpit interface?

- Describe your dream helm/cockpit and it’s features abilities

4. User Experience (UX)

- How do you typically use the cockpit while operating your boat? (e.g., navigation, control of systems, socializing)
    - Is easy access to navigation and communication equipment from the cockpit important? How?

- How do you feel about possible customization of the helm for you? (what will be on the screens, placement of joystick, material and color on the steering wheel and so on…)

- Do you have friends/social gatherings on your boat?
    - How is the entertainment system today? Any improvements?

5. Digital vs traditional

- Is there any aspect of driving your car that is better that does not exist in your boat?

- How do you feel about the driving experience of boats becoming more digital like the cars (more screens, reduced number of buttons, voice over, AI, VR, heads-up display, electric steering..)?
    - Is boating a time where you want to disconnect from technology?

- Are there any technological advancements or innovations you've seen in other boats' cockpits that you would like to see implemented on your own?

6. Ergonomics

- What are the most important factors for you when it comes to comfort in the cockpit while driving? (e.g., seating, ergonomics, visibility)

- Are there any specific safety features or design elements you believe are essential for a comfortable and secure driving experience in the cockpit?

Part two - Mediating tool

- What is your opinion about the EVC2? What is good and what is bad about it? (shows EVC2)
- What is your opinion about steering the boat only with a joystick? (shows Strana)
- What is your view on screens for controlling things in a boat?
- What is your view on buttons for controlling things in a boat?
- What is your opinion about steering the boat using a VR/AR?
- What is your view on the development of the car industry cockpits? (show several cockpits)
- What is your opinion on these helms? (show competitor cockpit/helm

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Interview Guide - Lead users

Part one - Questionnaire based, semi-constructed questions

1. Demografiskt:
Same as for primary users.

2. Vessel-specific questions:
What kind of boats (vessels) have you operated?

If many, which you have most experience with

What year(s) is it from?

What is included in your helm?

What brand(s) is the helm?

How satisfied are you from a scale 1-10 with the cockpit/helm?

3. Driving experience

- Can you describe memorable or *enjoyable experiences* you've had while using the boat, and what made those experiences special?
- What is *important* for you when ***driving*** a boat?
  - Is there anything *missing* for you when driving the boat that could make the experience better? (A feature/ability)

- Can you describe any *challenges or frustrations* you've encountered while driving your boat from the cockpit (helm)?
  - Inefficient driving frustrations with regards to the helm? Unnecessary movements, etc.
  - Do you have any *weather-related frustrations*? (e.g., wind, rain, sun) Do you wish for any new features that would help mitigate these frustrations?

4. Was there any specific technology on these larger vessels that you would like to see implemented on smaller vessels like yachts?

5. Could you come up with a specific situation where there was a critical moment where a technology could have been helpful? (example, joystick driving, drone to see better)

4. User Experience (UX)
- How do you typically use the cockpit while operating your boat? (e.g., navigation, control of systems)
  - Is easy access to navigation and communication equipment from the cockpit important? How?

- How do you feel about possible customization of the helm for you? (what will be on the screens, placement of joystick, material and color on the steering wheel and so on…)

5. Digital vs traditional

- Is there any aspect of driving your car that is better that does not exist in vessels?

- How do you feel about the driving experience of boats becoming more digital like the cars (more screens, reduced number of buttons, voice over, AI, VR, heads-up display, electric steering..)?

- Are there any technological advancements or innovations you've seen in other vessels' cockpits that you would like to see implemented?

- How do you envision integrating modern technology, such as touchscreen displays or voice commands, into the helm and cockpit interface?

- Describe your dream helm/cockpit and it's features abilities

6. Ergonomics

6. What are the most important factors for you when it comes to comfort in the cockpit while operating? (e.g., seating, ergonomics, visibility)

7. Are there any specific safety features or design elements you believe are essential for a comfortable and secure driving experience in the cockpit?

Part two - Mediating tool

- What is your opinion about the EVC2? What is good and what is bad about it? (shows EVC2)
- What is your opinion about steering the boat only with a joystick? (shows Strana)
- What is your view on screens for controlling things in a boat?
- What is your view on buttons for controlling things in a boat?
- What is your opinion about steering the boat using a VR/AR?
- What is your view on the development of the car industry cockpits? (show several cockpits)
- What is your opinion on these helms? (show competitor cockpit/helm)

Questions to the internal R&D at Volvo Penta:

- What is your view on the EVC 2?
- What are the pros and cons with the EVC 2?
- What features/abilities would you like to see in a future helm?
- If you could redesign the EVC 2, and change it in some way, how would that be and why?
- How do you feel about the design and material selection of the EVC 2?
- How do you feel about the driving experience of boats becoming more digital like the cars (more screens, reduced number of buttons, voice over, AI, VR, heads-up display, electric steering..)?

Questions to the service and technical personnel;

- What is your view on the EVC 2?
- What are the pros and cons with the EVC 2 in terms of service?
- What are the most common defects/failures of the EVC 2?
- If you could redesign the EVC 2, and change it in some way, how would that be and why? (in terms of service)

Questions to the boat builders;

- What are the main modern features of your boats in the cockpit?
- How do you think the helm and cockpit will look in 5-10 years?
- What are the most important parts of the helm and cockpit for you? What do you value?
- What are the main advantages and disadvantages with your current helm/cockpit?
- How do you feel about implementing a technology advanced helm to your boats?
- How important is customization of the helm for you as boat builders? (Colors, materials of the steering wheel for instance)
- How important is the ergonomy and UX for you while designing the boat?

C
Appendix 3

Person being interviewed	Category	Customer statement	Interpreted need
Jonas Carlsson (Sjöräddningen) - Expert	**Drivining expierience**	-Fewer screens, only show the information that is relevant in the moment -Be able to choose what information that is presented in the helm -Important to simplify the driving experience as much as possible -Good layout on location on throttle and buttons -Important that the helm has the ability to easy show the user how to debug	-Show relevant information in the helm -Be able to choose what information that is presented in the helm -Simplify the driving experience as much as possible -Intuitive layout and placement of controls (ex. throttle) -the helm has the ability to in a simple way Show the user how to debug
	Digital vs traditional	-Fewer screens, one larger where only relevant information is visible -Use hard-Buttons for controlling basic functions -Be able to present what is wrong with the boat, and how to fix it	-Minimize the amount of screens -Use hard-buttons for controlling basic functions -Be capable of identifying and articulating the issues present in the boat, as well as providing solutions for remediation.
	User experience	-Joystick is good when adding or in calm conditions, not while driving in a fast pace with high waves.	-It should be simple to steer the vessel in all conditions for all users
	Ergonomics	-Ergonomy is important, needs to have a lot of settings on the chair but also settings for placement of screens and buttons	-The user should be able to adjust the driving position with many parameters
	Suggested improvements for their vessel	-Main points are: Fewer screens, intuitive layout, hard buttons for basic functions.	
Anders Johnsson (Captain) - Lead User	**Drivining expierience**	-Important with redundance in safety systems. No systems are free of faults. -Wind info on screen does not give enough information about conditions.	-Have redundancy in systems in case systems fail. -Increased preception of forces from the outside.
	Digital vs traditional	-Sometimes too much focus on screens, rather than looking out.	-Keep focus on the outside enviroment.
	User experience	-Many different layouts of steering mechanisms, may lead to confusion and safety concerns. -Many inputs when driving is hard, especially when you have to prioritize concerns in crisis situations.	-Standardized layout to equally manouver boats -See only the most relevant concerns and problems at a given moment.
	Ergonomics	-Physical buttons are needed for important functions.	-Be able to find important functions in vessel quickly and easily.
	Suggested improvements for their vessel		
	Opinions about EVC 2	-Is flexible, a wide range of boats can have the system, easy to add features over time -Robust hardware, few case of them breaking -Smaller controls than competitors (positive) -The joystick is great for adding -The joystick needs improvement in the joystick driving -Latest glass cockpit has a good UI and is easy to use	-The joystick needs to be intuitive in both adding and driving situations -Joystick related settings needs to be accessible in all driving situations -The controls needs to have a reasonable size for different users.
	Drivining expierience	-The joystick is too small -The joystick have buttons on it which are difficult to press while operating (negative) -The joystick is often placed where there is extra room in the boat, (OEM rel.), means that it's placement is not good, needs to be closer to the driver.	-The placement of the joystick needs to be able to adjust for different users and situations.

Henrik Karlsson (Internal R&D), - Expert	**Digital vs traditional**	-Voice over to control things in the helm. -Make the adding situation even more simple, ex. see the boat from to top with 360 cam and press on the screen where to add. -More connectivity, see where other boats are on the screen -Regarding VR/AR, believes on AR for seeing important data but it might ruin the experience of driving the boat, boating is not only going from A to B.	-the docking situation needs to Be simple from the helm point of view. -the helm needs connectivity with other boats to enchance awareness -the helm needs efficient ways of controlling the vessel (ex. Voice over)
	User experience	-The joystick should be "flat" as controlling a computer mouse, not a lever, more intuitive -A feature where the boat analyzes the waves and controls throttle for a smooth ride. -More personalization on the screens and buttons where the user decides what they will do.	-The helm needs to be higly costimizable, both on the sceens and the buttons. -The helm needs to enable the user to operate the vessel smoothly (ex. via a feature that analyzes the waves and adjust throttle)
	Ergonomics	-More settings for the chair and placement of throttle, and steering wheel	-The user should be able to adjust the driving position with many parameters
	Suggested improvements for their vessel	-Penta could offer the OEM a armrest with the joystick attached to make it easier to implement it close to the driver. -General clearer direcions from Penta to the OEM's of how the helm should look.	-The helm needs to be simple to implement into the OEMs vessels.
Mikael Gårdfeldt (Internal R&D), -Expert	**Drivining expierience**	-Pain to have to reach to press buttons or screen. -Bad experience switching from docking to driving mode with joystick -Better feeling in the steering wheel. SInce the steering wheel is electric.	-Have controls close to the body. -Seemless driving without disturbances -Feel forces in the steering wheel.
	Digital vs traditional	-Wish for better interaction with displays. -Broader integration of more systems in the cockpit, chairs can be good.	-Screens to be able to connect to EVC system. -Increase integration of more systems to be Volvo Penta -Integration of tecnology into chair for safety and ergonomics.
	User experience	-Hard to experience forces in joystick -Collision warnings -Nice to have sounds and "klick" noises in electric boats -Hard to spot "grund"	-Feel and experience forces in the driving. -Need to be notified if you are on collision course. -Electriving to feel robust -Spot hazards that can be hard to see
	Ergonomics	-View is important, bad when docus is on displays	-Experience outside enviroments, decrease friction in screen handling.
	Suggested improvements for their vessel		
	Drivining expierience	-The steering wheel is too large -The docking/adding situation is the trickiest part, something to release that pain -The trimming of the engine could be done with a simple control wheel	The helm needs to be compact and not take up unnecesary space -The docking situation needs to be intuitive and simple from The helm point of view

Mats Nilersand, (Primary user)	**Digital vs traditional**	-Have one large screen to control several things, not many small screens. -Hard buttons for controlling things that often are changed -Heads up display as in cars could be a good thing i boats as well	The helm system needs to be centralized where several things is controlled from The same node (a screen) -The helm needs to be simple to control in all conditions (ex. buttons for some things that are changed during high speeds) -Relevant data needs to be presented clearly to The user (ex. via heads up display)
	User experience	-Sensors as in cars could increase the awareness while docking -Thinks that a joystick or something similar are better for steering than the steering wheel it takes up too much space. -A joystick that are wireless could be an idea to be able to move around the boat and steer.	-The docking situation needs to be intuitive and simple from the helm point of view (ex. with help of sensors and wireless joystick)
	Ergonomics	-Believes that the ergonomy could be improved, with more settings, espiaclly for the chair, cars are doing better on this aspect	-The user needs to be able to adjust the driving position with many parameters
	Suggested improvements for their vessel	-	
Mathias Petersson, (Primary user),	**Drivining expierience**	-Like the freedom to go anywhere -Should be interactive right from the moment you get into the boat. -Don't want to reach and let go of boat controls to change layout the navigation chart. Loss of safety -No direct problems on "sea", it is part of the experience. - Wants information about cooling liquid levels displayed when starting the boat.	-Diagnostics and general boat-health info displayed before leaving the harbour. For a safe boating experience -Prioritize information on screens. (prioritization)
	Digital vs traditional	-Touchscreens become cluttered with fingerprints in direct sunglight -Wants a traditional "boat experience", where the screens don't show unecessary information	-The choice to deactivate tech.
	User experience	-More buttons to control screens in joystick and steering wheel. -No comprehensive cockpit and helm. Wants one design.	-Have a system that is coherent -See screens in sunlight
	Ergonomics	- Does not want to reach and let go of steering hardware. It is about safety.	-Have hands on controls at all times . -Boat to be interactive
	Suggested improvements for their vessel		
	Drivining expierience	The most important things: -Number one is the plotter to be aware of the surrondings -Simple engine information, -The feeling that I as a user gets notified early if something is wrong, not when its too late -The engine trim to drive in the perfect speed is important	#NAMN?

William Persson, (Primary user),	Digital vs traditional	-I do not like touch screens for controlling things in the boat such as the sea card, difficult to press it while going 35+ knots since you move a lot in the boat. -Would like to see buttons o other physical hardware for controlling things on the screens, preferably on the left side, on the steering wheel, or on the throttle control. -Hard buttons for things that often changes during the ride, things that only are changed before the ride can be on the touch screen.	-The user needs to be able to control and steer aspects such as the sea card in all conditions (hardware instead of touch screens)
	User experience	-Thinks that it bright light can be difficult to see which buttons that are activated because their light is not bright enough. -Does not believe in cameras and sensors for increased control, the boat moves too much. -Autotrim to keep a fixed speed would be nice. -Never tried joystick but thinks it could be good if it gave feedback on comming too close to another boat or rock for instance. -On a safety aspect, believes that more systems for being aware of the environment could be useful, for instance other boats comming from behind, from the sides, a radar system that warns.	-The helm needs to display information to the user in all conditions (too bright sun, can't see if a button is activated or not) -Give feedback about the surroundings to the user (feedback in joystick/steering wheel based on distance) -The helm gives the user a better view and warns about the surroundings of other boats approaching (safety and comforting)
	Ergonomics	-Would like to see the amount of parameters to change in the driving seat as in a car, the driving seat is not comfortable enough now for longer rides. -Thinks that too much things are located behind the steering wheel, the steering/control hardware needs to closer to the driver.	-The user needs to be able to adjust the driving position with many parameters
	Suggested improvements for their vessel	-	-
Stefan Sjöstrand, (Primary	Drivining expierience	-Best thing with boating is the experience, enhance the feeling being on the sea, it should be simple and you should be free -Would like to see a system that analyzes what is infront of the boat to feel more safe. -Thinks cameras and sensors could be good to make the docking easier, especially when you are drivning the boat alone -Points out the importance that the technology is easy to understand, even if you are older -The steering wheel is not intuitive, difficult to know how how the boat will steer, no resistance. -Thinks the joystick is too "agressive" in it's movement of the boat. -Get better information from the helm about the anchor, how far it is sunken.	-Enhance the experience of boating -The system has a developed system for safety (collision avoidance with shallow or other boats) -The new technology must have an intuitive interface -The helm must be responive and intuitive (the steering wheel does not give feedback or a "feeling", and the joystick is too agressive in its movement of the boat)
	Digital vs traditional	-Hard buttons is important when there is a lot of waves, do not move everything to the touch screen.	-The helm must be simple to use in all conditions (prefers hard buttons vs touch in strong waves)

user),	**User experience**	-Would like to see the boat docking by itself to realise stress -Adaptive speed control, lower the speed while entering a marina for instance -Enjoys going fast with the boat, thinks that safety tech. such as collision avoidance is important for not hitting a shallow, or another boat	-The system has a developed system for safety and easy boating (automatic docking, adaptive speed control)
	Ergonomics	-Would like to see a arm rest connected to the throttle control, when there is a lot of waves, controlling the throttle becomes more difficult. -Important to have close to all the instruments in the helm, not having to reach	.The user needs to Be able to adjust The driving position with many parameters -Increased ergonomy for adjusting The throttle in higher speeds.
	Suggested improvements for their vessel	-Give the user more freedom to perform certain things even though it could be harmful, had an example where the boat would not start because it was in gear. -Cabling management is difficult -Oil sensor in the gear (drevet)	
	Opinions about EVC 2	-EVC2 is flexible, able to build a wide range of different configurations to smaller and larger vessles. -It is a complex system, requires a lot of knowledge, wants to see a system in the future where it is more clear of what can be installed and not. -Wants the system to be even more modular. -Important that the system is easy to install for the boat builders, more pre-installed things. -EVC2 is close to it's limit in terms of computional power, future helm needs more power -In the future with electromobility, it is important that the battery is more integrated to more things in the boat rather than only giving power to the engine. -More connectivity in the future helm, monitor the engine and battery health, debug on distance ,"wake up" components from distance.	-Future helm needs a simpler system design -Future helm needs to Be even more modular -needs to Be easier than "EVC2 to install for the boat builders -the system needs the Future battery integration to Be able to serve more parts of the boats rather than only th electric engine. -Future helm needs more connectivity
	Drivining expierience	-The ability to analyze the world around, object detection, take another route, help while manuevring in tight spaces. -Future helm should have a stronger focus on entertainment systems (music, movies...) -Facilitate things for the user during the ride, ex. booking of port spot.	-Future helm needs to analyze The environment to help The user (object detection, manuevring in tight spaces) -Future helm needs a more developed entertainment system
	Digital vs traditional		

Anders Thorin (Expert)	**User experience**	-Believes in a large screen to see the navigation clearly -Easy boating is important -Steering wheel and throttle control are today are today too clumsy, something more neat -The joystick works good while docking and in calm sea, needs better adaption to joystick driving -The steering wheel should have more functions, control the navigation, music and so on.	-The future helm needs to display the navigation in a clear way to the user. -The future helm needs a focus on easy boating -Joystick driving needs to be further develop on a hardware level -The user needs more alternatives to control aspects, not only on the touch screen (more buttons on the steering wheel)
	Ergonomics	-Be able to zoom in and out on the navigation should be easier than today, no touch for that.	-The zoom function on the navigation needs to be improved compared to EVC2
	Suggested improvements for their vessel	-Handlebars (as motorbike) could be a way of controlling smaller boats, not bigger.	
Anders Romeling, (Lead user),	**Drivining expierience**	-GPS stopped working when driving at night. -Important to keep vision on the surrounding	-Redundancy for GPS -Be able to see the surrounding
	Digital vs traditional	-Important to know who is around you, for safety	-Know where other boats are/Not to feel alone
	User experience		
	Ergonomics		
	Suggested improvements for their vessel		
Max Hammarén, (Service),	**Drivining expierience**	.Thinks the system in general is good .Some functions such as side push are placed on the screen, difficult to press it while steering with joystick .The responsiveness of the joystick could be improved	.Intuitve placement of controls .Responsiveness of steering hardware
	Digital vs traditional	.Likes a big central screen .Go from joystick docking to driving could be improved .General experience of joystick driving could be improved	.Displays information in a clear way .Centralize the information
	User experience	.Would like to see increased awareness of environment in future helm ex. diff. to see canoters while driving fast	.Increased awareness of environment in future helm
	Ergonomics	Would like to have more parameters to change	The user needs to be able to adjust the driving position with many parameters
	Suggested improvements for their vessel		
Truls Amundsson, Primary user	**Drivining expierience**	.Appreciate the freedom in boating .Would appreciate a DP-system to keep position and back camera to get a better view of the surrounding .Easier to couple third party products to the system. .More responsive joystick .Very difficult to drive the boat if an engine stops working, better safety there. .Display errors before it is too late.	.Easier to dock the vessel .More responsive hardware .Increased safety for engine failure .Display errors before it is too late
	Digital vs traditional	.Some screens are too small, diffcult to see .Would like to see a system where all important information is at one place.	.Displays information in a clear way .Centralize the information

	User experience	.Would like to see more connectivity, ex. engine data in phone .Automatic software updates	.Connectivity to see vessel data in other devices
	Ergonomics	.The chair is rather unfortable	.The user needs to be able to adjust the driving position with many parameters
	Suggested improvements for their vessel		
Petra Jonsson, Primary user	**Drivining expierience**	Difficult to feel the control of the boat. The boat is always moving Stressful in docking situations	Simplify control of the vessel Easier to dock vessel
	Digital vs traditional	Would rather have it more like the cars, with simpler interface Wants to be connected to the boat through the phone	Increase connectivity
	User experience	Stressful to drive when loads of boats are around	Be aware of vessels and hazards in the nearby area
	Ergonomics		
	Suggested improvements for their vessel	Less unecessary buttons	
Annika Trogen, Boat Instructor	**Drivining expierience**	Many inexperienced users get scared when docking Inesperienced users find it hard when enviromental factors, such wind or currents interfere with the vessel	Simplify control of the vessel Easier to dock vessel
	Digital vs traditional	New technologies such as speed limiters in docking is good. Does not like a single screen	
	User experience	Stressful to drive when loads of boats are around	Be aware of vessels and hazards in the nearby area
	Ergonomics		
	Suggested improvements for their vessel	No 45 degree angle lever for engine control. Confuses inexperienced users.	

D

Appendix 4

24 Simplify contol of the vessel	23 Increase connectivity	22 Easier to install EVC system	21 Have a choice to deactive tech.	20 Better entertainment system	19 Make steering hardware respond to inputs smoothly	18 Make steering hardware more responsive	17 Vessel should assist in operating smoothly	16 See screen and hardware lights in sunlight	15 In case of failure, have redundancy for all systems	14 Helm offering should be compact	13 Coharent design of the helm	12 Standardized layout of controls	11 Size of steering hardware should fit a wider user range	10 Increase preception of forces in the vessel enviroment	9 Assist in solving errors in system	8 Indentifying errors in the system	7 Easier to dock vessel	6 Enhance focus on enviroment	5 Show relevant information to the user	4 Be aware of other vessels and hazards in the nearby area	3 Adjusting driving position	2 Make important functions easily accessible	1 Not to let go of steering equipment to change settings on screen	**Need** / **Metric**	
																						*	*	Minimize time hands are not on steering hardware	1
*																						*	*	Minimize distance travelled by limbs	2
																						*		Size of interface for function	3
																						*		Feedback from interface	4
													*								*			Amount of ergonomic parameters of change	5
	*						*							*			*			*				Maximize input from outside enviroment	6
	*								*						*	*			*					Maximize connectivity between helm and vessel	7
																		*						Minimize time spent looking at the helm	8
																	*							Minimize steps by user when docking	9
																	*							Minimize time spent docking	10
											*	*												Maximize amount of similar components in vessels	11
											*	*												Maximize amount of similar functions in vessels	12
											*													Maximize similarity in colors and material selection	13
										*														Minimize amount of components in the helm	14
									*															Maximize number of backup systems	15
								*																See screen in sunligths equivelant to XX lumen	16
								*																Minimize amount of fingerprints on surfaces	17
							*																	Minimize user adjustments when driving	18
						*																		Minimize time between input and output when manuvering	19
					*																			Maximize rpm range control	20
				*																				Amount of features present for entertainment purposes	21
			*																					Deactivation of technology	22
		*																						Minimize steps for installation	23
		*																						Minimize time for installation	24
	*																							Maximize computational power in system architecture	25
*																								Minimize steps required to perform control actions	26

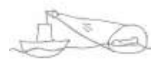
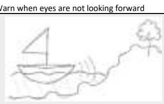
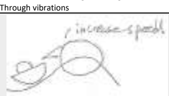
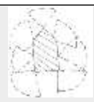
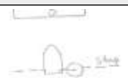
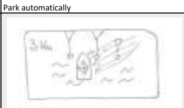
E

Appendix 5

Metric no.	Need nos.	Metric	Imp.	Units
1	1, 2	Minimize time hands are not on steering hardware	5	s
2	1, 2, 24	Minimize distance travelled by limbs	5	mm
3	2	Size of interface for function	5	mm
4	2	Feedback from interface	5	N
5	3, 11	Amount of ergonomic parameters of change	5	Amount
6	4, 7, 10, 17, 23	Maximize input from outside enviroment	4	Amount
7	5, 8, 9, 15, 23	Maximize connectivity between helm and vessel	4	Amount
8	6	Minimize time spent looking at the helm	4	s
9	7	Minimize steps by user when docking	4	Amount
10	7	Minimize time spent docking	4	s
11	12, 13	Maximize amount of similar components in vessels	3	Amount
12	12, 13	Maximize amount of similar functions in vessels	3	Amount
13	13	Maximize similarity in colors and material selection	3	Amount
14	14	Minimize amount of components in the helm	3	Amount
15	15	Maximize number of backup systems	2	Amount
16	16	See screen in sunligths equivelant to XX lumen	2	Lumen
17	16	Minimize amount of fingerprints on surfaces	2	Amount
18	17	Minimize user adjustments when driving	2	Amount
19	18	Minimize time between input and output when manuvering	2	s
20	19	Maximize rpm range control	2	Step length
21	20	Amount of features present for entertainment purposes	2	Amount
22	21	Deactivation of technology	1	Yes/No
23	22	Minimize steps for installation	1	Amount
24	22	Minimize time for installation	1	s
25	23	Maximize computational power in system architecture	1	Calc./s
26	24	Minimize steps required to perform control actions	1	Amount
		General metrics		
		Handle mechanical loads in boat situations		MPa
		Handle fresh and salt water		Yes/No
		Handle thermal loads in boat situations		C
		Minimize production cost		SEK
		Maximize modularity		Amount
		Usage of enviornmentally sustainble materials		CO2/kg

F

Appendix 6

Needs	Abilities						
Enhance focus on environment	Show relevant information on the windscreen	Warn when eyes are not looking forward	 Get information through steering-wheel. Through vibrations	See relevant information regardless where eyes are looking	 See hazards more easily in darkness and in fog		
Be aware of other vessels and hazards in the nearby area	See all other vessels in a connected syster	 See hazards under the water	 Automatically adjust speed based on wave type	Get a clear view of my surroundings from above	 See other vessels and objects using sensors		
Easier to dock vessel	 Se vessel from all angles	 Park automatically	 Feel force when you get close to hazard	 To stop movement of boat when risky situations arise	 Move the steering hardware	 Autostop when approaching hazards or fastening anchor points	Visual and audio guidance of direction on screen
Increase perception of forces in the vessel environment	 Feel the outside forces when steering						

G
Appendix 7

Company & product	**Sea machines** **AI-RIS COMPUTER VISION SENSOR**	**Sea.AI** **SENTRY**
Price	321 138 SEK	544 381 SEK
Sensor technology	1x Optical Camera, 4K (3840×2160)	2x thermal: 640×512 px 2x lowlight: 2592×1944 px
Identifaction	AI/ML model, built on a database of imagery (Computer vision)	Computer vision
Field of view	Horizontal: 90° Vertical: 49°	Horizontal: 360° Vertical: 20°
Range	500 meters	Smaller objects: 700 meters Larger boats: 7500 meters
Components	External AI-RIS Processing Module AI-RIS Camera (User Interface Display - Teguar 15.6” LCD Sunlight Readable Touch Display)	Vision unit (2 thermal cam. & 2 low light cam) Integrated processing unit
Features	Can record an event, detect, track, classify and geolocate surface targets, collision avoidance	Collision avoidance, Object tracking Perimeter surveillance, Manual control of cameras UI in Onboard computers, tablets & smartphones (iOS & Android)
Interface	1x Gigabit Ethernet port by Intel® I219- LM 1x Gigabit Ethernet port by Intel® I210-IT 2x Gigabit Ethernet port Intel® I350- AM2 802.3at POE+	Ethernet
Casing & Rating	IP66/NEMA 4X-rated, IK10 impact-resistant aluminum	Not stated
Operating temperature	-40 °C to 60 °C	Not stated
Shock rating	Operating, MIL-STD-810G, Method 516.6, Procedure I, Table 516.6-II	Not stated
Power input	Camera:PoE IEEE 802.3at Type 2 Class 4 Typical 13.3 W, max 24.0 W Processing module:8-48 VDC input with Ignition Control, 24 V Nominal, 300W	24 V DC
Vibration rating	Operating, MIL-STD-810G, Method 514.6, Category 4	Not stated

Sea.AI Offshore one	**BSB AI & Sea.AI OSCAR 320**	**Ouster OS1-128 LiDAR**
127 357 SEK	317 274 SEK	79 657 SEK
2x thermal: 320×256 px 1x lowlight: 2592×1944 px	2x thermal: 320×256 px 1x RGB: 1920×1080 px	Class 1 eye-safe per IEC/EN x 512 @ 10 Hz or 20 Hz • x 1024 @ 10 Hz or 20 Hz • x 2048 @ 10 Hz
Computer vision	Computer vision	LiDAR
No tilt, Horizontal: 50°	Horizontal: 110° (daytime) No tilt	Vertical: 45° (+22.5° to -22.5°) Horizontal: 360°
Smaller objects: 100 meters Larger boats: 1000 meters	Smaller objects: 100 meters Larger boats: 1300 meters	Max 200 meters
Vision unit (2 thermal cam. & 1 low light cam) Integrated processing unit	Vision unit (2 thermal cam. & 1 RGB cam.) External processing unit	LiDAR component
Identify objects, track course, distance information, collision warnings UI: iOS, Android, PC, B&G, Furuno, Garmin, Raymarine, Simrad	Identify objects, track course, distanceinformation, collision warnings UI: iOS, Android, PC, B&G, Furuno, Garmin, Raymarine, Simrad	Unparallel mapping capabilites Distance detection Object detection
Ethernet NMEA 2000 external Alarm Buzzer	2 x Ethernet – 1 x NMEA 2000	Output: UDP over gigabit Ethernet Input: EEE1588 Precision
Not stated	Not stated	IP68, IP69K
Not stated	Not stated	-45 °C to 60 °C
Not stated	Not stated	Not stated
24 V DC	12V - 24V DC	CAT6 cable, 24 V power adapter, 5 m sensor cable 14 - 20 W
Not stated	Not stated	Not stated

Lookout	Dream Vu Alia	Hesai PandarXT-32 LiDAR
124 311 SEK	51 786 SEK (Camera only)	67 335 SEK
Camera array with computer vision and dedicated GPU	6x cameras. thermal and optical 6912 x 3072 @24 FPS per image	
Computer vision	Computer vision	LiDAR
Not stated	360° (H) x 175° (V)	360 H 31° V
Smaller objects: 50 meters Larger: "Much further out"	120 meters face recognition 40 meters	80 meter
Camera unit Processing unit	Camera unit Integrated process unit	-
Identify objects, track course, distanceinformation, collision warnings, AR vision on screen Back-camera view while docking ntegrates with satellite compass and AIS, WiFi streaming to Apple/Android phones and tablets	Identify objects, face recognition distance detection speed detection	-
NMEA 2000 enabled	Ethernet (Over SSH), Wifi(Over SSH), USB3.0, USB 2.0 & HDMI	-
"Marine-grade water-proof enclosure"		
Not stated	[illegible]20°C to +70°C	
Not stated	Not stated	
	19V +/- 0 .5V [illegible]0W	
Not stated	Not stated	

H

Appendix 8

Components	Quantity	Price - Worst	Price - Best	Worst-case	Best-case
Processing unit - NVIDIA Jetson AGX Xavier	1	SEK 20,000.00	SEK 14,000.00	SEK 20,000.00	SEK 14,000.00
FLIR Vue Pro Thermal Camera	2	SEK 40,200.00	SEK 30,150.00	SEK 80,400.00	SEK 60,300.00
Camera - Arducam IMX477	2	SEK 1,000.00	SEK 700.00	SEK 2,000.00	SEK 1,400.00
Installation cables	1	SEK 2,500.00	SEK 1,750.00	SEK 2,500.00	SEK 1,750.00
Weather proof casing	1	SEK 3,000.00	SEK 3,000.00	SEK 3,000.00	SEK 3,000.00
Total for Penta Enviroment Detection				**SEK 104,900.00**	**SEK 80,450.00**
Spotlight with electric motor	1	SEK 11,699.00	SEK 11,699.00	SEK 11,699.00	SEK 11,699.00
Total cost for both systems				**SEK 116,599.00**	**SEK 92,149.00**

Components	Quantity	Price - Worst	Price - Best	Worst-case	Best-case
Processing unit - NVIDIA Jetson AGX Xavier	1	SEK 20,000.00	SEK 14,000.00	SEK 20,000.00	SEK 14,000.00
FLIR Vue Pro	4	SEK 40,200.00	SEK 30,150.00	SEK 160,800.00	SEK 120,600.00
Camera - Arducam IMX477	5	SEK 1,000.00	SEK 700.00	SEK 5,000.00	SEK 3,500.00
Installation cables	1	SEK 2,500.00	SEK 1,750.00	SEK 2,500.00	SEK 1,750.00
Weather proof casing	1	SEK 3,000.00	SEK 3,000.00	SEK 3,000.00	SEK 3,000.00
Total for Penta Enviroment Detection				**SEK 188,300.00**	**SEK 142,850.00**
Spotlight with electric motor	1	SEK 11,699.00	SEK 11,699.00	SEK 11,699.00	SEK 11,699.00
Total cost for both systems				**SEK 199,999.00**	**SEK 154,549.00**

I
Appendix 9

		Pros	Cons	Pass
Enhance focus on environment	**1.1 See relevant information on windscreen**	-Usage of AR in the heads up display as Volkswagen brings an extra dimension of information, which is interesting. The technology is proven in other industries and are feasibile for the marine also.	-Not sure how much value the ability will bring to the customers, a way of presenting information, not more than that.	Yes
	1.4 See relevant information regardless where eyes are looking	-AR technology are promosing for the future and could reduce cost of having several screens	-The technology is expensive -Misses the point of being in the nature	No
	1.5 See hazards more easily in darkness or in fog	-A novel idea that has not been seen working automatically on the market yet, brings safety and awareness. -The technology presented are feasible.	-Limited to a specific driving situation (in darkness or fog).	Yes
Be aware of other vessels and hazards in the nearby area	**2.1 See other vessels in a connected system**	-Connecting other vessels together in a system with internet is a cheap solution to create more awareness that is feasible.	-The system will only work if all vessels are using the system, thinks that traditional and older boaters won't use the system which loses the systems function. -In some areas at sea, regular 4G/5G are not available	No
	2.3 Automatically adjust speed based on wave type	-The technology is feasible, but implementation of accurate sensors are needed.	-Implementation of a an AI or algorithm steering engine RPM based on wave height are needed, could be difficult and expensive to make work properly.	Yes
	2.4 Get a clear view of my surronding from above	-The drone technolgy has over the years been developed a lot, thinks that the technology are feasible for the function.	-There are complex laws for different countries regarding using drones.	Yes
	2.5 Detect other vessels and objects	-A promising idea with a wide range of different features to implement. More advanced autopilot, collision avoidance and so on. -The technology for this exists in the automotive industry so it is feasible.	-Could be expensive to get accurate long distance sensors for this system.	Yes
Easier to dock vessel	**3.1 Se vessel from all angles**	-360 Camera technolgy is proven in automotive industry and is great for getting a better perception.	-Might be expensive to implement with cameras.	No
	3.2 Park Automatically	-The technology exists for parallel parking for the automotive industry and is feasbile.	-Might be expensive to implement with sensors.	No
	3.6 Autostop when approaching hazards or fastening anchorpoints	-The autostop at a position already exists with DP-system for theassisted docking and are feasible.	-Might be expensive to implement with sensors.	No
	3.7 Visual and audio guidance of direction on screen	-The technology are feasible	-Might be expensive to implement with sensors. -Might be dificult to create a visual representation that helps the driver.	No
Increase perception of forces in the vessel environment	**4.2 Visualize external forces**	-An interesting way of increasing awereness.	-Unsure how the technology for analyzing the forces would work.	No

DEPARTMENT OF TECHNOLOGY MANAGEMENT AND ECONOMICS
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden
www.chalmers.se

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