

Securing a human-centered transition at the start of automation projects

A case study on hydrographic surveying in the Port of Rotterdam

Master thesis Strategic Product Design

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Securing a human-centered transition at the start of automation projects: a case study on hydrographic surveying in the Port of Rotterdam

Master thesis

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Preface

Dear reader,

This thesis marks the end of my Master's in Strategic Product Design at the Faculty of Industrial Design Engineering at Delft University of Technology. I truly enjoyed working on this project, as it allowed me to combine my interest in automation with human-centered design practices.

I would like to thank my supervisors, Achilleas and Garoa, for their help and guidance throughout this graduation project. They made time to sit with me regularly and gave thoughtful, detailed advice. Without their attention, this project would not have turned out the way it did.

I want to thank the members of the innovation team, and especially Nina, for the warm welcome at the port. From the very beginning, I felt at home in your kind and supportive team. I have learned so much from being part of your department. There was always room to ask questions and receive feedback, which I deeply appreciate.

I also want to thank the other employees at the Port of Rotterdam, including all the participants in my study. You were always open to sharing your experiences and knowledge about your work, and I was often invited to join on board or visit your offices. I am also grateful to the other colleagues I met with to gain insights into autonomous navigation in the port. The Port of Rotterdam is a unique place filled with incredibly skilled people with deep expertise. It was an honour to learn from you, and I will carry this experience with me.

Finally, I want to thank my family and friends for their kindness and support.

I believe that technology is at its best when it aligns with the needs of the people who work with it every day. I hope this thesis helps contribute to making that a reality.

Happy reading!

Maureen Boers
Delft, April 2025

Glossary

AIS = Automatic Identification System

IALA = The International Organisation for Marine Aids to Navigation

IMO = International Maritime Organisation

LOA = Levels of Automation

MASS = Maritime Autonomous Surface Ships

PoR = Port of Rotterdam

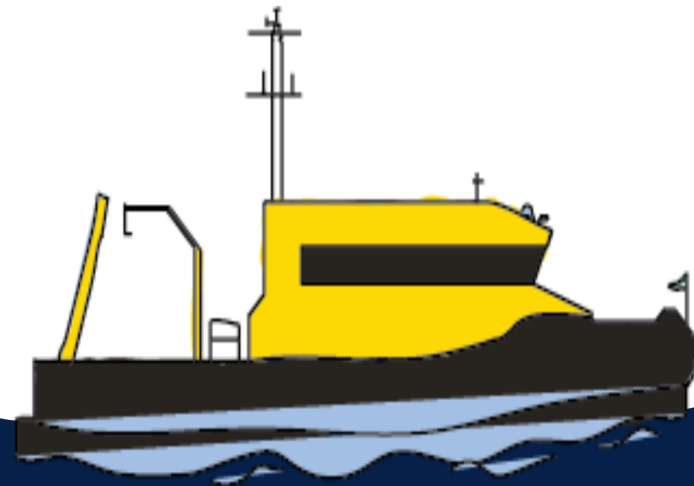
SCC = Shore Control Center

RIA = Robotic, Intelligent and Autonomous Systems

USV = Unmanned Surface Vessel

VHF radio = Very High Frequency Radio or mariphone

VTS = Vessel Traffic Services



Summary

In recent years, the focus of automation has shifted to collaboration between humans and robots. It is clear that human-centered design is crucial to achieve a successful collaboration, as it improves job quality, builds trust, and avoids design flaws by involving workers throughout the process. However, designing successful human-robot collaboration is difficult due to the multitude of stakeholders and the complexity of real world environments.

According to the literature, several pitfalls can hinder successful automation. First, automation is often perceived as a substitute for human work, leading designers to overlook how automation impacts the overall functioning of the system and neglect human factors in the design process. However, in practice, human work will always coexist with automation. Second, there is often too much focus on technical aspects, which causes the broader implications for the surrounding environment to be ignored and results in a failure to design for human work. Third, there is a gap between designers and workers, leading to an oversimplified understanding of human work and the implementation of technologies that do not align with workers' needs. To address these issues, workers must be involved in the design process from the beginning through human-centered design

methods. Additionally, the broader implications of automation must be understood.

The aim of this thesis was to explore how a human-centered transition to a more automated work environment can be ensured at the start of automation projects. To investigate this, a case study was conducted on hydrographic survey work in a major Dutch seaport: The Port of Rotterdam. In this port, the transition to a more automated work environment is planned but not yet defined, creating an opportunity to develop a proactive approach.

First, in order to get a clear picture of the trends that shape autonomous shipping, an analysis of the macro environment was done by looking at political, environmental, sociodemographic, technological, economic and legal factors (PES-TEL). From this it became apparent that there are many developments related to autonomous shipping in the industry, like the use of shore control centers and that Dutch regulations allow for unmanned vessels in 2025, making it likely that unmanned surface vessels (USV) will become operational in the near future. This thesis proposes an approach consisting of four practical steps to secure a more human-centered transition at the start of automation projects and applies them to the case study:

1. Identify key actors in the current process

From mapping out the ecosystem and information flows, it became clear that surveyors, skippers and VTS operators would be in direct contact with unmanned surface vessels and that their communication is key in survey operations in the port.

2. Understand the broadness of their work

Through context research it became clear that surveying at high traffic areas is intense for skippers, that surveyors dislike errors in the data and that VTS operators value predictability and experience overload in their work.

3. Understand their expectations of automation

Through interviews with surveyors, skippers and VTS operators, it became clear that the implementation of an unmanned surface vessel could have a negative impact on their work. For VTS operators, the USV could be an extra burden at peak times, skippers disliked working from an office and surveyors did not like increased measurement errors and technical issues.

4. Explore value creation with worker-technology fit

Through exploring worker automation fit it became clear that a hybrid scenario is necessary to allow skippers to also work in the field. Additionally, it is important that workers closely collaborate with development teams to quickly resolve technical issues with the USV. Since there is currently no digital VTS, a human skipper must remain in direct contact with a VTS operator for now. Here, communication delays must be prevented. A potential advantage for VTS operators is that the USV could share its tracks in the future. The USV must also be able to operate in areas with high traffic density. One way to achieve this is by leveraging the flexibility of remote control, ensuring that the USV is deployed in these areas only when vessel traffic is low. This would prevent VTS operators from being overloaded by the USV during peak times. It would also ensure that skippers do not have to conduct surveys mainly in busy areas because the USV cannot do so, and that surveyors do not receive poor-quality data due to prop wash disturbances from other vessels.

These insights led to a final scenario with a phased out implementation in which a hybrid, remote control approach is presented.

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1 Introduction

1.1 Research gap and objective

Robotic, intelligent, or autonomous systems (RIA) are technologies with some degree of self-regulation (ISO, 2020). These are a form of automation, which refers to machines taking over tasks previously done by humans (Parasuraman et al., 2000). In recent years, the focus of using robots in the workplace has shifted from a separation between humans and robots to an integrated environment in which humans and robots work together. In these workplaces, effectiveness depends on the success of the collaboration between humans and robots (Baltrusch et al., 2022). Especially in unpredictable environments, human robot collaboration is preferred. However, the design and implementation of this is complex, since it combines technical challenges of human robot collaboration with a multi-stakeholder environment (Schroepfer et al., 2024).

Existing literature describes how workers are affected after the implementation of automation in real world environments, like autonomous cars, or buses (Akridge et al., 2024) (Chu et al., 2023). From these studies can be learned that the introduction of new technologies, like autonomous vehicles, can greatly affect the nature of work as well as the power and social dynamics within workplaces (Chu et al., 2023).

Previous research shows "automation pitfalls" that can result in harmful outcomes, including reduced job satisfaction. These pitfalls are: The false idea that automation substitutes human work (Baur & Iles, 2023)(Bradshaw et al., 2013), an overemphasis on technology (Kristensen & Børsen, 2024), and a large gap between designers and workers(Chu et al., 2023)(Akridge et al., 2024).

According to Baltrusch et al., 2022, the use of human-centered design is essential in achieving successful human-robot collaboration and maintaining job quality. Human-centered design involves considering the needs of end users

during the design process (van der Bijl-Brouwer & Dorst, 2017). Furthermore, Baltrusch et al., 2022 and Chu et al., 2023 argue that involving workers in the development of human-robot collaboration improves work quality, builds trust, and prevents design flaws, as workers bring valuable practical knowledge.

However, a concrete approach on how the transformation of human work can happen in a more human-centered way is still missing.

Therefore, the research question is:

How can a human-centered transition to a more automated work environment be secured at the start of automation projects?

In order to answer this question, a case study will be done on hydrographic survey operations in a large Dutch seaport: The Port of Rotterdam. In this case, the transition towards a more automated work environment is planned to happen but has not taken shape yet. The immaturity of the project provides space to collect workers' needs and ideas related to autonomous technologies, before the transition has started. Getting more clarity on workers' current work experiences and their expectations and concerns of the future at the start of a project might allow organizations to take a more proactive approach in avoiding the pitfalls of automation during the design phase, which will result in a more human-centered approach to automation and a greater quality of work. In order to answer the research question, the following sub-question need to be answered:

- What are autonomous technologies, how do they effect human work, and what methods already exist for designing for automation?
- What trends can be found within the macro environment of autonomous ships and the Port of Rotterdam?
- Which workers would be most affected by the implementation of automation?
- What entails the current work of these workers?
- What are the attitudes and experiences of workers in the Port of Rotterdam regarding automation?
- In what way could autonomous technologies be a positive contribution to the current work environment?

1.2 Case introduction

It is important to make a distinction between the Port of Rotterdam, as a port full of companies and and the Port of Rotterdam authority as a company. The whole port area is over 8000 ha and has a length of over 40 km. It is the largest European port by throughput. The port area hosts over 3000 companies and 500000 workers. An overview of the port area can be seen in Figure 1. The Port of Rotterdam authority has the role of a landlord, they provide services to the companies that operate in the port and consist of around 1300 employees (Port of Rotterdam, 2024b). From now on I will refer to the port area as the port and to the Port of Rotterdam authority as Port of Rotterdam (PoR).

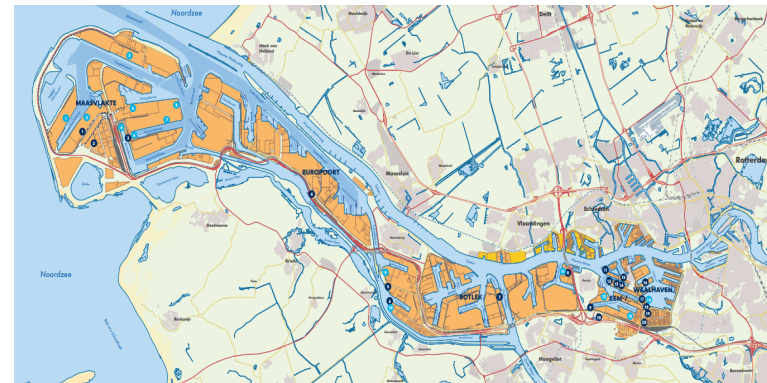


Figure 1: Map of the port area. Taken from (Port of Rotterdam, 2024b)

The project will be conducted for the innovation department of the Port of Rotterdam (PoR) within the context of the port. Maintaining its competitive position is crucial for the PoR. In terms of innovation, the port tends to be reactive, leaving most of it to the external environment and companies. However, a few years ago, the strategic focus of the port shifted. The PoR no longer aims to be the largest port, but the smartest and most sustainable, as physical growth had reached its limits. The emphasis has changed from increasing volume to creating value for businesses. This has also led to the development of a new purpose: *Connecting the world, building tomorrows sustainable port*. In parallel, the port is undergoing multiple major transitions: The energy transition, digital transition, raw material transition and the safety transition. The port aims to be a leader in digitalization and innovation. This push towards digitalization (of which autonomous shipping is a subsection) is driven by economic, political, and environmental factors (Belmoukari et al., 2023).

In the PoR, Asset Management is planning to modernize the surveying fleet. Hydrographic surveying is a process in which the port's seabed is mapped. Based on this information, it can be determined whether the port needs dredging. To perform this, a surveyor and a skipper navigate a survey vessel through the port.

The integration of unmanned surface vessels (USVs) into the hydrographic surveying process is seen as a way to prepare the port for larger unmanned, autonomous, ships in the future. However, despite the technological readiness of USVs, little is known on how the implementation of an USV would impact human work in the port. Surveyors and skippers are concerned that their roles may be altered or even replaced by automation. On the other hand, VTS operators, responsible for navigational safety, are worried about regulatory and safety implications of USVs. The innovation team is caught between advancing technology and address-

ing the concerns of these stakeholders. Having a concrete approach on how the transformation of human work happens could help the PoR and other organizations with a transition to increasingly automated work environments.

1.2.1 Project stakeholders

The project consists of multiple stakeholders. I will be working as a graduate intern from the TU Delft at the innovation department of the PoR. The PoR has a business side, of which the innovation department is a part and an operational side, which concerns the stakeholders involved with hydrographic surveying operations, like VTS operators, surveyors and skippers. Both sides of the organisation have different core tasks. The organisational side is responsible for the sustainable development of the the port area and the operational side is responsible for maintaining safe and smooth handling of all shipping. The organisational structure can be found in Figure 2.

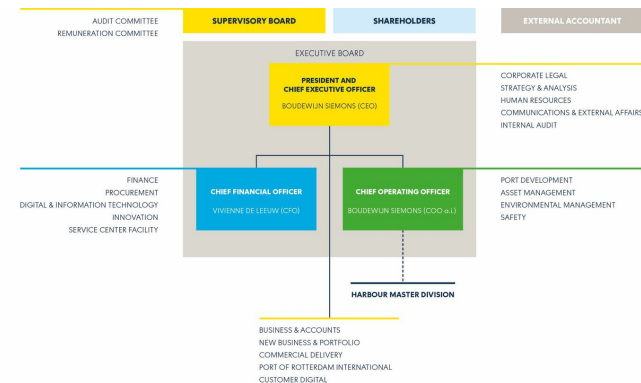


Figure 2: Organisational structure of the PoR. Taken from (Port of Rotterdam, 2024a)

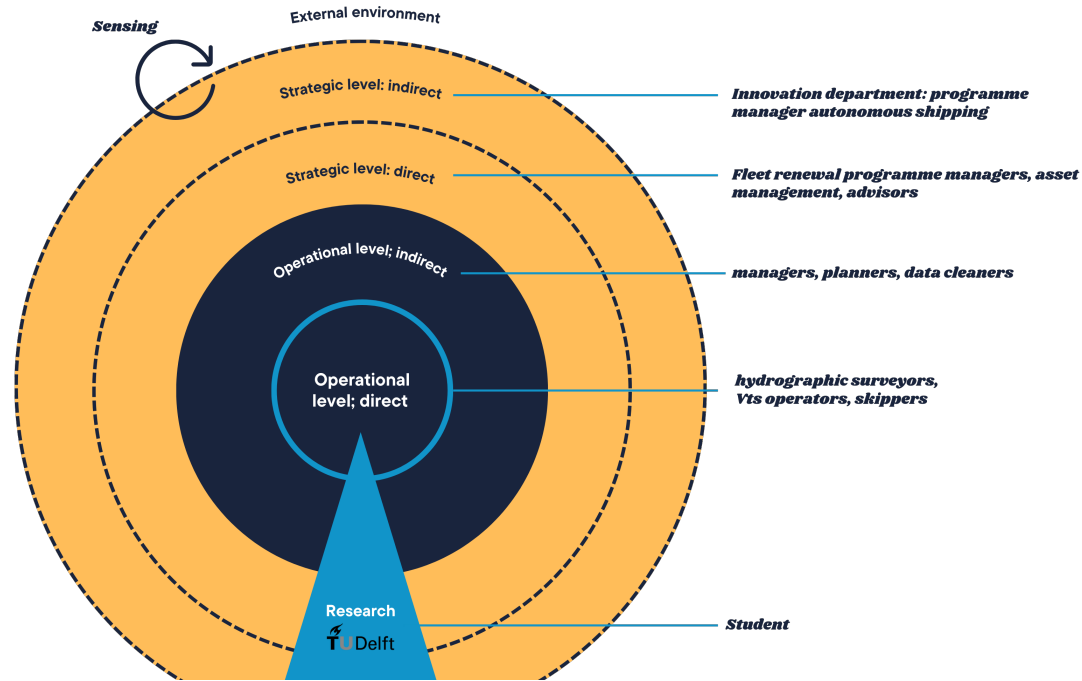


Figure 3: Stakeholder map of the project, mapped from operational to strategic involvement into the project

Many stakeholders within the PoR are either direct or indirect involved with hydrographic surveying or autonomous shipping (Appendix A). I have mapped these stakeholders on a scale from direct operational involvement towards indirect strategic involvement, which can be seen in Figure 3. In this circle, at the core are the people whose day to day work would be impacted mostly by the implementation of autonomous ships. These people are considered to be the end users and are surveyors, skippers and VTS operators.

The indirect operational level consists of people who are not directly doing the survey work or traffic management, but are involved with making the day to day operations possible, like planners, data cleaners and managers. The direct strategic level consists of people that are in control of the fleet renewal program or that are working on regulations. The indirect strategic level consists of people from the innovation department. Stakeholders from the innovation department that are involved with hydrographic surveying are for exam-

ple the autonomous shipping program manager. The innovation team is on the lookout for new emerging technologies and trends that could impact the port.

During my project, I will work at the innovation department. However, my focus will be on the inclusion of people from the direct operational level during the design and implementation of autonomous shipping in the port.

1.2.2 Autonomous shipping and the innovation department

The innovation department consists of 12 members and used to be two separate teams: the digital innovation team and the central innovation team. Since both teams are combined into one, the innovation department, is looking toward open ecosystem innovation (multiple helix innovation). In this approach joint value is created through collaboration with a multitude of public and private organisations.

In order to create consistency when discussing innovation in the port, they have created a port reference architecture. In this port reference architecture, the port is considered to be a piece of land (space) shared with infrastructure to facilitate transport and logistical processes (Figure 4). The lower the level, the more critical PoR's role becomes (Port of Rotterdam, 2024b).

It is important to note that in this definition not only space is shared but also time, during which developments come their way that impact the port. These developments are categorized into three horizons. This model is shown in Figure 4. The innovation department noticed an increased interest in autonomous ships in the maritime industry and wants to explore how autonomous ships could navigate safely in a port environment. In order to explore this, the innovation department is planning to take a hands on, iterative, approach: They do a lot of prototyping through pilots. Based on these pilots, improvements are made and tested again.

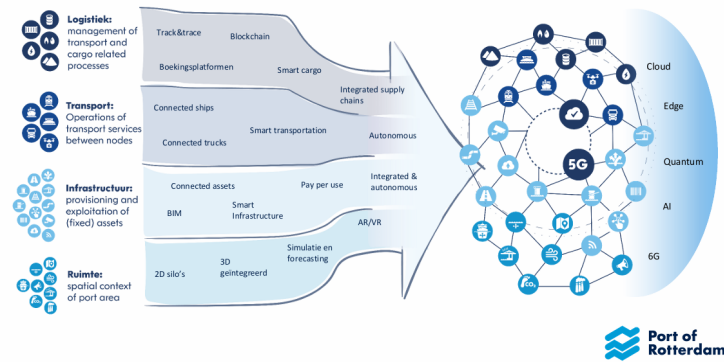


Figure 4: port reference architecture model mapped on time. Taken from (Port of Rotterdam, 2024b)

1.2.3 The fleet renewal program

The fleet renewal program was initiated because the vessels in the port's internal fleet will reach the end of their technical lifespan within the next 12 years. The port authority sees this as an opportunity to make the fleet completely emission-free by 2035 (the hydrographic survey vessels are planned to be built in 2030), which is in line with the general purpose of the PoR. For this the fleet renewal program believes that *"The only way forward is a sustainable one."* To realise this, the program is expressing to take a collaborative approach that addresses behavioural change and changes in processes. Due to the many uncertainties and assumptions, the program desires to have creative sessions in the early stages. Through these sessions they try to collaborate with fleet masters, explore market possibilities, and validate new innovations (Port of Rotterdam, n.d.). The fleet renewal program is about the entire fleet of the PoR, within this fleet, there are two survey vessels used for hydrographic survey operations.

A vision of hydrographic survey vessels has been included in the fleet renewal program. A detailed explanation of hydrographic surveying can be found in Appendix B. A driver to make surveying quicker and more efficient is the looming employee shortages. The current age of surveyors is 58 years, this means that most of the current surveyors will retire within the next ten years. The vision consists of two fully electric survey vessels and a USV that are deployed five times a week for eight hours. The minimum crew for these vessels is one skipper and one surveyor. The survey vessels will be equipped with a new "dualhead echobeam", which has an increased range of 25 percent compared to current measurement tools to make measurements faster and more efficient. There is also a plan to have a 100 percent coverage on embarkments (Snoek, 2024b).

The first survey vessel in the vision (vessel 1) is planned to

be used to measure close locations that are difficult to measure, like embarkments and docks. This survey vessel will be accompanied with the USV. A visualisation of this vessel from the fleets vision can be seen in Figure 5.

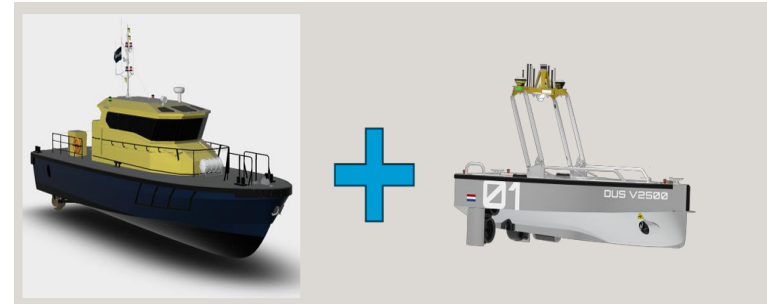


Figure 5: Vision of survey vessel 1. Taken from (Snoek, 2024b)

The second vessel in the vision (vessel 2) will be used for projects and all other tasks like silt measurements and additional depth measurements. A visualisation of this vessel from the fleets vision can be seen in Figure 6.



Figure 6: Vision of survey vessel 2. Taken from (Snoek, 2024b)

The USV handles the long stretches, while the manned vessel takes care of the slopes and difficult areas. In places where precise manoeuvring is needed, it's better to use the manned vessel to gather data. For now, the USV is seen as an extra tool that allows for quick coverage of a survey area stretching for kilometres with minimal ship traffic.

However, the communication between the unmanned vessel and passing inland ships is challenging, and there is still someone needed to monitor the surroundings, since skip-

pers have a lot on their plate already. An extra crew member will be assigned to account for the USV. This person should understand the practical needs of deploying the USV, managing batteries, and handling systems. The operating station for the USV is planned to be located on the starboard side, next to the skipper. This station is planned to double as a workstation. The workspace should also be arranged to allow control of the USV with a view of the back of the vessel. The primary task of the two vessels is to conduct depth measurements. Secondary tasks include silt measurements, current measurements, laser scanning, and visual inspections with a 360-degree camera (Snoek, 2024b).

1.3 Design approach

During the project, I will use the Double Diamond method (Design council, 2015). The Double Diamond is a human-centered design method consisting of two phases. Within each phase, exploration and convergence occur, followed by divergence. For this project I first conducted an analysis of the macro environment and literature research. Based on the findings from the first phase, a project approach consisting of four steps was created. This project approach is used in the execution of the first diamond. It involves the identification of key workers, understanding the broadness of their work, understanding their attitudes and expectations of automation and finally exploring worker-technology fit. Based on the findings from this first diamond, a final future scenario was created. This scenario and the project approach were validated with the innovation department. An overview of the design approach and the corresponding chapters is shown in figure 7.

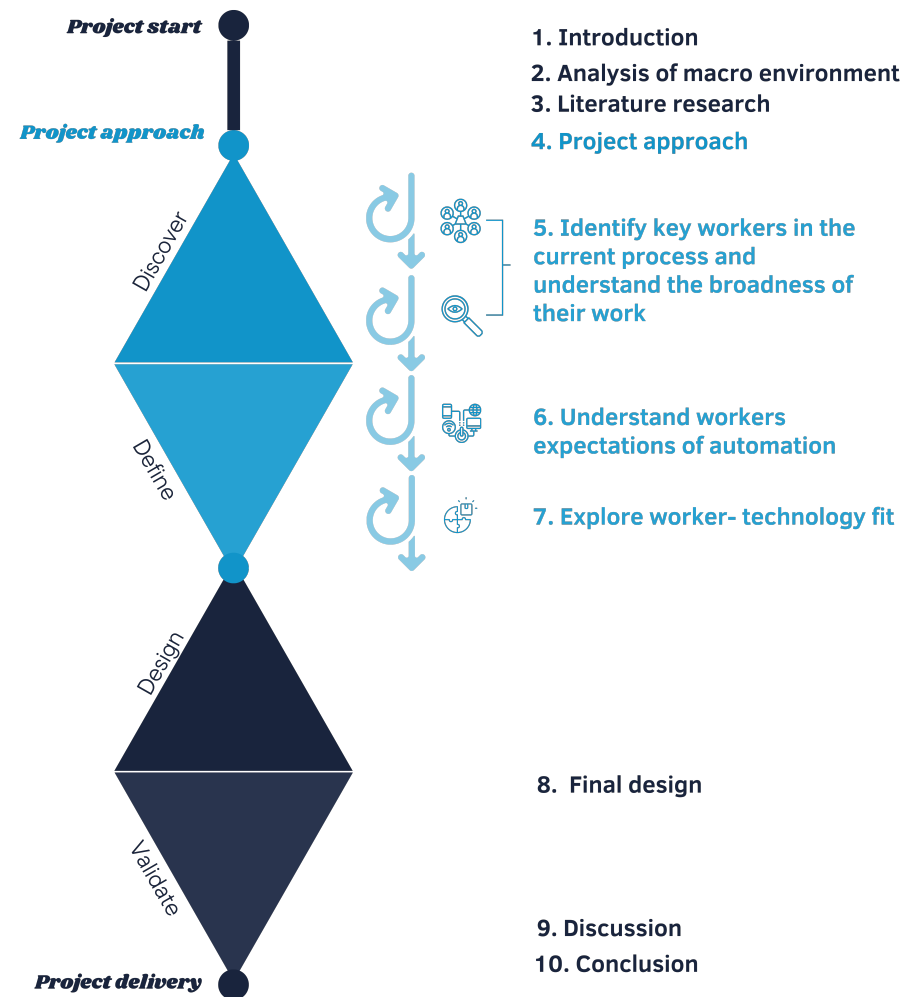


Figure 7: Design approach, following the double diamond model

2 Analysis of the macro environment

2.1 Introduction

In the current situation, the PoR is at the start of a potential transition. In the port area, a lot of manual navigation is still taking place, but some companies are already testing autonomous navigation. The technology in this phase functions reasonably well but is not without issues. Workers seem aware of the concept of autonomous ships and sense that it is on the horizon, but it still feels distant. Acting in this situation means working with technology that is not yet fully proven, with people who are not yet accustomed to working with it, and within a framework of new or missing laws and regulations.

It is essential to consider all these factors that could influence the future. To gain a comprehensive view of the macro environment surrounding autonomous shipping, a PESTEL analysis was conducted.

2.2 Methodology

Macro environmental factors influence entire industries and sectors. The PESTEL framework categorizes these factors into six main types: political, economic, social, technological, ecological, and legal (Aguilar, 1967). By organizing factors in this way, I ensure that each type of influence that could affect the future of autonomous shipping is considered.

Various factors were identified through conversations with industry experts. Others were found through online desk research on autonomous shipping. I categorized each factor within the PESTEL framework using Miro.

2.3 Results

The factors that were found with the PESTEL analysis are shown in Figure 8.

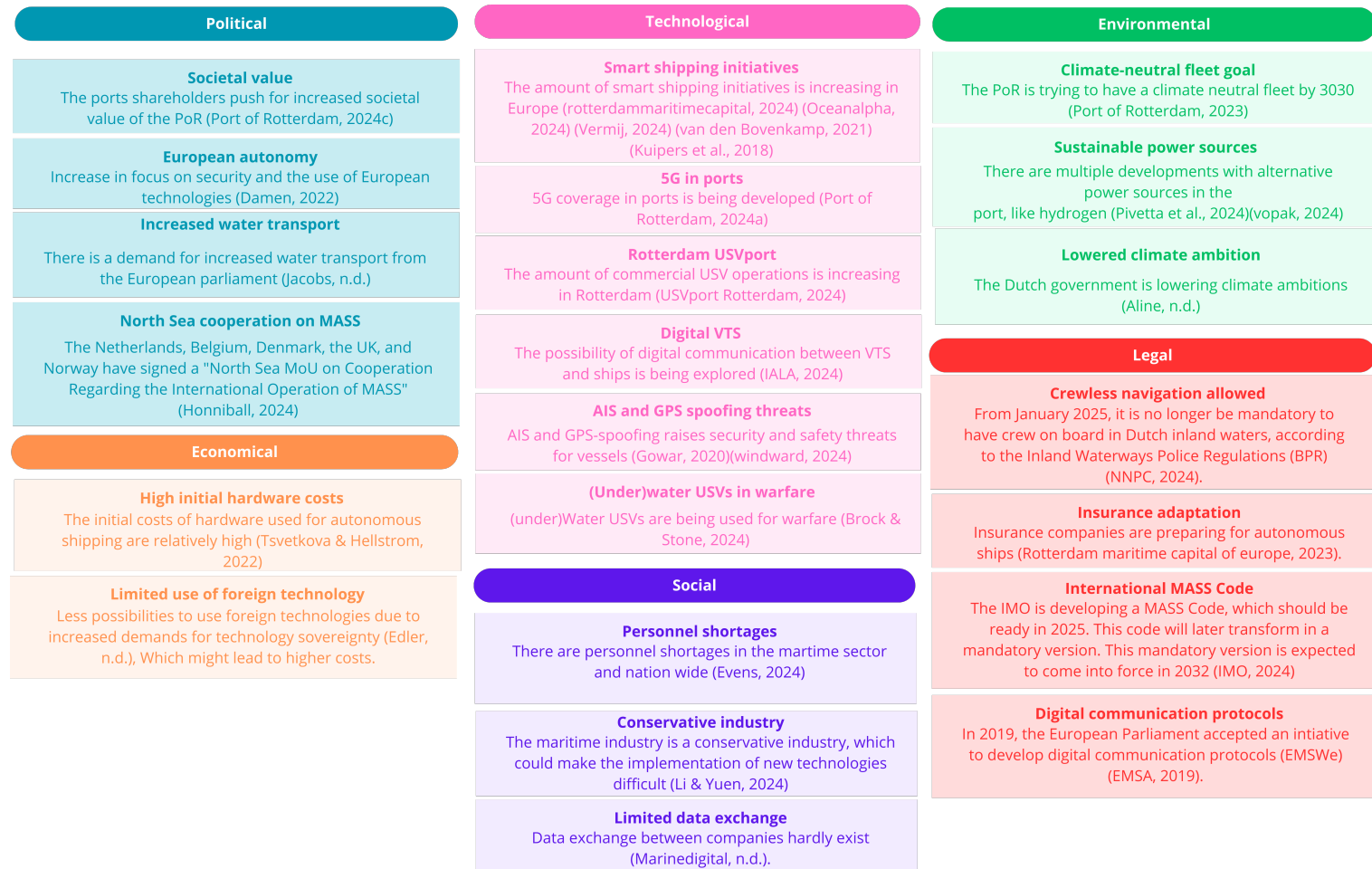


Figure 8: PESTEL analysis

2.4 Conclusion

A PESTEL analysis was done to get a holistic overview of different factors that influence the adaptation of autonomous shipping. From this analysis, the following can be concluded:

Regulation is very important in the maritime sector. At the moment, efforts are being made to enable autonomous shipping and digital VTS communication, but these developments are progressing slowly and are still in their infancy. However from 2025, crewless navigation is allowed within the Netherlands. This will likely push developments towards unmanned surface vessels (USV).

Regarding environmental factors, the port is making strong efforts to make its way of working more sustainable. What might work against this is the current government's reduced ambition to achieve climate goals.

Technological developments related to autonomous shipping are moving fast. There are many initiatives proving that autonomous shipping is becoming a reality, for example the use of shore control centers. At the same time, work on other technologies is ongoing, such as the implementation of 5G in the port and the creation of guidelines for digital communication with the VTS center. These technologies will be necessary to make digital communication between autonomous systems efficient. Additionally, drones are already being flown commercially in the port. This project could create synergies for autonomous shipping. There are also threats regarding (cyber)security, such as AIS and GPS spoofing and the use of underwater drones in warfare.

From a social perspective, there are labour shortages in the Netherlands, which presents an opportunity for autonomous shipping, as it could contribute to more efficient operations. A potential hindrance for the adaptation of autonomous ships, is the conservative maritime industry and the reluctance of logistics companies to share data.

From an economic perspective, the high initial costs of implementing autonomous ships present a barrier. This factor could become more pronounced in the future due to increasing pressure for technological sovereignty from the European Parliament, which could drive up hardware and development costs.

Several political factors play a role. In the coming years, the PoR will face increasing pressure from its shareholders, consisting of the government and the municipality of Rotterdam, to make a societal contribution to the city. Additionally, at a European level, there will be a growing focus on safety due to geopolitical unrest. The European Parliament also aims to increase shipping traffic, which will affect the already existing labour shortages. Finally, there is an increase in collaboration on innovations between countries.

All these factors directly or indirectly influence how the development of autonomous shipping will unfold in the future.

2.5 Next steps

Now that I have a comprehensive understanding of multiple factors that are of influence on the case. I will conduct literature research to gain a better understanding of automation and autonomous ships.

3 Literature research

3.1 Introduction

The goal of this study is to understand what autonomous environments are, how they affect human work, and what methods already exist for designing for automation. I also want to understand the potential factors that could hinder its implementation.

For the first exploration of the literature, I gathered a number of articles related to human roles in autonomous systems and resistance to automation. The data consisted of scientific publications. I collected these publications in various ways. For example, I attended a symposium on meaningful human control in increasingly autonomous systems (House of AI, 2024) and included publications from this event in my review. I also got some recommended articles from my supervisor on the topic of automation and human work.

After reviewing more general work on autonomous systems and their impact on work environments, I conducted a scoping review to focus specifically on the topic of autonomous shipping. The goal of the this scoping review was to gain an overview of the current knowledge on human roles and autonomous ships.

3.2 Related work

3.2.1 Definition of autonomy, automation and autonomous environments

When I refer to autonomy or autonomous technologies, I mean robotic, intelligent or autonomous technologies (RIA). This term is used by the International Organisation for Standardisation (ISO) to refer to technologies that have to some extent the ability to self-govern or regulate (ISO, 2020). RIA, or autonomous technologies are not the same as automation. Automation is defined as the takeover by machines of functions previously performed by humans (Para-

suraman et al., 2000). An automated work environment is an environment in which there is a certain degree of automation.

3.2.2 Balancing automation and human work

The traditional goal of automation is to substitute human control, decision-making, and problem-solving with machines and computers (Chu et al., 2023). Tasks are accelerated by technology through reducing the steps that are time consuming or prone to human error (Delfanti & Frey, 2021). This is done by enhancing a machine's autonomy to a level where it can reliably function independently (Delfanti & Frey, 2021).

When designing for automation, the design process is important, as pitfalls during the design process can lead to negative consequences when the system becomes operational (Bainbridge, 1983).

Automation is often promoted as a simple plug-and-play solution to ease daily tasks (Baur & Iles, 2023). Even though a key motivation behind automation is to reduce the workload for human operators (Delfanti & Frey, 2021), in practice, human work will always coexist with autonomous systems (Bainbridge, 1983)(Parasuraman et al., 2000)(Baur & Iles, 2023)(Boeva et al., 2023)(Bradshaw et al., 2013). This is because automating parts of the system will change the very nature of the work, rather than make it obsolete (Parasuraman et al., 2000). Which makes it impossible to replace human work without altering the system's overall function (Bradshaw et al., 2013).

For this reason, assuming that automation is a plug-and-play solution can be harmful, as it may lead to overlooking how automation alters the overall function of the system (Bradshaw et al., 2013) (Baur & Iles, 2023) or neglecting the human perspective, while in practice, human work will always coexist with autonomous systems (Bainbridge, 1983). As a

result, Human operators are often left to handle tasks that the designer were not able to automate or design for, resulting in more difficult work (Bradshaw et al., 2013). If the above pitfalls occur during the design and implementation of autonomous technologies, Bainbridge, 1983 argues that the operator is often left with a set of random tasks for which no support is designed. These tasks fall into two categories: manual control and monitoring. The irony of manual control and monitoring is that the operator's manual control skills deteriorate when most of their time is spent merely monitoring the system, yet they face more challenging tasks when manual control is required. When the operator is tasked only with monitoring the autonomous system and cannot intervene, there is a paradox where the operator must supervise a system that thinks faster than they do (Bainbridge, 1983). Another pitfall that occurs during the design process is the existence of a large gap between designers and workers. In practice, technologies are often not created by those who will ultimately work with them (Chu et al., 2023). For example, Akridge et al., 2024 argues that the socioeconomic gap between bus operators and designers developing autonomous vehicles leads to a reductionist perspective on the work of operators. While Chu et al., 2023 say that the disconnect between designers and operators leads to a lack of awareness of the impact of their designs on workers. This Ultimately leads to the implementation of technologies that are not in tune with its workers' needs (Chu et al., 2023)(Akridge et al., 2024).

In complex and dynamic environments, fully autonomous technologies remain a myth (Bradshaw et al., 2013). Despite this, much focus is often placed on the advancement of technology (Kristensen & Børsen, 2024). Calvert et al., 2024 claims that overconfidence in technology can lead to safety issues and that human-centered design can be used to combat this. (Bradshaw et al., 2013) suggest that instead of striving for as much automation as possible, we should

assess whether full automation is desirable in a context.

3.2.3 Towards a responsible transition

As previously discussed, errors in the design process are a cause of problems (Bainbridge, 1983). But how can we properly design for automated work environments? To effectively implement automation, designers need to consider not only technology but also the broader social implications of their designs (Chu et al., 2023). Secondly, it must be understood that automation will always need human-machine collaboration. Therefore, the focus in the design process should be on machines that can effectively collaborate with humans rather than machines that replace human work (Bradshaw et al., 2013). Achieving this requires the use of human-centered design principles (Baltrusch et al., 2022).

Human-centered design involves considering the needs of end users during the design process (van der Bijl-Brouwer & Dorst, 2017). Baltrusch et al., 2022 and Chu et al., 2023 argue that workers must be involved in the development of the process for human-robot collaboration and that their input should be valued. Several benefits of involving workers in the design process are mentioned. First, the quality of work would be improved. This is because a human-centered approach takes into account the needs and desires of workers. Second, trust between workers and robots will be increased, which is necessary to establish a cooperative relationship (Baltrusch et al., 2022). Finally, it will improve the quality of the design and prevent unnecessary problems during trials or safety issues. This is because workers have direct experience with the technology and specific knowledge about its practical use (Chu et al., 2023).

Furthermore, Baltrusch et al., 2022 propose five design guidelines to sustain job quality when implementing autonomous technologies in work environments. First, technologies must provide a clear improvement over the current

work. Second, the technology should not be placed above humans but should support and advise them. Third, the design and movements of the technology should not intimidate people. Additionally, the technology must be predictable and transparent in its actions towards the operator. Finally, the technology must be adaptable to the specific preferences of employees.

3.2.4 Existing frameworks of automation

In the literature, there are various frameworks available regarding levels of automation, but only a few focus on the human element. Parasuraman et al., 2000 proposes a human-centered automation framework. This framework takes the four phases of human information processing as a starting point (sensory processing, perception/working memory, decision making, response selection). The paper assumes that automation can be applied for each of the four phases: information acquisition, information analysis, decision and action selection, and action implementation. Each form can have its own degree of automation, based on a scale ranging from 1 to 10. The authors emphasize that designing using the framework is an iterative process in which both the consequences for human workers, which are: mental workload, situational awareness, complacency, skill degradation must be considered, as other factors like: automation reliability and costs of decision.

Van Diggelen et al., 2024 builds on this framework presented by Parasuraman et al., 2000 by highlighting five design patterns of meaningful human control in military systems. (1) The first pattern is "real-time human control," where the operator has direct control over the robot and must be fully

aware of the environment, tasks, and robot behavior. Examples of this are remote control or standby for real-time intervention. (2) The second pattern the author mentions is "distributed real-time meaningful human control," where multiple operators collaborate to control a robot. This occurs when the situation is too complex for one operator to have sufficient situational awareness. By combining their specific knowledge, a collective awareness is achieved. (3) The third pattern is "prior meaningful human control." Real-time control isn't always feasible, especially when rapid response is required or when too many robots need to be managed. In such cases, humans can pre-program the robots, but this is only effective if the robot's environment is predictable. (4) The fourth pattern the author mentions is "goal-based meaningful human control." This occurs when the environment is too unpredictable for prior control. In this case, the operator simply provides the robot with a goal, and the robot determines its own actions. To do this, the operator needs anticipatory awareness and a good understanding of the system. (5) The fifth pattern the author mentions is "human-machine teaming." This pattern combines aspects of real-time control and goal-based control. The human operator can simultaneously control multiple autonomous systems and delegate tasks to robots. In this pattern, human operators collaborate with the robot as if the robot were a human teammate. This pattern requires the human operator to trust the system. According to the author, employing more complex patterns is not necessary in all situations. Van Diggelen et al., 2024 says that high operational tempo, stealth missions, poor communication capabilities, and systems with more elements are reasons for implementing more complex design patterns. The patterns in the framework are illustrated in Figure 9.

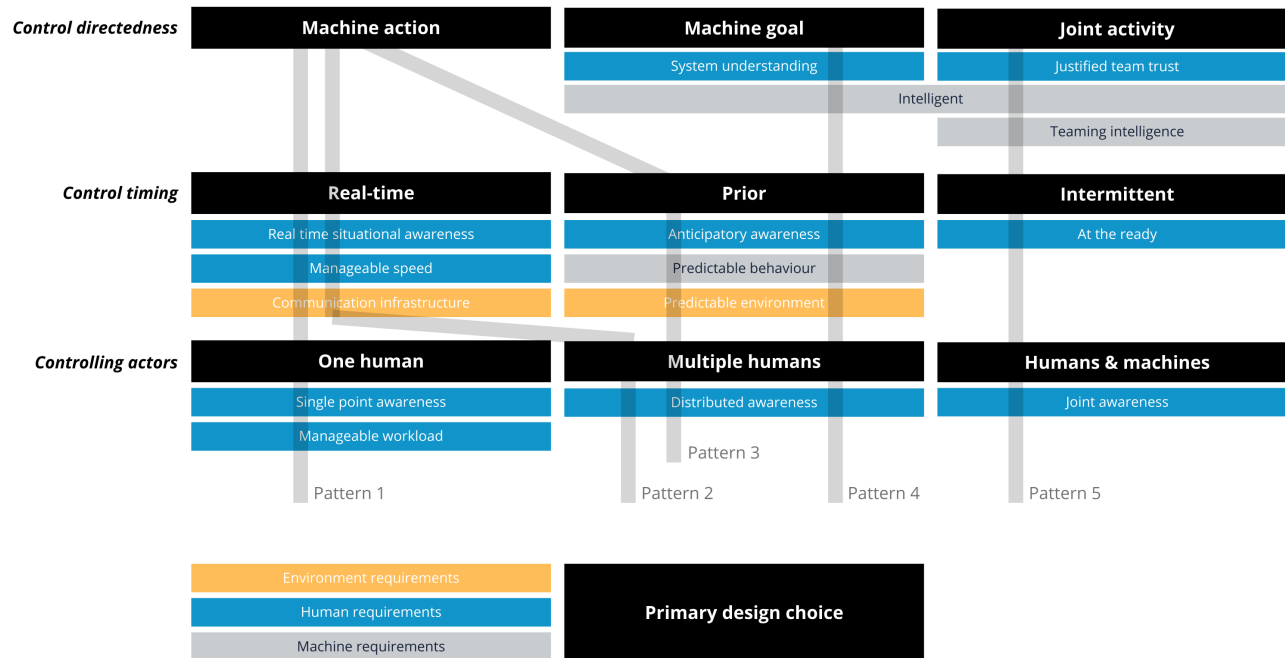


Figure 9: Design patterns for meaningful human control with autonomous systems taken from (Van Diggelen et al., 2024)

3.2.5 Resistance to automation

Tijan et al., 2021 Identifies various success factors, drivers, and barriers to digitalization in the maritime transport sector. It is noted that managers and employees' resistance to change, among other factors, can be a barrier to digitalization.

As previously discussed, it is undeniable that automation will change the work environment. A change of the work environment

in the form of automation can be particularly challenging, as employees may not see the benefit of it and may fear losing their jobs (Goodwin-Sak et al., 2019). Besides the fear of losing ones job, automation will have a disruptive effect on existing social relationships and on established habits of employees (Goodwin-Sak et al., 2019). Changes in the work environment are timeless, and the phenomenon of 'resistance to change' is a widely discussed topic. Recardo Ronald J, 1995 describes 12 possible

causes of resistance to change in organizations. These can be divided into five subcategories: (1) The first reason is that change can have negative consequences for employees, for example, because it seems to create more work or because there is a chance that someone's job will be replaced. (2) The second reason is poor communication from the organization. For instance, when change is poorly introduced and expectations are not communicated to employees. (3) A third cause is when established habits or social relationships are disrupted by the change. (4) The fourth cause is when the organization is inconsistent: for example, when bad behavior is not punished, good behavior is not rewarded, or when change is expected, but no resources are provided to employees. (5) Finally, past negative experiences can lead to resistance to change.

When employees resist change, this can manifest in various ways. They may openly resist by sabotaging efforts, voicing their concerns, or rallying others against the change. However, resistance to change can also occur in less clear ways.

For example, individuals may work less, withhold information, request more studies, or form committees to slow down the process (Recardo Ronald J, 1995).

Goodwin-Sak et al., 2019 identify factors that influence the willingness to adopt automation in an organization for individuals. They concluded that perceived necessity is the primary driver for an individual to be open to automation. This relationship is weakened when the perceived risk, in the form of job loss or more difficult work, is high and strengthened when the perceived benefit is high. Perceived benefit is more likely to be experienced as high when individuals have a lot of trust in the technology. In the visualization below, these relationships are illustrated (Figure 10). The author mentions executive sponsorship, early user engagement, and good communication as ways to increase perceived necessity. Early user engagement, gathering information about user needs, and employee comprehension and support are methods to increase perceived benefit. Finally, early user involvement and transparency are mentioned as ways to reduce perceived risk.

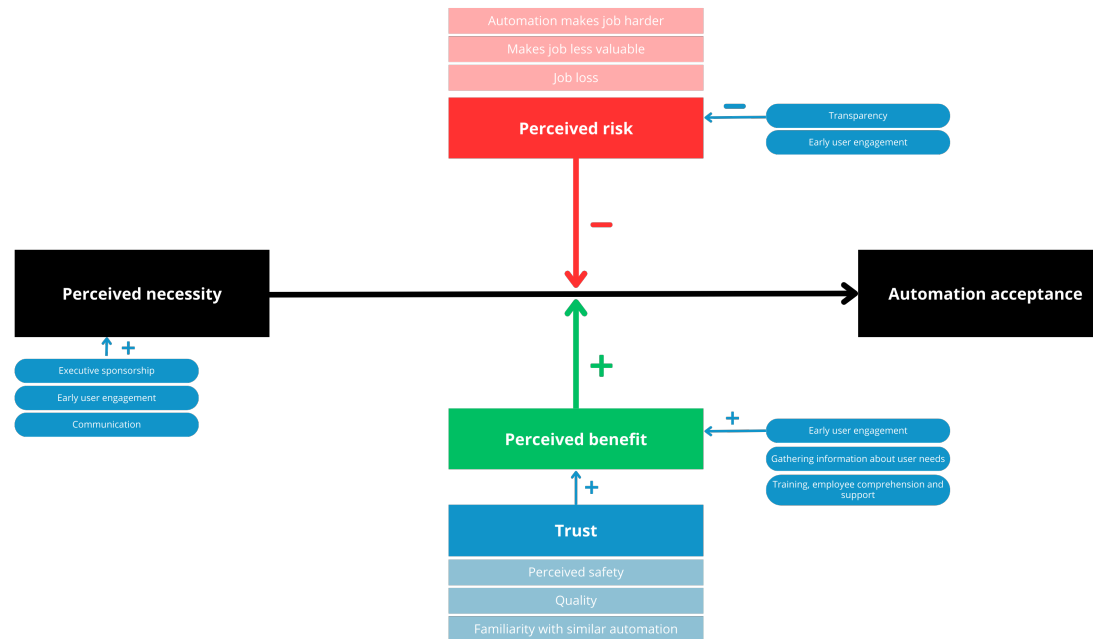


Figure 10: Resistance to automation framework taken from (Goodwin-Sak et al., 2019)

Parker and Grote, 2022 state that automation can have either a positive or negative effect on autonomy, skill variety, feedback, social interactions, and job demands. Gödöllei, 2022 goes into more detail about changes resulting from automation within companies and states that the automatizability of someone's job can be perceived by an employee as either positive or negative. Examples of a negative perception, include thinking that automation makes your job redundant, while examples of a positive perception include believing that automation enables you to work harder, smarter, or more safely. According to the researchers, people are

more likely to have a positive perception when they experience greater control over their work and the changes. Finally, Goodwin-Sak et al., 2019 emphasizes the importance of organizational culture. If the organization has a culture that embraces innovation, takes risks, and values learning, the likelihood of automation being embraced increases. If this is not the case, the likelihood that employees will be open to automation decreases.

3.3 Search strategy

In this section the method for the scoping review is discussed. The analysis was done using the PRISMA-ScR (Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews) checklist (Tricco et al., 2018). This approach suits our research as I aim to identify key factors in the specific field of human work and autonomous shipping.

To answer the research questions, I searched for articles in the Google Scholar database using the keywords "Autonomous ship*" AND "Human work" OR "Human roles," resulting in 93 search results in October 2024. Google Scholar was chosen because other databases, such as Scopus, provided very few and less relevant results (n=situational awareness7) for these search terms. I then screened these articles by title, focusing on those where human roles in autonomous shipping were central to the research. Based on this, I selected 44 articles. After reading the abstracts, I removed 18 articles due to lack of full text or abstract availability or due to the topic being irrelevant, a different focus than human work and autonomous shipping, or duplication. Abstract review and article management were conducted in Mendeley. The full text articles were read through and coded inductively in Atlas.ti.

A visualisation of the process can be found in Figure 11

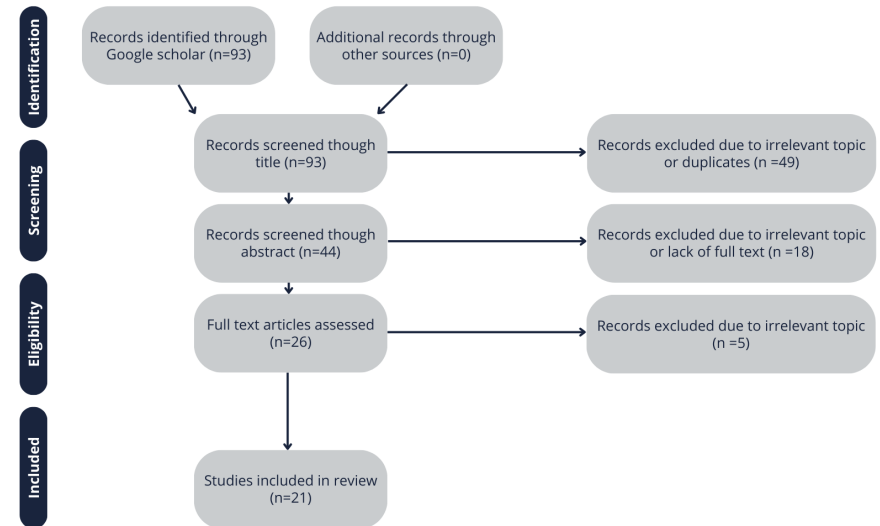


Figure 11: Search strategy

3.4 Results

3.4.1 Definition of autonomous ships

The IMO (International Maritime Organization) defines MASS (Maritime Autonomous Surface Ships) as vessels equipped with AI that enable a certain degree of autonomy. These ships, whether remotely controlled or partially to fully autonomous, still require the expertise of experienced personnel to function effectively (Veitch et al., 2024). This integration of human involvement classifies MASS as a sociotechnical system, which is defined as a system where technological systems and humans interact so closely that they either cannot or should not be separated (Law, 1987).

3.4.2 Benefits of autonomous ships

In the body of literature, multiple benefits for the development and implementation of autonomous ships are mentioned. The main benefits are efficiency and safety. Autonomous ships have the potential to be more efficient than conventional vessels, as they are capable of navigating optimal routes (Kristensen & Børsen, 2024). This also reduces fuel consumption, making shipping more sustainable and cost effective (Mackinnon et al., 2015)(Li & Yuen, 2024)(Veitch et al., 2024)(Saager, 2022). A significant portion of accidents on the water occur due to human error. With the introduction of autonomous ships, it is expected that these errors can be avoided (Mackinnon et al., 2015) (Saager, 2022).

3.4.3 Levels of automation and automation dimensions in ships

Several articles mention specific levels of automation, with the most frequently cited being those defined by the IMO, which includes four levels: LoA 1, "ships with automated

processes and decision support," where automated systems assist with operations but seafarers remain onboard to manage the ship. LoA 2, "remotely controlled ships with seafarers on board," involves remote operation while a small crew remains onboard for system management. LoA 3, "remotely controlled ships without seafarers on board," has no crew onboard, with operations managed entirely from a remote control center. LoA 4 is "fully autonomous ships," where the system can make operational decisions independently of human input (Li & Yuen, 2024)(Tam et al., 2021). The levels of automation that are proposed by the IMO are plotted on the framework of (Shneiderman, 2020) by (Veitch & Alsos, 2022) in Figure 12. These levels are adaptive, meaning that a single ship can adapt to different levels of automation, depending on the context (Hynnekleiv & Lützhöft, 2022).

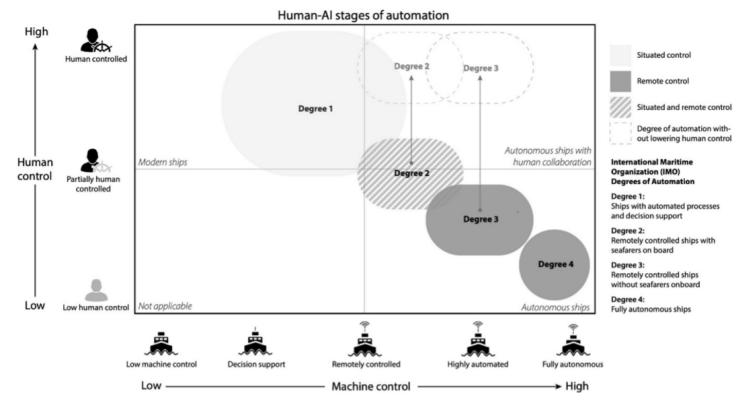


Figure 12: Levels of automation proposed by IMO plotted on axis of human control and machine control. Taken from (Veitch & Alsos, 2022)

While the technology to support high levels of automation is largely available, the challenge lies in making it work ef-

fectively in real world environments. This is because autonomous technologies are often fragile. They operate well in specific situations but fail when unexpected situations arise (Ramos & Mosleh, 2021). In real world environments a lot of unexpected situations happen, because they are made up of many different tasks an people, making them to be complex and unstructured (Veitch & Alsos, 2022). This means that in a real world environment like a port, an autonomous ship is more likely to fail. In order to account for this, a cooperative relationship between operators and autonomous ships might be more beneficial than fully autonomous ships (Hynnekleiv & Lützhöft, 2022)(Schroepfer et al., 2024) (Tam et al., 2021).

Therefore, as higher levels of automation are reached, this does not mean that people will be less involved. Instead, operators and machines are expected to be working together more (Veitch et al., 2024). This complicates the design and implementation of autonomous ships, as we will need to look at the integration of robots into diverse stakeholder networks (Schroepfer et al., 2024). Ramos et al., 2021 Takes into account this complexity and states that there are three dimension of automation that interfere with each other. They note that environmental complexity and cognitive effort must be considered in relation to levels of automation (Figure 13) in order to understand human tasks in autonomous environments. The specific role of the operator can vary depending on factors such as the level of automation of the ship and the complexity of the route (Veitch & Alsos, 2022)(Song et al., 2024).

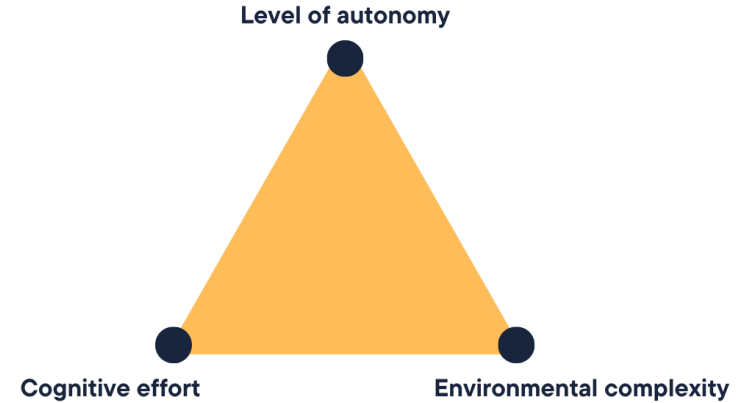


Figure 13: Dimensions of automation taken from (Ramos et al., 2021)

3.4.4 Future human roles

Whatever the context or LoA might be, autonomous shipping is expected to change many jobs in the maritime industry (Alamouh et al., 2024). Nearly all articles discuss the shift from human work at sea to shore-based human work, often mentioning shore control centers (SCC) (Li & Yuen, 2024)(Veitch et al., 2024)(Veitch & Alsos, 2022)(Mackinnon et al., 2015)(Saager, 2022)(Ramos & Mosleh, 2021). Porathe et al., 2014 Envisions a future in which a fleet of autonomous vessels will be controlled by a human operator from a SCC. In a case that the operator needs to intervene with the vessels, this could be done in three ways. The first method is indirect control. An example of this would be updating the route due to weather changes. The second method is direct control. This could be done by ordering a vessel to go a specific route. The third method is called situation handling. In this scenario the operator takes over manual control of a vessel. (Saager, 2022) Proposes a remote cooperation structure in which a remote operator and a remote maritime captain work together from a SCC. Within this structure, the remote operator monitors the situation in which the autonomous ship is sailing. If the remote operator assesses that the situation might become dangerous, they can instruct the remote maritime captain to take over manual control of the autonomous ship. This structure is visualized in Figure 14.

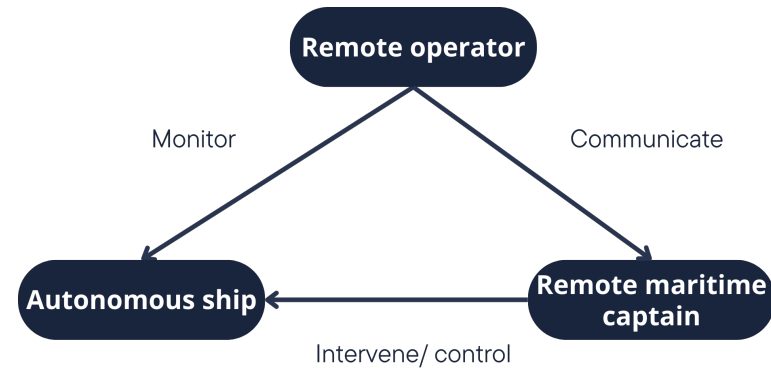


Figure 14: Collaboration between human operators and an autonomous ship. Taken from (Saager, 2022)

Veitch et al., 2024 Identifies three overarching categories of operator roles in the literature on autonomous ships. These categories are dependent on operational contexts and technological possibilities. All categories involve some degree of human machine collaboration. The first role is an active role, involving continuous monitoring and decision-making by the operator. The second role is more of a backup role, where the operator is not actively involved in all operations but takes over the system in case of failure. As autonomous systems grow, the operator's role is expected to shift to a managerial or supervisory role in which cooperation will be important (Tam et al., 2021)(Mackinnon et al., 2015). The third role mentioned is a passive role, where the operator only observes the system. Remote operators of autonomous ships should have sufficient knowledge on maritime navigation and need to understand the technology that is used (Jin, 2023).

3.4.5 Effects of autonomous ships on operators

Many authors discuss the effects of autonomous ships on operators (Veitch et al., 2022)(Hynnekleiv & Lützhöft, 2022)(Mackinnon et al., 2015)(Saager, 2022)(Alamouh et al., 2024) (Tam et al., 2021). Some articles discuss more indirect effects, like organisational trust and resentment (Veitch et al., 2022) (Hynnekleiv & Lützhöft, 2022).

The most mentioned effect on operators is the need for sufficient situational awareness (Mackinnon et al., 2015)(Saager, 2022). Situational Awareness is used to describe an operators understanding of their surroundings (Endsley, 2017). A lack of situational awareness is a possible safety issue that could arise with overseeing autonomous systems or remote control (Alamouh et al., 2024). This lack of situational awareness also refers to a so called "information gap". The information gap is the difference between the amount of information that is needed for the operator to monitor the ship effectively and the amount of information that is given to the operator (Saager, 2022). If there is too little information, the operator is not able to have sufficient situational awareness. However, if there is too much information displayed, the operator could suffer from an information overload (Alamouh et al., 2024), which also leads to a lack of situational awareness.

Another effect that is often mentioned is increased stress or boredom. Veitch et al., 2024 conducts empirical research on automated ferries in Norway and finds that operators feel like they are in a backup role. This backup role involves overseeing autonomous work and stepping in during stressful situations. The most stressful situations occur during manual takeover, lack of situational awareness, or slow response times from the vessel that is being controlled. There are also high stress levels in hectic situations, for example when entering and leaving ports (Tam et al., 2021). When high stress events, like mentioned above occur, an operator may

not be able to take manual control in time to prevent an accident (Mackinnon et al., 2015). This effect will likely be even stronger when skill degradation appears. Veitch and Alsos, 2022 Found that there was a high risk of the degradation of skills with passive monitoring, which could have a negative effect on safety as the crew was expected to do manual takeovers. In order to solve this, operators tried to do a manual shift twice a day to avoid losing their skills. The other side is increased boredom. Automation frees up time and attention of the operator, because it often results in less tasks. If the time that is freed up can not be used for different tasks that are at the skill level of the operator, it can cause the operator to feel bored Veitch et al., 2024. An example of this is given by Veitch et al., 2022, where operators expressed a desire to sail the autonomous vessel into busier areas to get more stimulation, but resented management for giving them the additional task of selling food to passengers.

A factor that is often mentioned in the body of literature is trust. Hynnekleiv and Lützhöft, 2022 Argue that trust is an essential to the possible success or failure of the implementation of autonomous ships. A lack of trust could be a barrier for reaching higher levels of automation in ships (Tam et al., 2021). Hynnekleiv and Lützhöft, 2022 Describes two categories of trust at interaction level: Operational trust and trustworthiness. Operational trust is the trust that is needed between an operator and autonomous ship to be able to work together effectively. To achieve this, the operator needs to understand how the autonomous ship works and the autonomous ship needs to understand how the operator behaves. Trustworthiness is the extend in which the operator perceives the autonomous ship as reliable. This is dependent on: previous experiences, level of understanding of how it works, confidence in own skills, and personal values and culture. If trustworthiness is not balanced well, there is also a risk of over trust. This is when an operator has too much trust in the system. If this is the case, there is a risk

of complacency, which could cause accidents (Alamoush et al., 2024).

3.4.6 Effects of autonomous ships on the broader ecosystem

Effects of autonomous shipping can go beyond human machine interaction and different tasks. Veitch et al., 2022 Found that operators had grown to resent the developers and managers implementing the new technologies, because they experienced that their operational knowledge was not being valued enough.

What also needs to be considered when implementing autonomous shipping in a port environment is ripple effects (Schroepfer et al., 2024). These are the effects arise, because autonomous ships do not operate in a vacuum and have indirect consequences on many people in the ecosystem. An example of this is a VTS operator having to communicate with an autonomous ship.

Saager, 2022 Discuss a possible future in which there is a combination of manual controlled ships and autonomous ships navigating in the port. They argue that vessel traffic management will become even more complex in this scenario. The same is stated by (Saager, 2022). In the port vessel traffic management is mostly done by VTS. They provide information, navigation and traffic organisation services to ships in the port (Barthelsson & Sagefjord, 2017). Relling et al., 2022 use participatory design to find ways in which VTS can contribute to a successful combination between autonomous and manual vessels in ports. This resulted in the following requirements: First, conventional traffic should be standardised and automated vessels should have a predefined route and the entire area needs to be fully covered by radar. They also suggest to assign time slots for departures and to have stricter clearances for departure. These clearances could have colours (like green or red) to indicate

traffic density to the remote operator (which is expected to be on shore). When the autonomous ship has departed, they should stick to a predetermined route and have a constant speed, unless there is a conflict. In this case, the ship should be able to come to a full stop. This will contribute to a role shift for VTS operators from real time problem solving to more tactical planning in advance.

3.4.7 Designing for human roles with autonomous ships

Veitch et al., 2024 Used interviews with skippers and designers of an autonomous ship to investigate how designers can integrate human collaboration with systems in their process. They found a mismatch between what designers assumed was appropriate and the actual preferences of skippers. This could be, because people on land do not fully understand what occurs on the water, making it challenging to implement new technologies effectively (Kristensen & Børsen, 2024). This is a problem because technology can only truly succeed if it aligns well with the people that do the work automation is trying to improve. By spending time with these people it is possible to understand their perceptions of their context and technology. Without this knowledge there is a risk of focusing too much on the technological artifact instead of the real world environment (Kristensen & Børsen, 2024). According to Kim and Schröder-Hinrichs, 2021 and Schroepfer et al., 2024 A way to deal with this lack of knowledge would be to look at why people throughout the entire system think new technology is needed. Early user involvement will also improve user acceptance (Schroepfer et al., 2024).

To include users, multiple methods are mentioned. Stolt and Joseph, 2023 use methods like future wheel workshops, semi structured interviews and scenario validation to design a voyage planning system for unmanned ships. (Kris-

tensen & Børsen, 2024) Use multi sided ethnography and semi structured interviews to understand the macro environment and system in which technology will be embedded. Relling et al., 2022 Use combinations of participatory design and system thinking to define the contribution of VTS to the combinations of manual and autonomous traffic in the port. Schroepfer et al., 2024 Use a combination of stakeholder mapping, ethnographic research and user participation in the design of robotic prototypes.

Despite the many possible methods, participatory design is challenging to realize in practice (Kristensen & Børsen, 2024). Three barriers to participatory design were identified in the maritime industry. The first barrier was the lack of clarity regarding who the users were: In practice, often only the customer or a very specific group was involved in the project. The second barrier was that technological feasibility was frequently the starting point, resulting in a focus on replacing operators rather than supporting them. The third barrier was funding, as funds often prioritized hard technical innovations and overlooked user needs. To overcome these barriers, Kristensen and Børsen, 2024 recommends involving users early in the design process, reorienting innovation to support users rather than replace them, and adjusting funding structures to promote greater user involvement.

3.5 Conclusion

The goal of this study was to understand what autonomous environments are, how they affect human work, and what methods already exist for designing for automation. I also wanted to understand the potential factors that could hinder its implementation, specifically in autonomous shipping environments. Furthermore, a scoping review was conducted to gain insight into existing knowledge on human roles and autonomous ships. A summary of the findings can be found in table 1.

From this research can be concluded that during the design process of autonomous technologies, the designer must be aware of the impact on their designs on workers and the broader context.

It is also important to move from automating as much as possible to a more critical on if automation would be desirable in the context, as automation does not simply substitutes human work, but changes the work.

There exist some frameworks and design patterns in which the human takes a central role.

When automation is adapted to a real world context, there are several factors that influence whether or not people accept the new technology. These factors are the perceived necessity, perceived risk and perceived benefits of the technology.

From the scoping review on literature related to human roles and autonomous ships can the following be concluded: First, multiple articles mention increased efficiency, and increased safety as the main benefits of autonomous ships, which

each lead to multiple sub-benefits, like decreased costs and increased sustainability.

Within the body of literature, the four levels of autonomous ships proposed by the IMO are often mentioned, ranging from ships with autonomous functions to fully autonomous ships. However, the desired level of automation is dependent on the context of use and the level of automation is expected to be adaptive. For complex and unpredictable environments like ports, a cooperative relationship between humans and ships with autonomous functions is desired over fully autonomous ships.

As autonomous ships become more widely implemented, the literature expects a shift from offshore to onshore work in which autonomous ships will be remote controlled or monitored from shore control centers. In this transition, operators work is expected to shift from an active role to a backup role. In this shift it is important to take some direct factors into account, like situational awareness, engagement and trust that need to be taken into account. If these factors are not managed well, undesirable effects like, job dissatisfaction and dangerous situations could arise. Besides direct factors, autonomous shipping also leads to ripple effects on its environment.

Multiple methods, like human-centered design and participatory design are mentioned to integrate human operators in the design process. To realize these methods effectively it is important to involve users early in the design process, reorient innovation to support users and to take into account ripple effects.

Category	Insights
Balancing automation and human work	- Automation changes the nature of work rather than simply substituting it. - There is too much focus on technological factors. - There's often a disconnect between designers and workers, resulting in technologies that are not serving workers' needs. - Workers should be actively involved in the design process of autonomous systems. This improves work quality, increases trust in the technology, and helps prevent implementation issues.
Existing design approaches for automation	There are frameworks that place humans at the center, such as the human-centered automation framework and design patterns for meaningful human control.
Automation acceptance	Acceptance of automation is influenced by the perceived necessity, risks, and benefits of the technology.
General insights on autonomous ships	- Efficiency and safety are often mentioned as key benefits of autonomous ships, leading to lower costs and increased sustainability. - The IMO defines four levels of automation. The desired level depends on context. In complex environments such as ports, collaboration between humans and autonomous systems is preferred.
Human work and autonomous ships	- Work is expected to shift from offshore to onshore, with roles moving from active operation to remote monitoring or backup support from control centers. - Key factors are situational awareness, engagement, and trust. If these are not properly addressed, dissatisfaction and unsafe situations may occur.
Design recommendations for implementing autonomous ships	- Apply human-centered and participatory design methods. - Involve users early in the process. - Support human roles instead of replacing them. - Consider both direct and indirect effects of automation.

Table 1: Key themes and insights related to automation and human work

3.6 Next steps

Previous research shows "automation pitfalls" that can result in harmful outcomes, including reduced job satisfaction. These pitfalls are: The false idea that automation substitutes human work, an overemphasis on technology, and a disconnect between designers and workers. To avoid the pitfalls mentioned above, workers should be included early on, collaboration with workers should be prioritised over the

substitution of workers and the impact of the technology on the broader context and social relations need to be considered. In order to get more insight into the broader context of automation, systems thinking methods could be applied. Human-centered design methods, like observations and interviews could be used to gain more insight into workers needs. In the next chapter, a suggested approach to proactively avoid the pitfalls of automation will be presented.

4 Project approach

4.1 Introduction

Previous research indicates that in automation projects, the interests of employees and the impact on the broader ecosystem need to be considered. Given the lack of a concrete approach on how to transform human work, this project will take a structured approach using human-centered and system thinking methods.

To prevent the common pitfalls of automation, this research will use human-centered design to ensure that workers' perspectives shape the technology from the start. This should avoid the misconception that automation simply replaces hu-

man work and close the worker-designer gap. Additionally, methods from system thinking will be applied to map the broader ecosystem and information flows, ensuring that automation integrates into the broader context and work structures.

Combining these methods at the early stages of an automation project should result in a more human-centered transition to a more automated workspace.

In this chapter, I will dive deeper into the approach of this project and the steps it entails. An overview of this step-by-step plan is shown in Figure 15.

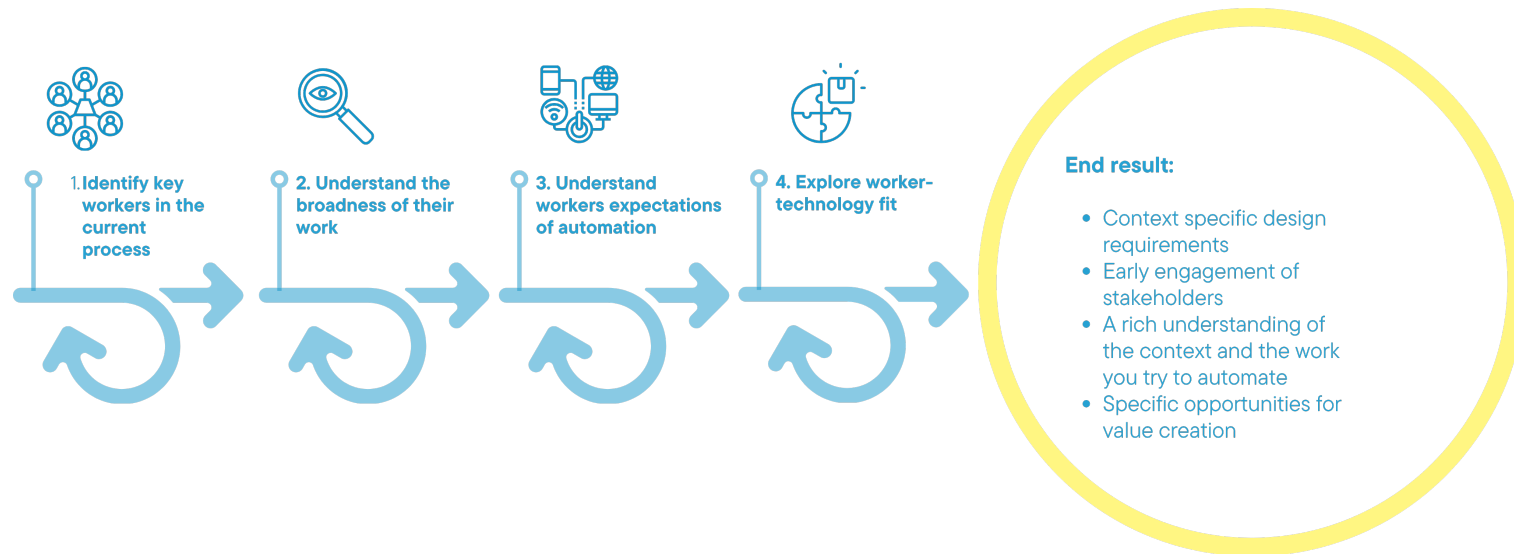


Figure 15: Steps in project approach

First, I will map the actors in the ecosystem and study how information is exchanged. Next, I will conduct contextual research to fully understand the broadness of human work. Following this, I will design fictional scenarios and use them in interviews to gain insights into workers' expectations of an USV within their work environment.

Finally, using the value proposition canvas, I will determine how an USV can create value for workers. Based on this research, I will design a scenario and provide recommendations on the steps needed to make this scenario operational. These recommendations will incorporate insights from the contextual research and interviews. It is important that after each step, the results are validated.

By following this structured approach, this research will contribute to developing a concrete approach for a more human-centered transition to an automated workplace.

4.2 Identify workers in the current process

The first step involves identifying the key actors in the current process. The goal is to map out individuals who play a central role in the process being automated. These individuals will likely experience direct consequences from automation in their daily work and may need to collaborate closely with the new technology.

While a primary end-user often comes to mind first, it is crucial to also identify individuals who play a more indirect role in the process but may not be immediately obvious, such as those who support the process behind the scenes. These individuals will also be affected by the transition and possess valuable, experience-based knowledge about the context in which automation will be introduced.

This can be achieved by mapping the system. For example, a stakeholder map can be created to visualize all the people involved in the current process. Next, connections between stakeholders can be drawn using arrows to indicate

how information flows between them, forming an social network map (Haythornthwaite, 1996). This visualization helps clarify how the process is embedded within a larger network and enables the early identification of potential (social) ripple effects of automation. By analyzing social networks, it becomes possible to determine which actors are key to the process.

4.3 Understand the broadness of their work

After identifying key actors, it is important to immerse in their work and experience the context firsthand. The aim of this step is to develop a deep understanding of the full broadness actors' work within the given context. This could be achieved by shadowing these individuals for a day and making detailed observations. These observations can be documented by creating a journey map of their workday.

4.4 Understand workers expectations of automation

The objective of this step is to define initial requirements for an USV and gain insight into how key actors anticipate that autonomous technology will impact their work.

This can be achieved through individual interviews. To enable a realistic discussion on automation within the specific context, speculative design scenarios based on current trends and technologies should be created. These scenarios help maintain a focus on human-machine collaboration, which is inevitable in complex and unstructured environments such as ports. Preparing speculative future scenarios in advance facilitates discussion by providing visual reference points, allowing participants to express their expectations, concerns, and needs regarding automation more easily (Zhu et al., 2024).

4.5 Explore worker-technology fit

The goal of this step is to identify how automation can create value for workers. To achieve this, the value proposition canvas can be used for each key actor (Strategyzer, 2025). This framework consists of a user side and a product side. On the user side, it is important to document the tasks they perform, the challenges they face in their work, and their goals. On the product side, the proposed solution should be described, along with how it addresses these challenges through pain relievers and how it enhances their work through gain creators. The aim is to align these elements as closely as possible with the needs and concerns of each key actor. Additionally, this step includes visualizing how an USV could

potentially diminish value for certain actors and identifying strategies to mitigate these negative effects.

4.6 Next steps

In the remainder of the report, these steps will be applied to the case of hydrographic surveying in the port to assess the practical feasibility of the approach. To demonstrate a tangible outcome, a potential future scenario will be proposed based on insights from the value proposition canvas and design requirements. Alongside this, a high-level pilot roadmap will be provided to support the implementation of the proposed scenario.

**5 Identify key workers
in the current process
and understand the
breadth of their
work**

5.1 Introduction

In this chapter, step one and step two from the guidelines that were presented in the project approach will be applied to the case study in the Port. First, a social network map will be created, after this context research will be conducted.

Within the current context of the case study it is still unclear whom are involved in the broader context of hydrographic surveying. The goals of this study are to gain a deep understanding of the current operations and the broader system in which new technology will be embedded. Having a deep understanding of these processes will enable me to gain empathy as a designer, which is important to understand operator needs (Meyer et al., 2016).

To achieve this, a social network map will be created. From this map, the most important actors will be identified and a context study will be conducted with these actors.

5.2 Method and data collection

To fully understand the current hydrographic survey operations, I am interested in gaining insights from various groups involved in hydrographic surveying. Therefore, it was necessary to understand the broader ecosystem in which hydrographic survey work takes place. Multi-site ethnography is a suited method for this, because it makes it possible to understand how different groups of people are related to a specific phenomenon (Marcus, 1995) (Hannerz, 2003). Before conducting the research, a document analysis was done to gain a deeper understanding on hydrographic surveying. The findings from this can be found in Appendix B. Based on informal conversations with port employees, I set up an initial stakeholder map (Appendix A) and concluded that VTS operators, skippers and hydrographic surveyors would be key perspectives to include. Based on this I visited a VTS center and two survey ships. For each visit, I informed the oper-

ators about my research and that I was part of the innovation department as an intern and did my research for the Delft University of Technology. I asked them permission to take notes (physical notes with timestamps) and photos and videos and ensured that the data would be anonymised and that participation is completely voluntary. My first visit was at a VTS center. I first had informal conversations and got a brief tour of the office. When I started observations with a VTS operator. I told them to act as if I was not present. Occasionally, I had chats with them during the process or asked him to explain some actions he was performing on the screen. I ended up spending 6 hours at the VTS office. The observations with the skipper and hydrographic surveyor took place on a different day. First I joined a ship that was going to do inspections of port assets. I stayed on this ship for 3 hours in which I observed the skipper and the inspectors work. After that, I was invited to join the hydrographic survey ship. The ship was operated by a skipper and a surveyor. I stayed on this ship for 3 hours and did observations and informal chats. I explained that I planned to make an journey map from my observations and that I wanted to validate my findings with them.

5.3 Data analysis

After the site visits, I digitalized the notes and data in a spreadsheet for further analysis. From this raw data, insights were written down on notes in Miro. After all insights were written down, they have been clustered to create themes. This process is shown in Figure 16.

Step 1: All insights were put in Miro

Step 2: The Insights from each group were clustered based on meaning

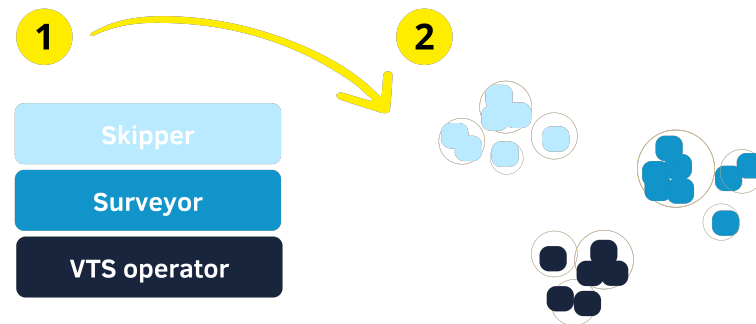


Figure 16: High level overview of the data analysis

The data gathered during the site visits was also used to create journey maps. Journey maps are a tool to understand the total user experience. The journey map was made according to the guidelines presented by (y Michael G. Luchs,

2015). y Michael G. Luchs, 2015 Divide the journey mapping process in three stages. The first stage is about developing a deep understanding of your users. The second step is to create a visual map of the current user experience. This map also consists information flows between different users. The next step is to identify pain points in the current situation based on the journey map. These pain points were identified through observations and non verbal gestures like signs.

To validate if my findings reflected the experience of users, I have shown the journey maps and findings to participants for feedback. This feedback has been used to improve the result section.

5.4 Results

In this section, the results of the context research are presented. An social network map was made of the ecosystem of hydrographic survey work. After that, I will provide more in depth insights and journey maps for the tasks of skippers, surveyors and VTS-operators.

5.4.1 The broader ecosystem of surveying

Based on the findings from the observations, an ecosystem social network map of the current hydrographic operations was created. This map gives an overview of the broader ecosystem of hydrographic survey work which will allow for a better understanding of how each role is interconnected (Haythornthwaite, 1996). In this information flow, a distinction is made between parties on land and on water, as shown in the Figure 17.

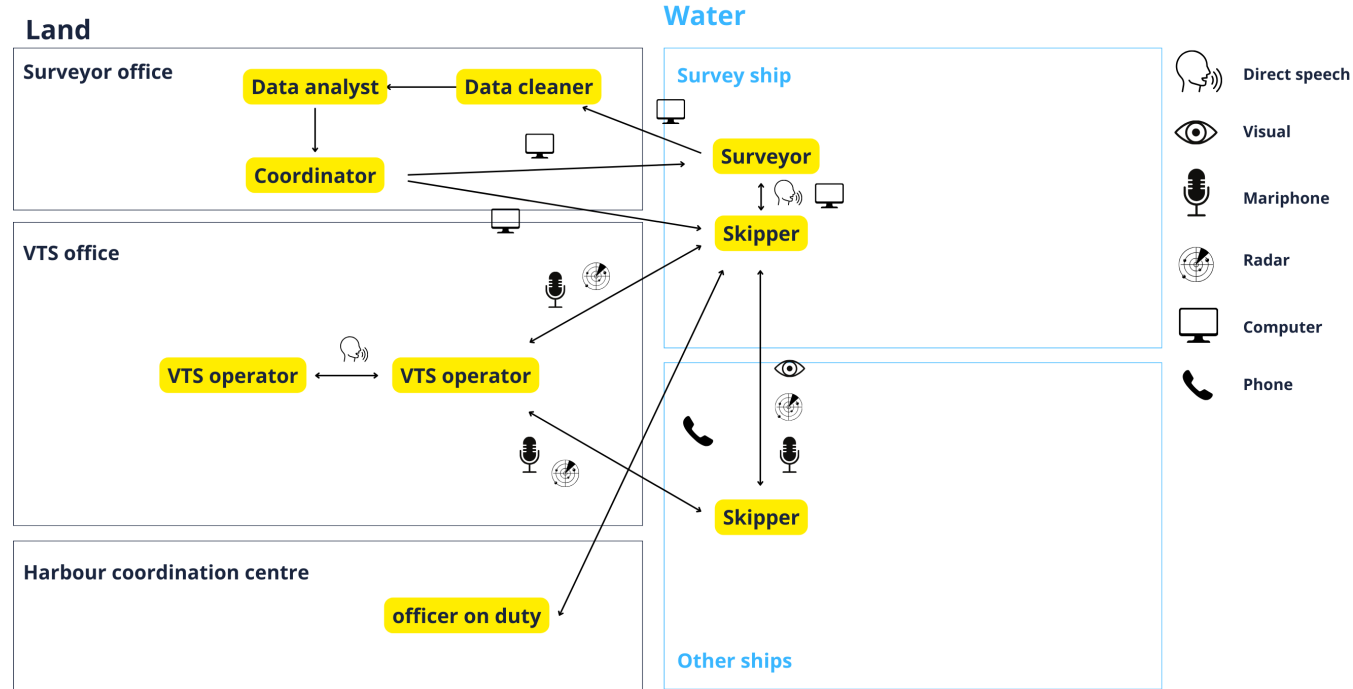


Figure 17: Information flow of hydrographic survey operations

Many port employees from different positions make effective surveying and safe navigation in the port possible. When part of the work would become automated, this will have an effect on the broader ecosystem. It is therefore important to not just consider the hydrographic surveyors working on the survey vessel, but also operators from the vessel traffic control center. Their work will also change as a result of autonomous shipping and their needs need to be considered as much as surveyors.

During the survey operations, meaning the ship is taking measurements on the water and sailing to new locations, the connections between the surveyor and the skipper are strong and consist of direct speech and communication through the survey program. The skipper is in contact with the VTS operator through VHF during special manoeuvres and when there is high traffic density. The VTS operator is able to see the survey ship on his radar as well. The VTS operator is in the same way in contact with other skippers

in the sector and the skipper of the survey vessel overhears these communications through VHF. The skipper is also visually looking out for other vessels during the operations by either looking directly out of the window for approaching vessels or through looking at the radar systems.

5.4.2 VTS operator

A VTS (Vessel Traffic Service) operator oversees all vessel traffic within the port area from the traffic control center. They do this by communicating via the radio. The VTS operator can monitor ships in their sector through camera footage, RADAR technology, and AIS systems. Based on the vessels' positions, speeds, and stated destinations, the operator assesses whether these vessels might come into potential conflict with each other. The VTS operator then uses the radio to provide relevant traffic information to the ships. This communication is done verbally and can be in Dutch or English. All vessels in the sector can hear the conversation between the VTS operator and any ship. It's important to note that the VTS operator has an advisory role and does not issue commands to the vessels. The skipper is ultimately responsible for the ship and knows it best to make the right decision based on the provided information.

The port area is divided into different sectors, and each sector is managed by a VTS operator. After an hour in a sector, operators switch to another sector. The schedule also includes morning, afternoon, and evening shifts.

During a shift, a VTS operator is constantly in contact with vessel skippers based on the information displayed on the screen. A picture of these screens was taken during the observations is shown in Figure 18.



Figure 18: Overview of VTS workspace

The screen shows a map of the sector with radar images (orange spots) and AIS information (names of the vessels). When you click on a vessel with an automatic identification system (AIS), it's possible to see the vessel's speed and destination. If a vessel is communicating via VHF, a red circle lights up around the vessel on the map. The participants explained that it is important that there is not too much information on the screen, as it can become cluttered and hard to keep oversight. Some vessels may not have AIS and only appear as orange dots on the map. Due to the high volume of vessel traffic, a radar disturbance, or an AIS signal issue, the VTS operator may sometimes lose track of vessels. To maintain clarity, large vessels are marked in green on the screen, and vessels performing maintenance, such as survey vessels, are marked in blue during maintenance. Additionally, the VTS operator can use external sites, such as VesselFinder (VesselFinder, n.d.) or a live stream of the sector, to view vessels in case of an AIS or radar signal disruption. Furthermore, the information about a vessel's destination is often outdated or incomplete, as vessels frequently change destinations. For example, during observa-

tions, a vessel called to inform the VTS operator that it had changed its destination because it needed to drop someone off. Knowing a vessel's destination is crucial for assessing potential collisions and future traffic situations. Therefore, VTS operators most frequently ask about destinations. The following quote illustrates this:

"For us, the most frequently asked question is: "Sir, what is your destination?"

The VTS operator remembers the destination or writes it down with pen and paper to keep track. These notes are also used during the handover between sectors. Additionally, observations showed that a ship's speed is important. To obtain this information, the operator constantly clicks on ships on the screen to view their speed, name, and destination. The VTS operator must convert the information they see on the screen into verbal information that is crucial for skippers to navigate through traffic. This is illustrated by the following quote:

"I have to put everything I see happening on the screen into words."

It is also important that the skipper receives the right amount of information, not too much. This is something that comes with more experience.

"Sometimes you have to put yourself in the skippers shoes. The more experience you have, the less information you provide."

In addition to converting visual information from the screen into useful information for a skipper, there are also skipper-specific challenges the VTS operator must deal with. For instance, there may be a language barrier if the skipper is not proficient in English or Dutch, which can lead to misunderstandings. This is illustrated in the following quote:

"Sometimes, you've told a story in Dutch, and then there's one German who hasn't heard it."

Skippers may also hesitate to admit they haven't fully understood an instruction, to avoid losing face with other Skippers in the sector who are listening on VHF. Further, a skipper may not respond to calls on VHF at all, or may disregard advice, preferring to follow their own plan.

Additionally, skippers may not be up to date on the current traffic situation or may provide incomplete information to the VTS operator (for example, not mentioning their destination). As a result, the VTS operator must constantly check that information has been understood correctly and ensure that everyone is up to date with the current plan. This is done by paying close attention to the nuances and manner in which someone responds to the information, as shown in the quote below:

"We want to know that someone has understood it; you only get that confirmation by hearing someone's voice. Sometimes, you can tell from someone's voice that they didn't understand what you meant."

The work of VTS operators requires experience and knowledge of location-specific factors such as weather conditions, water flow, and traffic patterns. This is demonstrated by the following quotes spoken by VTS operators during the visit to a VTS center:

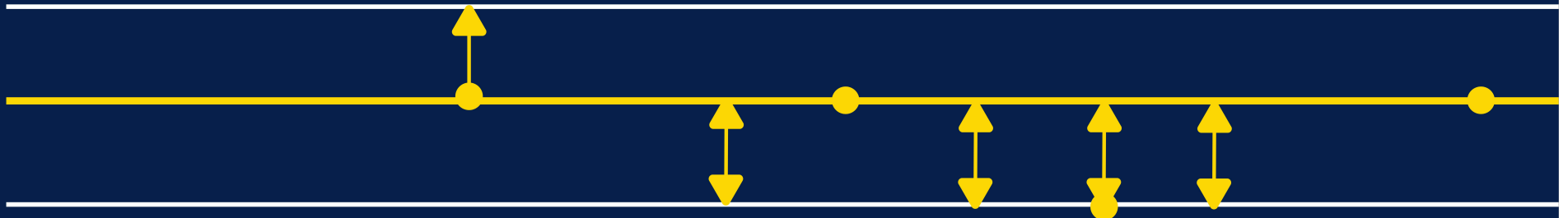
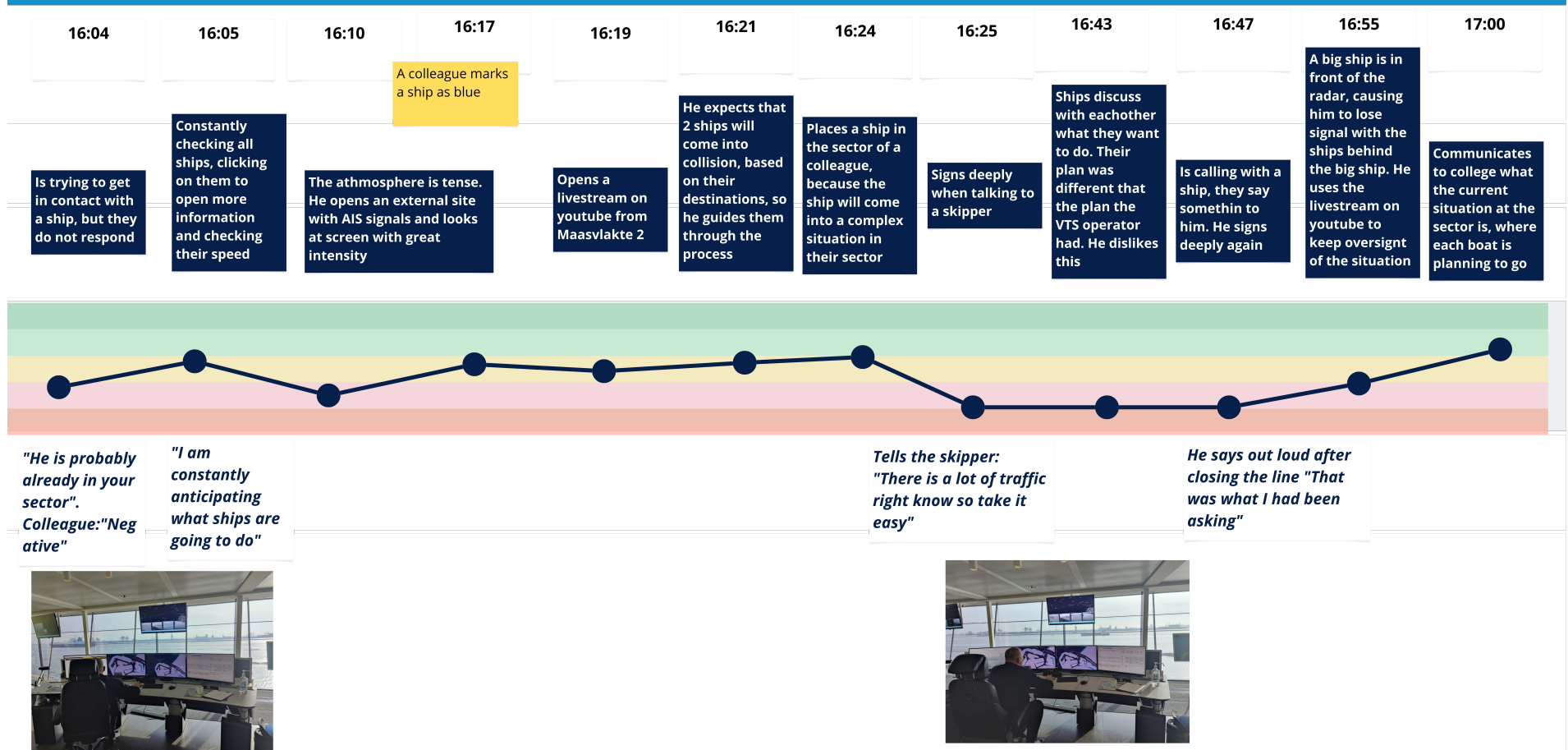
"The external factors like wind, weather and water flow make it difficult. "I am used to the patterns and can better anticipate where ships are about to go; the anticipating and planning ahead makes it difficult."

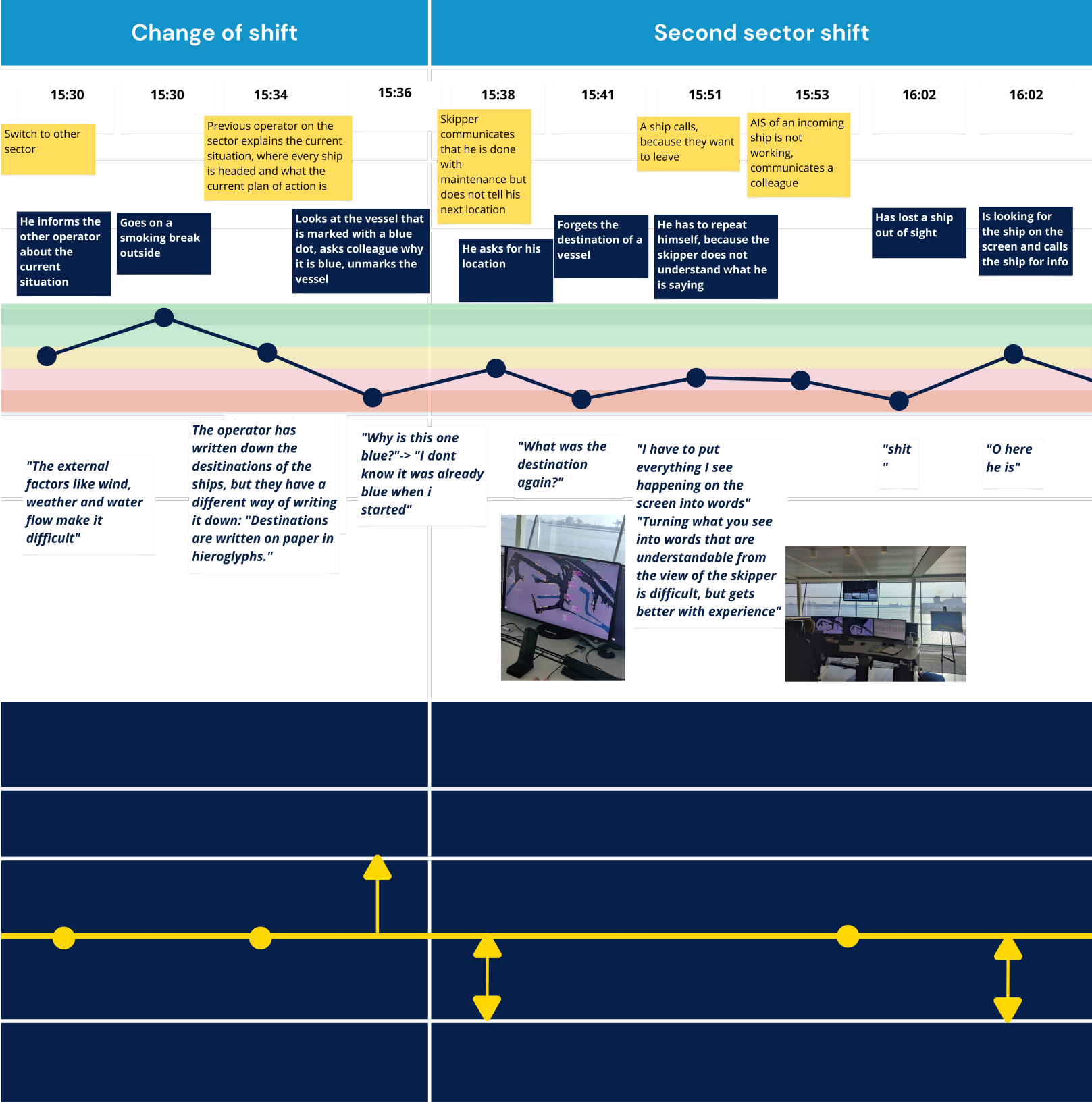
In addition to guiding traffic, a VTS operator also handles tasks related to providing extra information. An example observed during the observations is giving information about currents to skippers or warning ships to be cautious around tugboats.

User journey Based on the observations, a user journey of a VTS operators shift is made. This user journey can be seen in Figure 5.

	Start of shift	First sector shift										
Timestamp	14:40	14:50	14:58	15:06	15:07	15:12	15:14	15:15	15:16	15:19	15:20	15:27
Context	2 ships are crossing and inform them about their situation		Is being contacted by the maintenance vessel that they have finished maintenance	Is being called by a ship about their destination	Is being called by a ship telling that they change their destination to drop someone off	Is being contacted by a ship	Is being called by another ship that wants to know how strong the current is	If a ship is done speaking through the Mariphone, A red dot lights up around the ship on the screen		Colleague lets him know that a ship is about to enter his sector. The ship is not communicating well		Colleague tells that in a specific ship there is an english man that does not listen
Actions	Is being told by colleague what the current situation at the sector is	Is being called through mariphone	He unmarks the ship (takes away blue mark)	Writes the ships name and destination down on paper to remember their destination and their plan	Responds that he has understood	He realises the ship has old, incorrect information and corrects them	Looks up the current and provides information	Notifies an unidentified ship on the radar	Loses the ship out of sight and searches for it. After he finds the ship he calls it to give an update	Constantly calling with ships while looking on screen, often clicking on the ships to see their speed, name and destination		Tries to call the ship, but gets no response back
Emotions												
Quote		'I wonder what language he will speak'	"Survey vessels are labelled with blue when they are doing maintenance to keep them visible"	'If a ship goes around the corner the AIS signal is gone'	'You have many small ships sailing here. Even for bringing water to bigger ships'	'if you give to much information it can be dangerous'	"Sector rosenburg, Over"	"Sometimes you lose the dots (ships) out of sight"	"Oehoe procedure" Is telling eachother that a ship is about to enter your sector"	"Each sector has specific difficulties and features"		
Picture												
Information flow												

Second sector shift





From the journey map, it can be observed that the handover between sectors occurs verbally between colleagues, with written destinations of ships passed along. The handover is quick and takes less than three minutes. During the shift, the VTS operator is in constant contact with ships in the sector and occasionally with colleagues to share cross-sector information or report abnormalities. Notably, the operator is constantly clicking on ships on the map to view their destinations and speeds. Based on this information, the operator predicts whether ships might potentially come into conflict. The VTS operator uses pen and paper to note down ships and their destinations.

The emotion row represents interpretations of the operator's emotions based on observations. Negative emotions appeared to arise in the following situations:

- When a ship had incorrect information that needed correction
- When the operator lost track of ships on the screen and had to search for them
- When the operator forgot a ship's destination and had to ask again
- When there was confusion about why a ship was marked blue in the system
- When ships did not respond
- During hectic situations in the sector
- When a ship misunderstood the operator

The blue bar represents the information flow between VTS operators and ships. It shows that the VTS operator is constantly in contact with ships but also consults with colleagues.

Pain points for the VTS operator seem to happen when they lose control over the situation, this happens when ships are lost out of sight, or when skippers do not follow instructions.

5.4.3 Skipper

The skipper steers the survey vessel. Along with the skipper, the surveyor is also present on the survey vessel. The skipper navigates based on the instructions and planning provided by the surveyor, who has an overview of what needs to be measured that day. To navigate, the skipper uses digital nautical charts and radar which is shown in Figure 19.



Figure 19: Overview of Skipper workspace

The port map shows different sections that need to be coloured in during the survey work. It is also possible that the surveyor, while calibrating equipment, draws a line for the skipper to follow. The skipper sees this line on their screen, along with the ship's position. The skippers describe steering the vessel as colouring in a colouring book or playing a computer game. This is illustrated by the following quote:

"It's just like a computer game where you have to colour in, but it's reality and there are ships coming toward you."

The skipper must ensure that there is a 10 percent overlap with the previous route during the survey. Therefore, the navigation path cannot deviate, and the ship must follow the exact route. A skipper compares this to being channel-bound, as seen in the following quote:

"Some ships are channel-bound (cannot deviate from their route due to draft restrictions), I'm actually channel-bound too, but then to my map."

When there is strong current, the skipper steers the ship at an angle to maintain a straight path. Since the route must be followed as precisely as possible, the ship cannot remain stationary, as it may drift off course. The skipper knows the environment and ship well enough to decide on a proper survey route. Deviating from the route could result in the ship needing to turn around and retrace the line a second time. What makes surveying complicated is the other ship traffic in the port, which has priority over survey vessels. Since survey vessels must cover the surface of an entire area, they often have to sail against the traffic. This is illustrated by the following quote:

"Here (while surveying) you sail on differing courses, you're actually always in everyone's way."

A collision with another ship could suddenly interrupt a measurement. Afterward, the survey must wait until the mea-

surement can be taken again once the water has settled, because propeller wash interferes with measurements, as stated in the following quote:

"Sometimes you have to wait until it's calm enough to survey."

This makes skippers extra alert to approaching vessels. A measurement is often only started when it seems calm. Skippers sometimes say they don't mind the traffic, but at times find it intense, as expressed in the following quote:

"Surveying work is very intense with ships around you. Especially at a busy intersection."

Traffic density seems to depend on specific areas, like the Botlek or other places where many waterways cross, which can become very crowded with ships. Furthermore, during their work, skippers may encounter misunderstandings from the VTS operator, as shown in the following quote:

"The VTS operators sometimes don't understand why you don't move aside and can get angry."

Another skipper mentions that lately, the VTS has been more considerate of survey vessels.

User journey Based on the observations, a user journey of a skippers shift is made. This user journey can be seen in Figure 5.

Surveying

Timestamp

11:11

11:12

11:13

11:17

11:20

11:27

11:31

11:33

11:37

11:38

11:38

Context

There is a strong current

An inland ship is headed towards them

VTS calls over mariphone to ask for their destination

Actions

Looks around to check for incoming traffic

Starts to drive over the black line on the screen

Breaks the survey cycle prematurely

Cycles the ship around to start over

Starts to drive over the black line on the screen again, multiple rounds

Breaks the survey cycle to make way for the inland ship

Waits till the inland vessel has passed and the water is calm again

Answers the VTS who is interested in their future destination

Looks around to check for incoming traffic

Starts to drive over the black line on the screen again.

Turns the vessel around after succesfully following the line.

Emotions

Quote

"It looks calm"

"I'm stopping it because I wasn't straight on the line."

"Damn, damn it!" "There's an inland vessel coming, so I have to stop."

"I think we can give it another try."

"We already did this one, right?"

Picture



Information flow



Informs that he is about to start

Informs that he is starting over and cycling the ship around

Informs that he is breaking off the survey

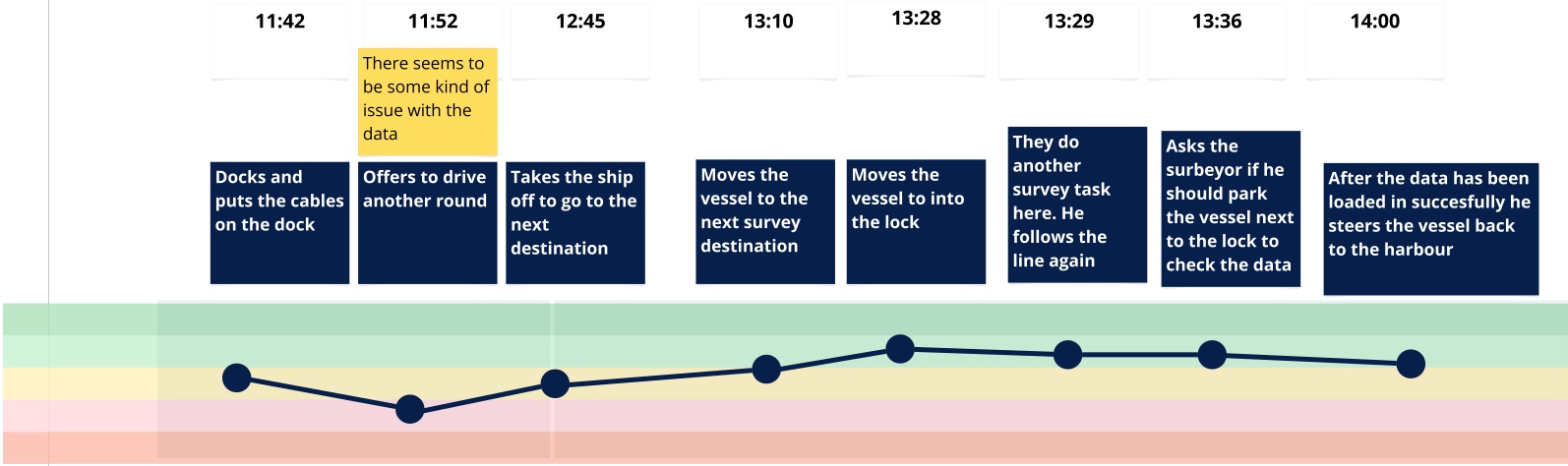
Informs that he is about to start

Sees an inland ship approaching

Communicates next destination to VTS

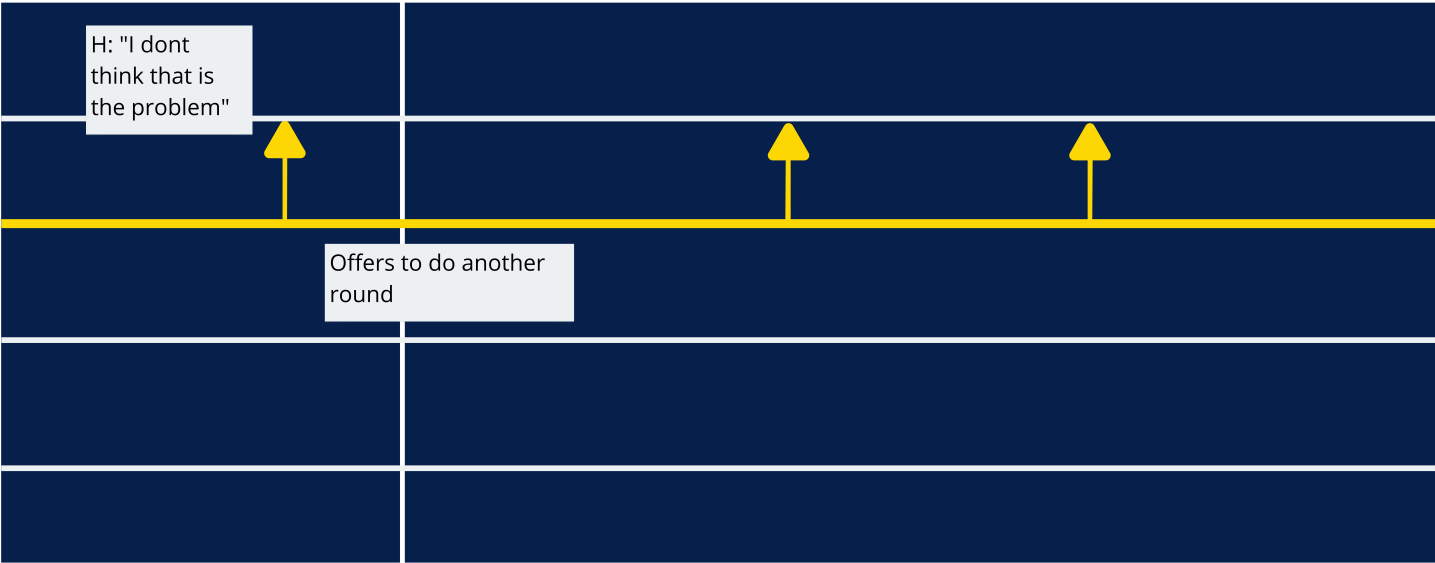
Checks with surveyor if all work is completed

At dock	Travel and next survey spot						
---------	-----------------------------	--	--	--	--	--	--



"We can still do some extra back-and-forth passes. The first line is quite off due to the current."

"Shall I leave him at the lock for a moment to let you load in the data?"



From the user journey can be seen that the skipper is highly attentive to passing maritime traffic and determines when the situation is suitable to start a measurement (11:11). The skipper can also decide to abort a measurement based on incoming maritime traffic (11:27). When a ship passes, the skipper must wait until the water is calm again and there is no incoming traffic. During the observations, this waiting period totalled 11 minutes (occurring between 11:27 and 11:38). During this time, the skipper maintained contact with the VTS operator and reported their destinations. Additionally, the skipper has knowledge of the quality of the measurements and can recognize when a measurement does not meet the required standards. This is evident when the skipper offered to redo a section because the line had been followed inaccurately (11:13). This was communicated verbally to the surveyor by the skipper. After a measurement is completed, the vessel must remain at the location until the surveyor has checked the data. If there is an issue with the data, the measurement would need to be redone. During calibration, the skipper docked the vessel at 11:42. An issue occurred during the data import (handled by the surveyor) and calibration, resulting in the vessel being docked for a total of one hour. The vessel departed for the next measurement destination at 12:45. After performing the measurement (to calibrate the depth), the skipper stopped the vessel to allow the surveyor to load the data. This occurred between 13:36 and 13:46. Once the surveyor communicated that the measurement was successful, the skipper navigated the vessel back to the quay. The emotions row represents an interpretation of the emotions the skipper appeared to experience during the observations. Signs of frustration were observed when a measurement had to be aborted due to an incoming inland vessel. The blue row represents the communication between the skipper and the surveyor. During the measurements, the skipper and surveyor closely collaborated. The surveyor communicated about the measure-

ments, while the skipper focused on the external environment and precisely manoeuvring the vessel.

5.4.4 Surveyor

The surveyor performs the measurements using a laser, single beam, or multibeam. For this, he is present on the vessel and has a desk with several computers on the ship. The surveyor is responsible for all measurement activities and validation of the measurement data and strives to execute them as accurately as possible, as illustrated by the following quote: *"I do everything as thoroughly and accurately as possible."* To achieve this, he works closely with the skipper, who navigates the vessel during the measurements. During the measurement, the results appear live on the screen. For a normal multibeam measurement, two maps are used that can be overlayed on top of each other. One map shows the current measurement, and the other shows the previous measurements. This allows for quick comparison of the differences between the two measurements. Surveying is delicate work, and various factors, such as water temperature and density, influence the variation in speed of sound, and thus also the measurement results. For example, a difference in water temperature disturbs the measurement because a different sound profile needs to be used for cold water compared to warm water. The settings also need to be adjusted depending on whether the measurement is in fresh or saltwater (due to different densities), and areas with heavy silt cannot be measured. All these factors are situation- and area-specific and require knowledge and experience to manage.

User journey Based on the observations, a user journey of a surveyors shift is made. This user journey can be seen in Figure 5.

Surveying

Timestamp

11:12	11:13	11:21	11:23	11:27	11:38	11:41	11:41
-------	-------	-------	-------	-------	-------	-------	-------

Context

Writes down values on paper and prepares for the measurement

Checks scan while surveying

Draws a new black line on the screen

Draws a new black line on the screen

Checks scan while surveying

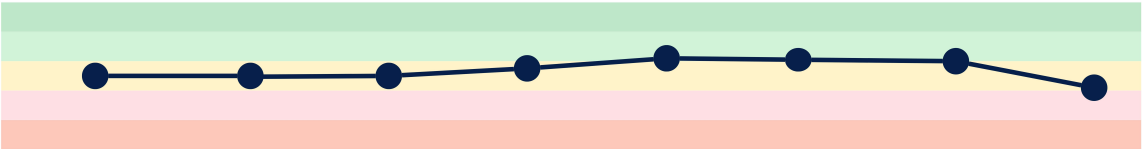
Looks at the measurement data on his computer

Writes down SVP values on paper to put in the calibration software

Turns data into a specific file format to transfer it to the calibration software

Actions

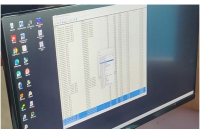
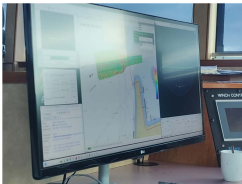
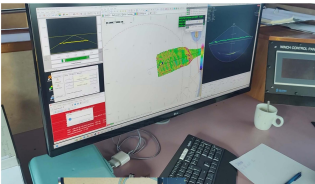
Emotions



Quote

"I am going to check if I have something useful."

Picture



Information flow

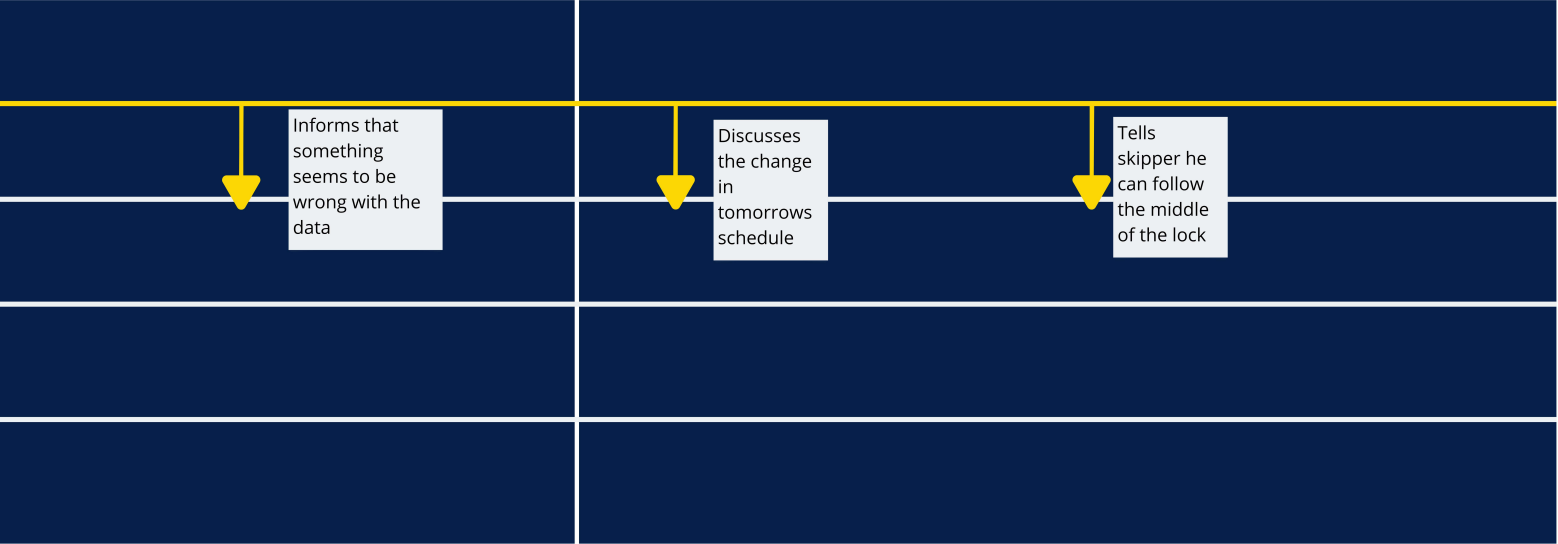
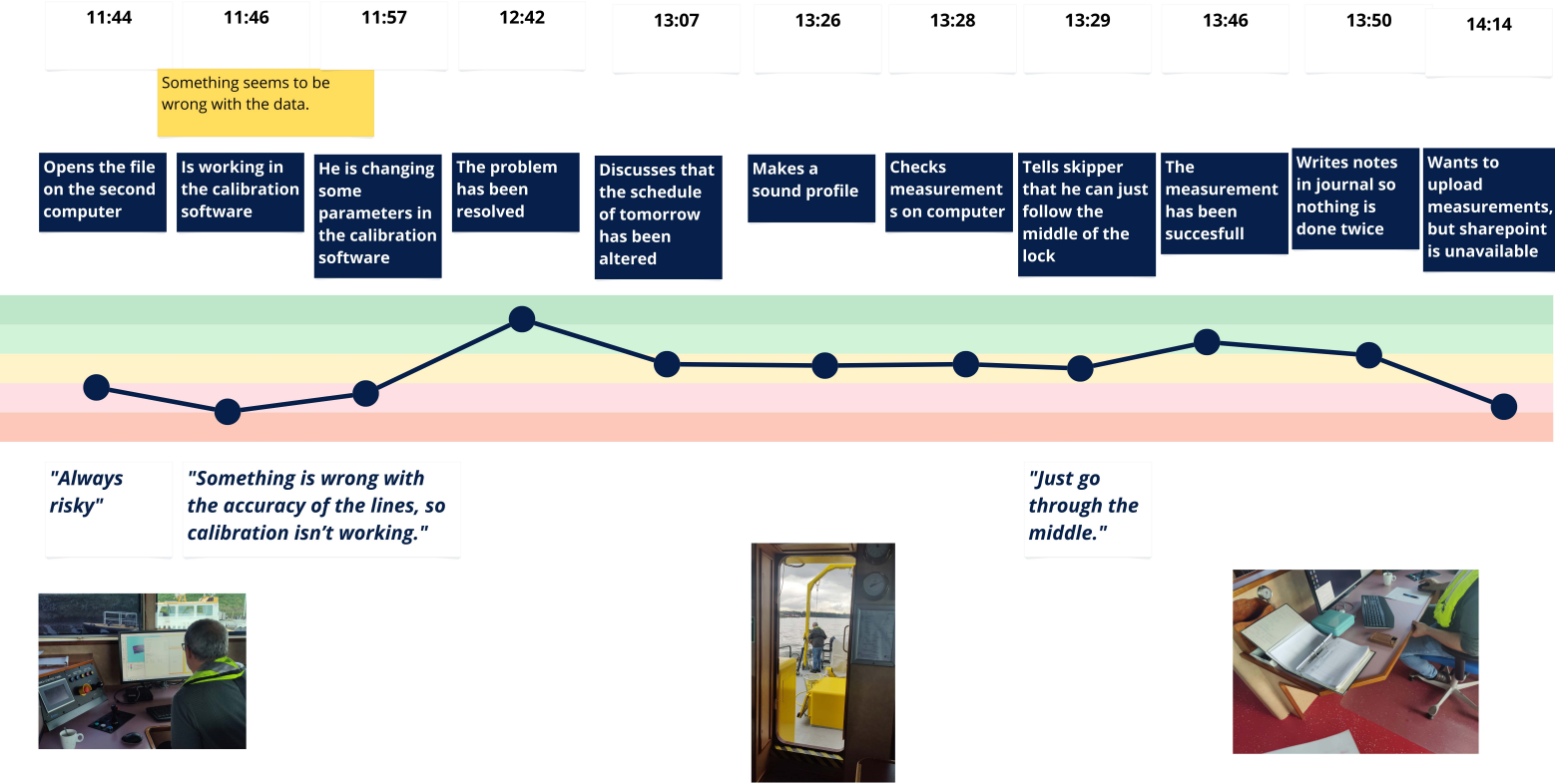
Surveyor
Skipper
VTS
Other ship

Draws line that skipper can follow

Draws line that skipper can follow

At dock

Travel and next survey spot



From the journey map, it is evident that the surveyor is focused on measurement data and setting up the equipment for a measurement. During calibration, the surveyor also drew a black line on the screen, which the skipper could follow via their own screen. While calibrating, the surveyor monitored the live measurement results on the screen. After the measurement was completed, the surveyor began processing the data. For calibration, this included transferring the data to another computer, which was done using an external hard drive. Upon opening the data, the surveyor remarked, "Always risky." It turned out there was an issue with the data that needed to be resolved in the software.

The entire process of transferring and calibrating the data took place while the vessel was docked, between 11:38 and 12:42. Following this, the vessel proceeded to the next measurement location. During transit, the surveyor created a sound profile of the water and reviewed the data. During the measurement, the surveyor once again monitored the live data on the screen. Afterward, the surveyor reviewed the data and made a note of it in the physical logbook. This logbook is maintained to avoid unnecessary repeat measurements of locations. Finally, the surveyor attempted to upload the data to Sharepoint, but this was challenging as Sharepoint was unresponsive.

The emotion row reflects the interpretation of emotions the surveyor appeared to experience during the process. Negative emotions seemed to occur when data was incorrect or when encountering software issues, such as at 14:14, when

Sharepoint was not functioning.

The dark blue bar represents the communication between the surveyor and other stakeholders. The surveyor communicated with the skipper but was not involved with other traffic or the VTS operator. That responsibility seemed to rest entirely with the skipper.

5.5 Conclusion

The goal of this study was to gain a deep understanding of the current operations and the broader system in which new technology will be embedded. In order to gain these insights, observations were conducted with multiple stakeholders (surveyors, skippers and VTS operators) that are involved with hydrographic survey operations in the port.

Based on these observations, social network map of the broader ecosystem in which hydrographic survey operations take place was created. In this ecosystem, the skipper and surveyor have verbal communication with each other and communication through the interface of the survey software. The skipper sees other ships on the radar, navigational maps and through visual sight. He also hears other skippers talk through VHF channel, but does not communicate directly with the other ships. Communication about incoming traffic, destinations and special manoeuvres is done through the VTS operator of the sector.

An overview of the findings from the observations can be found in table 2

Role	General description of role	Pain points	Quotes
VTS Operator	Monitors and manages vessel traffic from the control center using AIS, radar, cameras, and live communication via VHF. Provides real-time, traffic information to skippers based on ship positions, speed, and destination. Tracks vessel info manually and digitally, rotates between sectors every hour, and communicates cross-sector with colleagues.	• Loss of vessel tracking due to radar or AIS issues • Skippers not responding, ignoring advice, or providing incomplete information • Overload of information on screens • Language barriers with international skippers • Miscommunication or lack of confirmation of understanding • High workload in hectic traffic situations • Forgetting the destinations of ships	• “I have to put everything I see happening on the screen into words.” • “You can tell from someone’s voice that they didn’t understand what you meant.” • “I am used to the patterns and can better anticipate where ships are about to go; the anticipating and planning ahead makes it difficult.”
Skipper	Navigates the survey vessel using radar and digital charts. Follows precise routes planned by the surveyor, ensuring overlap and data quality. Constantly adjusts for water flow and nearby traffic. Decides when to start or pause measurement depending on traffic. Communicates with VTS and surveyor.	• High traffic intensity and sailing against traffic • Survey work interruption due to passing ships or propeller wash • Frustration when misunderstood by VTS operators • Waiting times to resume surveying	• “It’s just like a computer game where you have to colour in, but it’s reality and there are ships coming toward you.” • “Sometimes you have to wait until it’s calm enough to survey.” • “Surveying work is very intense with ships around you. Especially at a busy intersection.” • “Here (while surveying) you sail on differing courses, you’re actually always in everyone’s way.”
Surveyor	Conducts and validates measurements on board using multibeam, single beam, or laser equipment. Sets up calibration, configures software based on temperature, salinity, and silt. Monitors and compares live data to previous surveys. Responsible for post-processing and uploading data. Closely collaborates with the skipper.	• Measurement errors due to environmental conditions • Technical/calibration issues • Frustration with software problems or failed data uploads • Sharepoint unresponsiveness	• “I do everything as thoroughly and accurately as possible.” • “Always risky.” (about data transfer)

Table 2: Overview of insights

VTS operators are constantly anticipating on situations in which ships could come into conflict. In order to be able to predict the situation properly, the VTS operator needs to have reliable information on the destination of each ship and the confirmation from skippers that they have understood his instructions. The VTS operator is in contact with the skipper through VHF. Survey vessels are also marked as blue to not lose them out of sight.

The skipper of the survey vessel is responsible for navigation and complete coverage of the area that is to be surveyed. Because survey ships sail against the usual flow of traffic, it is important to stay alert for upcoming ships. If a ship is approaching, the survey work must be broken of and continued when the water is calm again.

The skipper is working closely together with the surveyor, which is present at the same ship. The surveyor is responsible for the quality of the measurements and decides what parts of the port are measured when during the week, according to the ship planning. The surveyor is also responsible for uploading the measurements to Sharepoint.

5.6 Limitations

It should be noted that due to time constraints, not every stakeholder in the ecosystem, like managers and data an-

alysts could be observed. Therefore the focus was on the three most prevalent stakeholders in the system: the VTS operator, skipper and surveyor.

What should also be taken into account is that only one shift of each stakeholder was observed, which leads to a single point view of their work. For example, observations with the surveyor and skipper were held when they were calibrating the multibeam, which is a specific task that is only done once every three months. Besides depth measurements, there are many other types of work, like silt measurements that are carried out by the surveyor. This should be taken into account when using the journey maps for further research.

5.7 Next steps

After this research, I have gained insight into the key actors involved in hydrographic survey operations in the port, namely VTS operators, surveyors, and skippers. I have also developed a broader understanding of their work. However, I also want to explore their attitudes and expectations regarding the implementation of an autonomous drone in their context. In the next chapter, I will investigate this through interviews.

6 Understand workers expectations of automation

6.1 Introduction

Even though, many examples of the implementation of autonomous ships are given (Porathe et al., 2014)(Veitch et al., 2024)(Veitch et al., 2022), the challenges of automation are often context-dependent (Ramos et al., 2021). Currently, little is known about the experiences of multiple stakeholder groups in the port and their ideas on autonomous ships possibly being introduced into their work environment in the future.

The goal of this thesis is to create concrete guidelines for the design of a new ecosystem of human roles with autonomous USVs based on the views of workers in the port. These workers have context-specific knowledge and deep knowledge about the broadness and challenges of their work. By building the guidelines from the experiences and expectations of workers, human preferences, instead of technological possibilities, are put at the center of the design process. Therefore, the question I aim to answer for this interview study is:

What are the attitudes and experiences of skippers, surveyors and VTS operators working in the Port of Rotterdam regarding USVs?

6.2 Participants

A total of nine participants were interviewed for this study over the duration of three weeks in January 2025. Each participant belonged to one of the three stakeholder groups that are at the core of the hydrographic survey operations: Skippers, surveyors and VTS-operators. Participants were chosen from these groups, because they have a lot of experience working in a port context and their work is most likely to be affected after the implementation of an USV.

Before the interview study, a context study was conducted, which can be found in chapter 5. During the context study I

was able to informally meet with surveyors and skippers and to ask if they would be willing to share their contact details to participate in an interview study later on. To these participants, an invitation was sent by email for this research. The invitation explained the purpose of the interview and the duration of the interview. Through the use of snowball sampling, other participants were found to participate in the study. Due to the limited pool of participants, one substitute employee and one former employee were recruited for the interview. It was made sure that they had recently been employed to conduct survey operations in the port. Skippers and surveyors belong to the hydrography department. This is a small department part of the overarching Asset Management department. Due to the small size of the department, there were only a few skippers and surveyors available to interview. During the interview. In total, two skippers and three surveyors were interviewed. The VTS operators belong to the harbour master division. This group of possible participants was much larger. In total, four VTS operators were interviewed. Due to the small pool of participants, as little information as possible about the participants has been disclosed. An overview of the participants is shown in table 3.

Participant	Role	Duration of interview in minutes
P1	VTS operator	64
P2	Surveyor	45
P3	Skipper	45
P4	Surveyor	67
P5	VTS operator	41
P6	VTS operator	40
P7	VTS operator	25
P8	Skipper	42
P9	Surveyor	77

Table 3: Overview of participants

6.3 Procedure and scenario design

During the interview, the path of expression will be followed. The path of expression helps participants to better articulate their wishes for the future (Sanders & Stappers, 2012). First, participants were asked to think about their current work. Then, participants were asked to think about changes in their job that they have experienced and how they have perceived these changes. After discussing their current work and past changes, participants were asked about their vision of an USV. Following this, a simplified coloured drawing of the current operational situation (two survey ships in different parts of the port, with each a skipper and surveyor and VTS operators) was shown and explained. After showing the drawing of the current operational scenario (Figure 20), two fictional future scenarios were presented in the same art style. The scenarios aim to provide participants with a concrete picture of a possible future with USVs. Presenting a

drawn scenario makes it easier to discuss ideas about the scenarios and to express concerns (Zhu et al., 2024).

For the design of the scenarios, I drew inspiration from the initial pilot plans of the port and literature on the future of human roles and autonomous ships, in which shore control centers and situational awareness were often mentioned (Li & Yuen, 2024)(Veitch et al., 2024)(Veitch & Alsos, 2022)(Mackinnon et al., 2015)(Saager, 2022)(Ramos & Mosleh, 2021).

Additionally, trends from the PESTEL analysis (chapter 2), as well as technical feasibility with current developments were taken into account. Furthermore, business requirements such as increased efficiency and reduced personnel were considered. A multitude of scenarios were created, but only two were chosen to include in the interview. These two scenarios will be discussed below. The other scenarios and their explanation can be found in Appendix C.

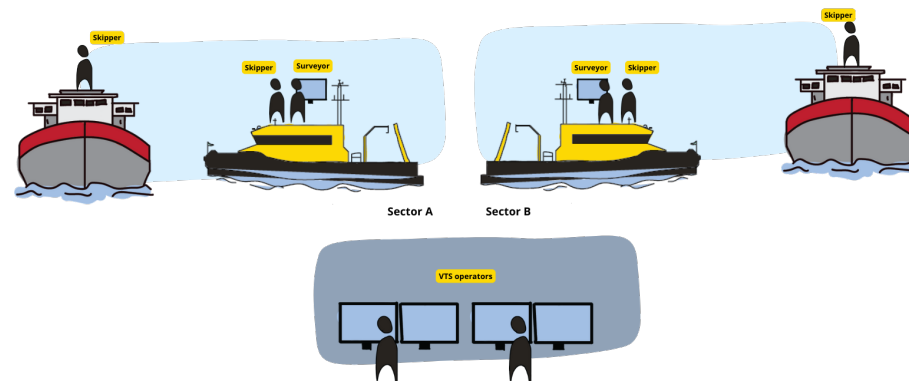


Figure 20: Simplified drawing of the current operational scenario

6.3.1 Scenario one (mothership scenario)

In the first fictional scenario, one of the two survey vessels is accompanied by an USV. This USV can be remotely operated by a remote operator. The USV can perform measurements simultaneously with the mothership and sail along with it. While doing this the USV is able to sail its own tracks autonomously. In case of a change in the situation or an ap-

proaching ship, the remote operator could take over remote control over the vessel. In this scenario, the surveyor checks the measurement data from both the USV and the mothership. The scenario that is shown to participants during the interviews can be seen in figure 21. This scenario is interesting to include in the research because it is similar to the pilot scenario of the Port of Rotterdam authority.

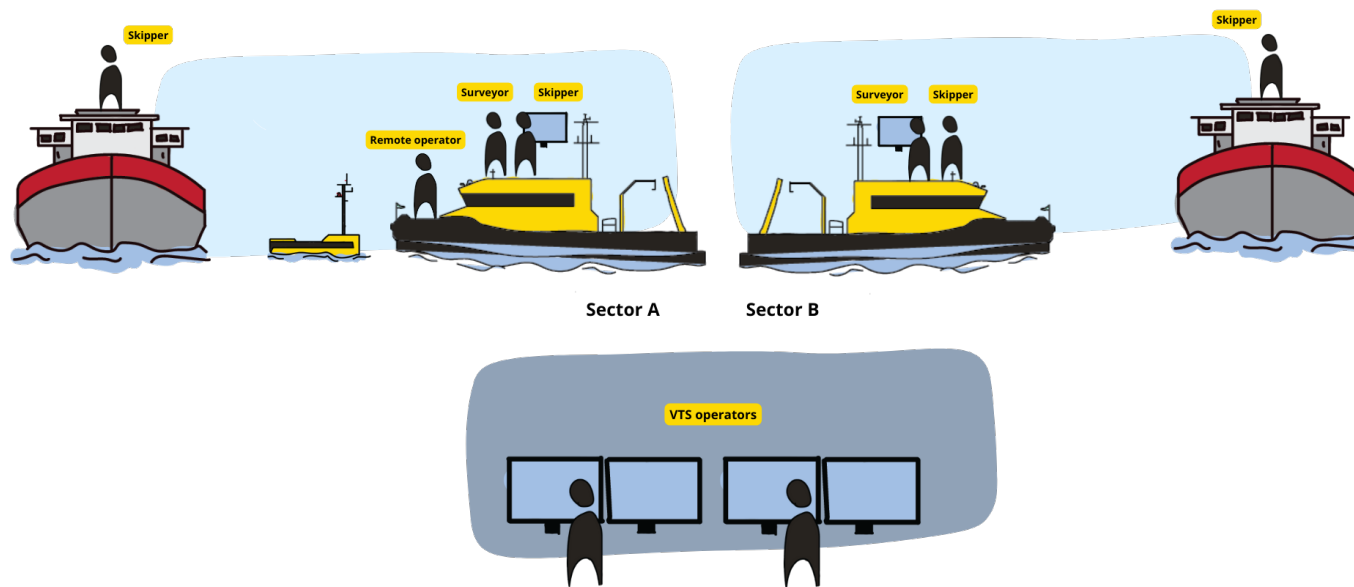


Figure 21: Scenario of two VTS sectors with one survey ship being accompanied by an USV

6.3.2 Scenario two (remote control scenario)

In this scenario, the remote skippers is a new role, which in some aspects is similar to the role of a VTS operator. They monitor the surrounding traffic of the USV and communicate with the VTS operators. If a ship approaches and the USV needs to move aside, or the USV needs to cross a busy intersection, the remote skippers can take over control. The surveyor checks the incoming measurements from the USVs and communicates with the remote skippers about which measurements need to be taken where. While the remote skippers ensure that the USVs arrive safely at the measurement destination, the surveyor prepares the settings for the survey (also for autonomous operation, for example, drawing the area that the USV needs to survey). If something goes wrong with the measurement, the surveyor

communicates this with the remote skipper so that appropriate action can be taken. It is important that the remote skippers and surveyor can work closely together and communicate verbally. This scenario is interesting to discuss because it utilizes distributed situational awareness (Van Diggelen et al., 2024)(Saager, 2022). The mental load of monitoring surrounding traffic for two USVs and remotely operating a USV is likely too high for a human to perform. Therefore two remote operators are assigned to this role. It would be interesting to gather the opinions of participants on remote control and how this would affect their communication. The scenario should theoretically meet the business and technical requirements. It is technically feasible and theoretically increases the efficiency of operations while reducing personnel. The drawing of the second scenario that was presented to participants is shown in figure 22.

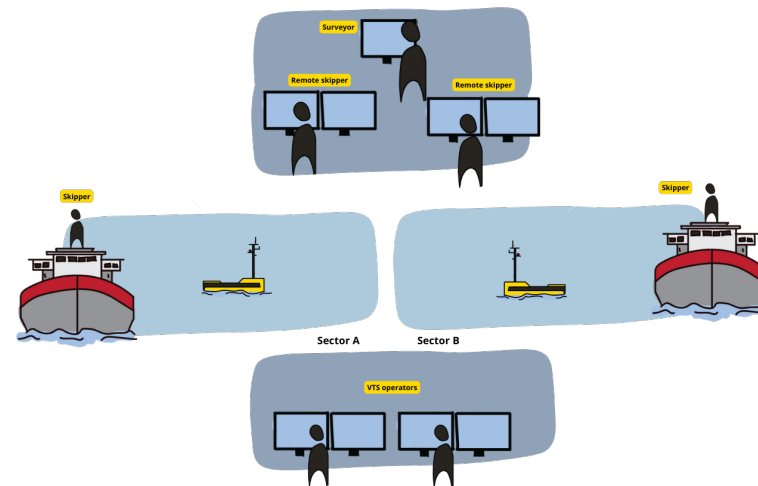


Figure 22: Scenario of two Vts sectors with each an USV

Before the first interview, a pilot interview was conducted. The purpose of the pilot interview was to get an idea of the duration of the interview and to check if the scenarios and questions would be clear enough for participants. In the pilot, a more complex version of the scenarios was presented. In this version, the people responsible for checking the data in the office after the measurements and the person responsible for boat planning were also included. This made the scenario too complex to understand. For this reason, these roles were omitted in the scenario that was ultimately used for the interviews. The final interview protocol can be found in Appendix D. Before each interview, participants were asked to sign an informed consent, which was approved by the human research ethics committee of the Technical university of Delft. The informed consent forms can be found in Appendix E.

6.4 Data analysis

While coding, I apply an inductive approach. While doing this I applied a bottom up approach in coding. This approach is suitable, because the goal of the research is to gain a deeper understanding of the feelings and views of VTS operators, skippers and surveyors on USVs and how

they perceive the implementation of these would affect their work experience. Furthermore, I aim for the themes to reflect the content of the entire data set. This is favourable over a more detailed description of specific themes, because the views and feelings of skippers, surveyors and VTS operators on autonomous ships are not yet known (Braun & Clarke, 2006).

The data was coded in line principles of grounded theory (Charmaz, 2014). First I familiarize myself with the data. This is done by reading through the transcripts, which are automatically created through word or Microsoft teams. When going through the transcripts I play the recorded interview as a reference and check if the generated transcript is the same as the recorded audio. While doing this, I wrote down initial codes and patterns I noticed. When the transcripts were cleaned they were loaded into Atlas.ti. The data was approached through an realist lens. This means that I assume that the data directly reflects the participants' opinions (Braun & Clarke, 2006). The first round of coding resulted in a total of 722 initial codes.

After three interviews, the initial codes were clustered in Miro. An high level overview of this process is shown in Figure 23.

Step 1: First the codes from each participant were copied into Miro

Step 2: The next step involved clustering the quotes into broad categories based on meaning

Step 3: Then the broader clusters were split into smaller specific clusters, creating an initial code structure

Step 4: This initial code structure was refined and expanded using the data from the other interviews

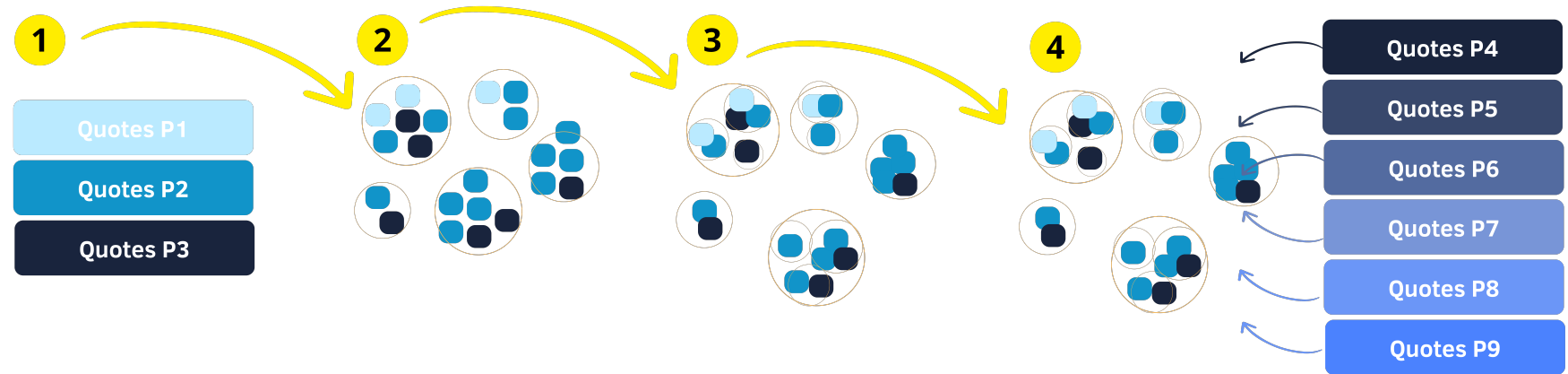


Figure 23: High level overview of the data analysis

Clustering the codes resulted in an initial codebook with several main themes: characteristics of the port area, concerns about the USV, ideas about future work, advantages of the USV, technology and work, current work, and requirements for the USV. After this, I have gone through the codes and transcripts of the remaining interviews and refined the

codes. Finally the themes are reviewed once more. This is done by going through all themes and the transcripts. When the themes accurately represented the data, the themes were named and a description was given, as can be seen in Table 4. The final codebook can be found in Appendix F.

Theme	Description
Characteristics of the port area	This theme addresses the specific characteristics of the port area mentioned by participants, such as traffic density, the multitude of factors, and unpredictability. It also covers what distinguishes survey work in the port area from survey work elsewhere.
Future of work with USVs	This theme examines how participants expect USVs to impact their work, with both positive and negative changes anticipated. It covers general work changes, as well as those specific to the mothership scenario, the remote control scenario, and the context of advanced autonomous navigation.
Implementation process of USVs	This theme explores participants' expectations and attitudes toward the implementation of USVs in the port, emphasizing the need for collaboration, the importance of organizational culture, and the necessity of a gradual transition.
Concerns about USVs	This theme captures participants' concerns regarding USVs in the current operational context, including the lack of perceived advantages of USVs, the need for additional personnel, stability issues, vessel traffic challenges, regulatory uncertainties, reduced human control, communication and connectivity issues, and limited visibility.
Advantages of USVs	This theme highlights the advantages of USVs in a port environment, such as their smaller size, ability to access areas that conventional ships struggle to reach, and increased efficiency.
Expectations of USVs	This theme covers all expectations and requirements that an USV must meet to operate within the port context, according to participants.

Table 4: Overview of themes and descriptions

6.5 Results

In this section, the results from the interview study are discussed.

6.5.1 The perspectives of surveyors, skippers, and vessel traffic service operators on present and future work with automation

During the interviews, participants were presented with the two different scenarios and asked how these scenarios would change aspects of their work. Some of the changes participants mentioned would occur with any USV implementation. For example, when an USV operates in the port, certain aspects of work for VTS operators, surveyors, and skippers would change, regardless of the scenario. Participants from VTS emphasized that maritime traffic would need to be aware of the presence of the USV, and that it would be their responsibility to communicate this. As P5 put it,

'It does become a kind of extra caution for me as a VTS all of a sudden that I have to pay attention to it.' (P5)

while another explained,

'That actually puts a lot of pressure on us, more pressure on us.' (P6)

The reason that verbal communication about the USV is necessary is that participants expect the location of the USV not to always be accurate, due to radar blockages by quays, as P1 mentioned.

Surveyors indicated that conducting measurements with an USV would not drastically change their work. However, an important difference for them was whether the data could be viewed in real time or only afterward. The latter would

require more preparatory work, and checking the measuring equipment on the USV before deployment would become an additional task for the surveyor, as reflected in the following code by P4.

'You can even do that from the office. But someone on the boat, when it is sent out, still has to check it once, turn it on.' (P4)

Some participants preferred current survey operations over working with the USV. Finally, participants highlighted the ongoing importance of collaboration between surveyors and skippers, emphasizing that communication should remain unchanged. As one participant stated,

'So you still have to have contact with him. Then you must be in a place where you have the skippers next to you. That you can give directions and instructions. I do that now too.' (P2)

Multitasking was also considered undesirable, as measurement data needs to be monitored closely, as P3 highlighted:

'You cannot use two echo sounders at the same time in areas where you have no interference at all and do not have to take anything into account. That might work. But we know from practical experience that this is important. So you cannot intervene on two echo sounders at the same time to do something or so.' (P2)

Some of the mentioned changes were specific to the mothership scenario (Figure 21). Participants found it important that there was a limited working distance between the USV and the mothership. This was related to the visibility of the USV. If other traffic could clearly see that the USV belonged to the survey vessel, for example, through the same colors or a short distance, this could increase the visibility of the USV, as was mentioned by P1.

'Maximum distance between the mothership and the USV. That it is visible that the USV is working, not that it is under a corner and the USV is not visible in the corner.' (P1)

Participants also wondered whether both the mothership and the USV would perform measurements simultaneously. If this were the case, the skipper of the mothership would need to account for the USV and navigate more broadly around other maritime traffic. As one participant explained:

'I think that if you, also if you are sailing on the big boat, you would have to look very carefully at how you set your courses, because you want to survey such an entire area in one go, together with the small boat sailing with you. That means you need much more space to sail your stretch. So you will have to navigate more broadly around ships. So actually, on the one hand, you want to gain something, but on the other hand, you lose it again.' (P3)

If the mothership and USV were not measuring at the same time, participants pointed out that the USV could be deployed completely independently of the mothership:

'But then you could also say, I use it separately. Instead of taking the boat with me.' (P3)

Finally, participants mentioned the emergence of new tasks specifically related to the USV, such as launch and recovery. This would add extra responsibility in the mothership scenario, and could take up significant time if not well thought out. One participant illustrated the potential issue:

'Then you do launch and recovery of that vessel. Either on the aft deck or in a smart way. So if that is not well thought out, you will spend half an hour on it, that is simply far too long.' (P9)

Participants also wondered whether the remote operator would communicate with the VTS or if the skipper would handle this communication for the remote operator. According to skippers, they would take on the responsibility of communicating with the VTS for the USV. However, this would add extra pressure on the skipper, as they would also need to communicate with the VTS on behalf of the remote operator. For the VTS, this scenario was undesirable because it meant they would have to speak to the remote operator through an intermediary, potentially causing delays and the loss of important information. As highlighted in the following quote:

'Normally, it is just me to the skipper who is making the decisions. And now there is actually a kind of intermediary. And what changes, I think, is the response speed. And yes, if it happens that the remote operator is at the back of the ship controlling that thing and I communicate via the VHF to the skipper in the wheelhouse, who then has to shout it to the back.' (P5)

Another participant shared these concerns:

'This scenario we have here is difficult for us. Yes, with that extra communication with that remote. That does not make it easier for us. That will certainly not be an improvement now.' (P6)

The participants described several changes related to work specific to the remote control scenario (Figure 22). Skippers expressed a strong preference for working on the water rather than from an office. One skipper remarked, for example, that he would feel more comfortable being on the job himself rather than 'watching from a distance,' emphasizing there were minimal benefits to remote control, because you still need a location and the same crew for the job (P8). Another participant noted the high costs involved, stating,

'They're not going to invest 3 million just to stop sailing and start watching TV. Skippers want to sail. That's how I see it, and that could be a challenge. So, it's a combination of autonomy and human involvement. And the costs.' (P6)

Participants raised concerns about reduced situational awareness when operating remotely. Without being physically on the vessel, a skipper could lose the ability to look around and respond to visual cues. As P5 explained, when a skipper is physically on board, they check their surroundings, check the radar, and react to what is happening. Sometimes, skippers notice things earlier than VTS operators whom are relying solely on radar, cameras and AIS. In such cases, the skipper would immediately call: *'Hey, what are you doing? Have you even seen me?'* That kind of situational awareness would be hard to replicate when operating remotely.

Additionally, operating remotely would mean skippers would have less physical feedback on how the ship is affected by currents, wind, and waves. As P3 explained that physically being on board allows him to *feel* the boat. Remotely, he fears that sensation is lost: *'No matter how small the vessel is, it's still influenced by currents and wind. Here, you see what your ship is doing, you feel how it moves, and you react instantly. The question is to what extent you can compensate for that. You would have to read that from your equipment. (P3)'* While radar and other tools provide indicators of what is happening to the ship, this information does not equate directly experiencing the ships movement. He also said that instinctive reactions, such as turning the ship to avoid an approaching vessel, happen more quickly when experienced first-hand.

Other than skippers fearing a loss of situational awareness and feeling for the ship, VTS operators mentioned that as long as they could still communicate directly with a human,

their role would remain largely unchanged. Surveyors also expected that their work would not change much in this scenario. They envisioned having the same visual information as they would on the water, but from home or an office.

The fact that surveyors and skippers would no longer have to be physically present in the port area could offer more flexibility in work schedules, according to participants. For example, a remote operator could start earlier to navigate the vessel to the survey area, while the remote surveyor could log in half an hour later once the vessel reaches the survey location, as is expressed by P9:

'Then again, they're always struggling with transportation someone still has to pick them up and bring them back to their departure point. They'd rather not deal with that. So maybe this could provide more flexibility, since people wouldn't have to travel back and forth in the morning.' (P9)

Finally, participants shared varied expectations about how the USV would reach the survey location. Some envisioned the USV being launched into the water via a trailer, while others imagined the development of automated docking stations specifically designed for the USV.

Other changes were not directly linked to either of the two scenarios but rather referred to a future scenario in which autonomous navigation technology had further advanced. Participants envisioned that in highly advanced autonomous navigation, ships would be able to communicate with each other, avoid other traffic, and make decisions independently. As P1 described:

'With full automation, a ship would send a signal within a 400-meter radius, saying, 'I'm here, working.' And another ship would respond, 'I'm leaving the dock oh yeah, that thing is still there, let me send a quick ping to check its location.'

There. I'm departing,' it says to the smaller vessel. The smaller vessel responds, 'Okay, I'm here now. No collisions.' (P1)

Some VTS operators shared concerns that in a fully autonomous port, their role could become obsolete. One participant reflected on this possibility, suggesting that if automation functioned flawlessly, their job might no longer be necessary: *'Because then ships would exchange information among themselves about where they're heading, where they might encounter each other, and how they will pass whether in front, behind, or by stopping. I don't know.'* (P5). Meanwhile, others believed that VTS operators would still be needed to manage exceptions. One participant pointed out that standard navigation patterns could be programmed into an autonomous system, but unexpected situations would still require human intervention. *'You have standard navigation patterns that you can rely on. And then there's a whole range of exceptions why and how they occur. I think we will still be needed for those exceptions. Because in a computer, you can input all the predictable scenarios and even create a model for an ad-hoc decision. But when multiple scenarios happen at once, that still needs to be figured out.'* (P1).

With the decrease in work, VTS operators expected that each operator would be responsible for a larger section of the port. Others expressed concerns that many might fear their work will lose value once everything becomes automated. As one participant summarized, *'And many VTS operators and others will be very skeptical about it. Because they are also afraid that their work will no longer have any value once everything gets out of hand and everything is safe.'* (P5) Participants expected that skippers would no longer be needed in a highly automated environment. On the other hand, surveyors anticipated that they would still play an important role in configuring measurement data and ensuring the quality of the data collected.

6.5.2 Sink or swim: Concerns and expectations for USVs

In this section, the concerns and expectations of automation in relation to the context of the port are discussed.

The port, a busy and unpredictable environment for automation

Conversations with participants often revealed that the port area is a highly trafficked and complex environment, with numerous busy areas and intersections in which *"The square meters are being claimed"* (P6). One participant compared it to an ant nest:

'But look, for example, at the Waalhaven or the Eemhaven, that is essentially one big ant nest. And also just the intersections here, like the Botlek, the Oude Maas. It's all super... Yeah, it's one big ant nest.' (P8)

The traffic situation can also change rapidly in the port, with an area that is calm one moment suddenly becoming busy. P6 provided an example in which suddenly four ships in a row appeared in a seemingly calm part of the port. Aside from vessel traffic, other unpredictable factors contribute to the dynamic environment of the port. P1 described these factors in the following quote:

'You have high tide, low tide, headwind, ebb, flood. So all these factors. There is always a plan. And as soon as the plan starts, deviations begin. And everyone has to adapt to those deviations. So within 10 minutes, everything can be different.' (P1)

The combination of factors and the high traffic density show the importance of local knowledge, which *"you don't learn*

from a book, especially not in Rotterdam.”(P8), but through operational experience.

Surveying operations in the port come with specific challenges compared to other environments, one of which is moving aside for other marine traffic. A participant noted that surveyors from other ports believe that *‘Everyone moves aside for them.’* However, in the Port of Rotterdam, *‘you move aside’* (P1). Even when surveyors are in the middle of a survey area and are clearly visible, they often have to move aside for approaching vessels, as is illustrated by P9: *‘I was conducting a survey in a specific spot, and we were highly visible, right in the middle of the port area. Then a ship came sailing in, and at some point, we simply had to leave our position’* (P9).

The geography of the survey areas presents another challenge. Because these areas are spread out, survey vessels spend a significant portion of their time simply reaching the survey locations. One participant estimated that *‘about one-third of the time is transit sailing, and two-thirds is actual data collection’* (P9).

Many areas are not easily accessible from the quay, as they are managed by private companies. Some areas are reachable by car, but this process involves complex regulations. A participant remarked:

‘You can hardly launch that USV from the shore anywhere. At least, that is possible, but that is very difficult, because of course you have all kinds of sites that surround the port area, industries that all have extremely strict regulations with permissions. That is required by the government, but also by the companies themselves, so going through those sites of the tenants and/or owners is simply very difficult. You do not have the ideal view there either.’ (P9)

In current operations, all survey areas are reached by sail-

ing.

Participants expressed many concerns about the feasibility and suitability of USV in the port context, including the lack of clear advantages, the need for additional staff to operate them, uncertainties about their stability and visibility, potential challenges with traffic and regulatory requirements, the reduced level of human control, and issues related to communication and connectivity. I will now discuss these concerns further.

No clear advantages of USVs

Surveyors and skippers saw few advantages in using an USV given the costs. One participant compared it to the energy transition, stating, *‘it costs a lot and people don’t do it either. If someone owns a cargo ship and sailing is profitable, they’re not going to invest 4 million just so they don’t have to touch the controls anymore’* (P6).

This criticism was especially strong in the mothership scenario, where the larger vessel could also survey hard to reach areas. *‘If it’s about slopes, I can also hang over a bit at high tide and rotate the echo sounder head. Then I have that data too, I do not need a USV for that’* (P2). Participants noted that an USV would mainly be useful in shallow, quiet areas, which are limited in the port.

As a result, deploying an USV with a mothership was seen as a waste of time. *‘That intermediate phase, it’s not going to bring much, I suspect, in terms of time and other factors. Maybe just more costs’* (P9).

Additional staff required for USV operations

Despite personnel shortages, participants expected USVs to require more staff. Workers would still be needed to transport and launch the USV. One participant noted that while automation is expected to reduce crew size, *‘it really is not feasible. You would still have to work with the same crew. I see no advantage in that at all’* (P3).

Even when deployed from shore using a trailer, more people are needed. One participant described tests where two people transported and launched an USV, after which surveyors on shore took over: *'That means that for one USV, three people are needed'* (P3).

Finding a suitable operator was also seen as a challenge. One participant pointed out that *'you often encounter breakdowns or technical issues, so the operator should be a younger, more technically inclined person. But if you want someone who meets all the requirements in advance, you will never find them'* (P9).

Concerns about USV stability and visibility Participants assumed an USV would be smaller than the current survey vessel, but this smaller size brings disadvantages. A small USV might struggle with wake waves from other vessels, as one participant explained that *'a huge push-boat produces a wake that lifts such a thing up. You can hit it against the quay. I think it immediately gets mangled'* (P2).

Visibility was another concern, particularly on radar. A VTS participant pointed out that *'sometimes we don't even see some of the yachts on the radar because they are so small that they are not visible,'* raising doubts about whether an USV would be detected in busy port areas (P7).

Maintaining a straight course in strong wind or currents could also be an issue. If the engine lacks sufficient power, the USV might not be able to *'hold those courses properly,'* making navigation unpredictable (P5).

For these reasons, some preferred a larger USV for stability, as *'you are more stable on the water than with such a small thing'* (P9).

In high-traffic areas, a larger vessel was seen as more suitable. One participant noted that in places like the Amazonehaven and Europahaven, where maneuvering is constant, *'your own boat can more easily maneuver between traffic there than a small boat, which can even operate autonomously'* (P4). A larger USV would also be more visible

to other traffic, according to participants.

Concerns related to traffic Participants expressed concerns about the use of the USV in busy areas. While it might function well in calmer parts of the port, one participant noted that in high-traffic zones, an USV would not be useful. *'In very specific situations. For example, along the Gloringen, in smaller ports where your survey vessel is already fully occupied. I would think that an USV wouldn't be a problem there. But in busy intersections, I think there will be more drawbacks'* (P8).

Participants also mentioned that other skippers might be reluctant to make space for the USV because there is no crew on board.

Furthermore, concerns were raised about the USV's ability to avoid prop wash, which is crucial for successful depth measurements. One participant explained:

'In an area with heavy shipping, you also have to consider how you miss the prop wash of vessels, that is the only factor that determines whether you get a good or bad measurement. And that is still difficult with an USV.' (P3)

Concerns about regulations

Another concern that participants had about the feasibility of a USV was legislation and regulations. Participants indicated that a barrier to the implementation of USVs would be the strict regulations. Participants also think that applying for permits will take a lot of time. Finally, there were questions about liability in the event of accidents caused by an USV.

Concerns about lack of human control

In the scenario of fully remote control, participants expressed concerns about the difficulty of human intervention and supervision, especially in case of problems with the USV. One participant questioned what would happen in case

of a technical failure: *'If something breaks on board, how does that work? Does the vessel just sit idle?'* (P6). Others questioned whether a backup system would be available in the event of a system failure and emphasized that intervention would be much harder when the operator is not physically present. *'Because you can intervene more easily if you are on board'* (P4).

Besides concerns about intervening during malfunctions, participants also worried about maintaining control over measurement quality in an automated system. As one participant stated, *'if something happens automatically, it also goes wrong automatically'* (P4). Without real-time oversight, errors could go unnoticed, potentially wasting an entire day of work. *'Unless the data connection is 100 percent and you can intervene everywhere, you might end up finding out at the end of the day that you've lost an entire day'* (P4). Another participant reinforced this concern, pointing out that *'if a malfunction occurs, you don't know what happened, because you are no longer directly overseeing it'* (P2).

Concerns about communication and connectivity Participants expressed the need for a strong and fast connection due to high shipping speeds and long stopping distances. Because, unlike cars, ships cannot simply pull over, so *'everything must be communicated in time'* (P5).

According to participants, remote operation would always involve delays: *'Whether you are in the office or on the boat and see nothing, that doesn't matter much. It is only the delay, the quality of the connection. . . I don't know if it is sufficient yet'* (P6).

These delays in response time were a concern to participants, especially in busy areas, where quick decisions are crucial. An example of this is given by P6: *'If it is very busy, that can cause problems. In the Botlek, everything moves fast. You say this and that, and a surveyor decides: 'Never mind, I'll go around it or pull it aside.' That decision is taken very quickly'* (P6).

Beyond delays, participants worried about total loss of connection, which could leave an USV stranded. *'If there is no data connection at random locations, then it is in a black hole and essentially gone'* (P4). Even under normal conditions in the port, *'the communication link is not 100 percent guaranteed'* (P4).

Due to increased construction in the port connectivity could become even more unreliable. Radar signals can bounce off wind turbines and buildings, making vessels hard to detect, as is illustrated by P1: *'We still have several places in the port where there are ships, but you do not see them'* (P1).

6.5.3 Advantages of USVs

One frequently mentioned advantage of USVs is their smaller size, which allows them to take up less space in the port. P7 explained that, a smaller vessel can *'come closer to the shore'* and *'inconvenience people less'* since others do not have to take it into account as much due to its small size.

Another advantage of the small size is that it makes it easier to access hard-to-reach areas. P8 noted that for *'measurements of slopes, dredging areas, and real corners and crevices of the port,'* a smaller vessel would be more practical than the current survey vessel.

This is because, manoeuvring between piers or measuring small angles is a time consuming task for the current survey vessel. P4 pointed out that an USV, in contrast to the current survey vessel, *'flies in between and then it's done,'*. Besides reaching difficult spots faster, participants noted that the USV could be efficient for large, repetitive measurements. P9 suggested dividing tasks strategically, with *'the side from which the wind comes measured by the smaller vessel, so that you finish a few hours earlier'* (P9).

Another advantage that was mentioned of the USV is safety.

Without a crew on board, risks are lower, because, according to P5, *'a little USV, when it hits the quay, is probably only troublesome for itself'* and unlikely to cause serious damage to other vessels.

Another advantage of USVs was that surveyors and skippers would not have to travel to the location daily. This would make deployment more flexible. Finally, USVs were seen as a potential solution to personnel shortages, as P1 mentioned: *'You need fewer people, and it is difficult to get people'* (P1).

Some saw the USV as an innovation and a valuable addition to surveying. *'As a surveyor, it is an expansion of your work package. These are innovations, you should not close your eyes to them. You are starting something very new, which may also be somewhat refreshing'* (P3).

6.5.4 Expectations of USVs

Based on the specific characteristics of the port area, participants' concerns about the use of USVs and its benefits, a number of clear expectations can be found that participants express about an USV.

Participants expected the USV to navigate independently, requiring human intervention only for retrieval as P4 says: *'The USV navigates by itself. You only need to be present when it is finished, when it needs to be taken back on board'* (P4).

The USV should maintain a safe distance from other vessels, especially when crossing other traffic. This would be important to stay visible, because, while a small USV might consider *'two meters of distance sufficient,'* a skipper on a large container ship *'might not see that USV'* from high up (P5).

The USV was also expected to avoid static obstacles and account for prop wash, as P4 states: *'When it sees an obstacle, it goes around it'* (P4). According to participants, quick

response times were crucial: *'The most important thing is that these USVs, when they need to take action to avoid something, can do so immediately'* (P7).

Besides responding quickly, the USV should also be able to anticipate movements to prevent sudden course changes that disrupt traffic. One participant compared this to a Tesla, which *'navigates on its own'* but must do so without *'causing a collision or chain reaction'* (P6). Sudden course changes would not be appreciated and VTS operators stressed the importance of predictable behavior: *'If it really follows its own lines, then I can tell a skipper to go around it. Predictability is better'* (P6).

Finally, it was expected by surveyors that the USV would be capable of automatically generating and applying sound speed profiles.

Participants indicated that the USV would be suitable for calm parts of the ports with little vessel traffic. For example, wide, quiet ports were seen as possible deployment areas (P3). In this, the absence of other traffic appeared to be the most important condition for participants, with some suggesting it would be best used in areas that are temporarily closed off for other traffic entirely, as P5 states: *'Autonomous navigation could work very well in areas where it is certain that no vessels will be entering or leaving'* (P5). One way to ensure this would be for VTS to temporarily close off a section of the port and communicate this to other vessels. In such a setup VTS operators would not have to care for the USV: *'I don't have to worry about it. It does the tracks, and I don't have to inform anyone'* (P1).

Many participants stressed the importance of making the USV clearly visible to other traffic. Due to the small size of an USV, it could easily disappear behind larger vessels, pilings, or buoys (P8).

To improve visibility, it was suggested by P7 that the USV be equipped with AIS and appear on radar: *'If they are equipped with AIS, others can see it on their maps. Then*

it stands out a bit more. I think that is the most important, especially if it is very small' (P7). Others said that radar reflectors could further enhance visibility.

Participants also emphasized that the USVs function as a survey vessel should be clear to other traffic. P1 stated: *'It must be clearly visible and associated with its identification, indicating what it is for'* (P1). Participants mentioned that could be achieved by displaying 'Surveyor' on AIS or by using specific colours to link it to the mothership. It was also suggested to add a feature, like lights, that immediately signals other waterway users that a USV is operating autonomously.

Participants emphasized the importance of communicating the USV's planned route to VTS and possibly other traffic. VTS operators supported the idea of making USV tracks visible on navigation systems, allowing vessels to adjust accordingly. *'Perhaps they can see on their maps: this one follows this route, so you must go around it'* (P6). Since survey vessels normally communicate their route verbally, it would be useful if an USV could do this automatically. *'If it can indicate how it is going to sail, that would help. Then I can make a plan and know where it will turn again'* (P5). P1 explained how this could work in practice:

'The vessel sails in the port, because it is performing surveys. If we can view the route, this way we see that it goes up to 150 meters, and then it turns around for its next track. Then we know that everything beyond 150 meters is clear. Then we can operate safely and others know what is going on.' (P1)

It is also important for other vessels to know whom to contact when wanting to communicate with the USV. Communication needed to be *'as short as possible, with as few intermediaries as possible'* (P1), leading some VTS operators to prefer a fully remote scenario as *'the best option'* (P6).

The USV had to remain in constant contact with its surroundings, especially regarding course changes. P1 stressed the need for a system that signals unexpected manoeuvres: *'What happens if it suddenly receives other orders? Does it suddenly turn? Then there must be a system that indicates this, so vessels can take it into account'* (P1). For example, if the USV decided to repeat a measurement after detecting an anomaly, it should send a notification to VTS operators that it deviates from its track: *'Would it then do that automatically without informing me? I would like it to tell me that'* (P5).

Finally, participants emphasized that the remote operator should be trained in VHF communication to ensure smooth coordination with VTS and skippers. The reason for this was given by P8: *'If you speak the same language as the VTS and the skipper, everything runs much more smoothly'* (P8). For remote control, participants expressed the need for sufficient situational awareness for the remote operator: *'You must always have a wide view around you.'* (P3). Besides sufficient situational awareness, it should also be possible for a human to take over control at any moment: *'You must be able to take over from one moment to the next'* (P3).

Participants expressed the need for physical intervention if something goes wrong with the USV. And while doing this it should be ensured that other vessels are not burdened. P5 suggested that there should be a vessel available to retrieve defect USVs: *'There must be arrangements for that, I think'* (P5).

Maintaining *'eye contact'* (P2) with the USV was important for some participants. P2 preferred sending an accompanying vessel to ensure a human was always nearby, he explained: *'You must be present. So you would rather have a small boat with you'* (P2).

Opinions varied on whether an accompanying vessel was always necessary. Some saw it as essential for intervention, while others believed a well functioning USV could operate

independently: *'But then you could also say, I use it separately. Instead of taking the vessel with me'* (P3).

Finally, the USV should have sufficient battery life to complete its tracks. According to one participant, this should be at least 5 to 6 hours of continuous operation: *'It should be able to cover both the larger areas and the smaller, more inland areas. The USV needs to be able to operate continuously for at least 5 to 6 hours. And also, if it could be quickly recharged from the vessel.'* (P9)

6.5.5 A slow but certain transition to a more automated work environment

Technical innovations did not seem new to the participants. Many of them could readily cite examples of how technology had transformed their work in recent years. For instance, several mentioned digital buoys and ongoing tests of autonomous navigation in the port area as clear signs of progress. P4 was convinced that autonomous navigation was inevitable, remarking that,

'I believe they will come, anyway. It is a development in the market that simply cannot be stopped.' (P4)

and adding that these systems would only get better at avoiding other vessels over time.

When discussing automation in the port, participants often envisioned a fully automated port running faultless. Yet, they also raised concerns about a hybrid environment where human and computer control coexist.

'half operate autonomously and the other vessels just have to sail around them.' (P5)

They also recalled past experiences with technology that, while innovative, didn't always work perfectly. One participant explained that *'the systems have indeed been updated,'*

(P6). However, he stressed that such improvements take time, noting that progress is slow. Another participant reminisced about the early days of AIS technology, describing how it was initially imprecise in the port due to signal issues around structures, but gradually became more reliable over three to four years (P1).

Just as technology evolves, the participants observed that people also gradually adapt to these changes. P1 noted: *'I see it in a positive light. It is already in that transition period over the next 8 or 9 years, where you have an intermediate form.'* (P1), suggesting that once a 40 percent autonomous system is in place, other traffic in the port will get used to USVs. Another participant warned that the transition would require new knowledge, comparing it to going *'back to school.'* (P4).

The participants said that if USVs are to be implemented in the port area, practitioners must be involved: *'if there are developments related to our field, then they should be handled by us.'* (P2). P6 stressed the need for *'very good planning,'* (P6), insisting that those with operational experience should be at the table and that arrangements should be clearly documented. In line with this, P5 recommended that procedures be developed jointly with the port authority. They stated, *'And that we, together with the port authority and those operators, develop some kind of plan.'* (P5)

It was also noted that any implementation should account for other port users. One participant said that while a lot of planning might focus on the new technology, what is often missing is consideration of: *'the other people who are in the port.'* (P2). P5 suggested forming workgroups with operators and developers who truly understand the ship's properties of the technology.

Testing of the USV was seen as a crucial step. P4 suggested starting with quieter parts of the port, so that measurements can be taken *'while there is simply no one there.'* (P4). Another participant warned that: *'you only really find out when*

you actually try it.' (P7), meaning that pilots in a real world environment will reveal unforeseen issues with the technology.

Finally, participants addressed the need for a cultural change within the organization. They noted that autonomous navigation could never succeed if people were not willing to embrace it. They also stressed the importance of involving young, technically skilled individuals in the implementation of USVs. P9 stated: *'It's not such a big deal, but I do think that you need some delicate people to set that up.'* (P9) Lastly, participants warned that small errors during the testing phase could lead to resistance and a loss of trust among users. As P8 put it,

'I think that if something happens, you really need to be able to trust that it works.' (P8)

6.6 Discussion

The results provide insight into workers thoughts on autonomous ships, their expectations and how they perceived this technology would influence their work. The results also touch on the implementation process of autonomous ships. This section will go into the insights and discuss how they relate to existing knowledge on human work and autonomous systems. I will discuss the possible burden of automation for human work, the definition of an automation friendly context, and the requirements for effective human-robot collaboration.

6.6.1 The possible burden of automation for human workers

In the literature on autonomous ships, the following advantages are often highlighted: they are more efficient, can navigate more optimal routes, and human error could be reduced (Kristensen & Børsen, 2024)(Mackinnon et al., 2015)(Veitch & Alsos, 2022). This differs from the advantages mentioned by participants in the interview study. Here, the focus was more on the smaller size of the USV, which allowed for easier surveying along quays, and the flexibility in personnel deployment. However, one advantage mentioned was that in the event of a collision, there would be no crew on board the USV.

Participants also had the impression that a USV could be more dangerous than a manned ship due to possible connection delays or reduced visibility to other vessels.

What is interesting, is that participants expected that their workload would not decrease after the implementation of USVs, however participants did expect that their work might become more complex or difficult. For example, surveyors and skippers feared that introducing an USV would lead to multitasking. Additionally, working with a USV would require

VTS operators to warn other traffic about its presence and potentially communicate with the remote operator through an extra communication link, as in the mothership scenario. Even if most of the port would be autonomous, VTS operators still did not expect their workload to decrease, instead, they indicated that they would likely oversee a larger area. This aligns with what Bradshaw et al., 2013 describes this phenomenon as the 'law of stretched systems,' which states that rather than relieving people of tasks, automation adds new cognitive tasks. As a result, people may end up doing more work or performing their tasks in a more complex way. Many participants indicated that the tasks where an USV could be advantageous were rare in the port or could already be performed with existing equipment. Furthermore, they did not see many advantages in using an USV. According to Goodwin-Sak et al., 2019, this lack of perceived necessity of USVs could negatively affect their implementation in the port. This is because, perceived necessity is the primary driver for an individual to be open to automation. If the perceived risk of automation, such as job loss or increased workload, the perceived necessity is weakened. If the perceived benefit is high, the perceived necessity becomes larger. Regarding the perceived risk, participants did not believe the USV would replace their jobs. Some suggested this would only happen if autonomous ships could navigate flawlessly and humans were no longer needed. Baltrusch et al., 2022 argues that technology must offer a clear improvement over existing work. Executive sponsorship, early user engagement, and good communication are strategies to increase perceived necessity among workers, which could be beneficial for the port. Other useful strategies could be: Understanding user needs and fostering employee support (Goodwin-Sak et al., 2019). User involvement was also mentioned by participants, who stated that people from practice should be included in the development of USVs. Chu et al., 2023 supports this idea, listing several

benefits of involving end-users, such as higher work quality due to better consideration of employee needs. Additionally, it can strengthen the trust relationship between humans and robots, which, according to Baltrusch et al., 2022, is crucial for effective human-technology collaboration. Finally, it improves design quality and prevents unnecessary issues during testing, as workers have direct experience with the technology and specific knowledge of its practical use (Chu et al., 2023). This last point was especially highlighted by participants as a reason to be involved in the implementation process. According to Veitch and Alsos, 2022, excluding workers can also have negative consequences. Workers might develop resentment toward developers and managers responsible for implementing autonomous technology if they feel their operational knowledge is undervalued. However, this was not explicitly mentioned by participants in the interviews. What was emphasized, was the value of operational knowledge in the port area.

6.6.2 The port: an automation-friendly context?

Participants stated that complexity of the environment and number of factors make automation in the port challenging. These findings align with Ramos et al., 2021, who argue that autonomous systems are fragile they work well in controlled situations but fail when unexpected events occur, which is characteristic of the port environment. Due to the unstructured and complex setting with multiple stakeholders, successful automation is difficult (Veitch et al., 2022). In addition to this, participants noted that while the USV would struggle in high-traffic zones, it could operate in a calm or fully restricted area. This says something about the trust participants have in the autonomous done and its capabilities. Bradshaw et al., 2013 illustrates the challenge of deploying technology that can withhold in its intended operational context by defining two dimensions of automation:

self-sufficiency (the ability of technology to sustain itself) and self-directedness (the ability to make independent decisions). In situations where technology is expected to fail, such as busy traffic it is common to reduce self-directedness by maintaining manual control. However, balancing this according to the context is crucial. Over-trusting an autonomous system in a scenario it cannot handle may lead to serious consequences, while a lack of trust could result in under utilization. If a technology requires too much human intervention, it becomes a burden. The innovation department should find a suitable balance between over trust and undertrust in the USV.

6.6.3 Organizational characteristics

Beyond environmental factors, participants also discussed a specific organizational culture needed to implement USVs. They believed younger workers, more open to new technology, were needed for successful implementation. Additionally, they felt that if the USV showed errors, workers would be unlikely to accept it. Participants also stated that a remote operator should have technical expertise and knowledge of maritime navigation, but finding such personnel would be challenging. Veitch et al., 2024 confirms that autonomous systems require highly skilled personnel. Jin, 2023 also notes that autonomous ship operators must understand the technology and possess maritime navigation knowledge. According to participants, workers should learn how to work together with the USV. Goodwin-Sak et al., 2019 emphasizes the role of organizational culture in automation. If an organization embraces innovation, takes risks, and values learning, automation is more likely to be adopted.

6.6.4 Human-robot collaboration

Some participants suggested that a fully autonomous port would function almost flawlessly since it would not need to account for other vessels. This reflects the myth that collaboration between humans and technology is unnecessary in a fully automated environment. Bradshaw et al., 2013 emphasize that human work will always be intertwined with autonomous systems, especially in unpredictable environments where systems must operate beyond their intended context. Moreover, human work cannot be fully replaced by automation (Bradshaw et al., 2013). Veitch et al., 2024 even argue that as systems become more autonomous, human collaboration with them will increase.

This is because human work often involves more than what automation can replicate. Akridge et al., 2024 found that bus drivers in the U.S. performed tasks beyond driving, demonstrating that automation should consider what aspects of human work might be lost. Similar concerns emerged from participant interviews. For example, skippers feared that an USV would be unable to avoid prop wash, something human skippers do instinctively. Additionally, they noted that outsiders often struggle to understand the full scope of their work.

Skippers also worried about reduced situational awareness when operating vessels remotely, preferring to work on the water rather than in an office. Situational awareness is a key topic in autonomous navigation research (Alamouch et al., 2024)(Endsley, 2017)(Mackinnon et al., 2015)(Saager, 2022). Alamouch et al., 2024 describes how remote control can create an information gap. Participants highlighted this gap, noting that visual perspective affects how much distance they keep from larger ships and that many port activities are not properly indicated on digital systems, such as diving operations.

6.6.5 Limitations and future work

Several limitations may have influenced the research findings.

First, the participant pool was small due to the niche nature of the field. Only nine participants were interviewed, which may have affected the results. Furthermore, the study focused on three stakeholder groups directly or indirectly impacted by the implementation of autonomous vessels. Interviewing additional stakeholders, such as survey planners or skippers from other types of shipping, could have provided broader insights. A future study could expand beyond three stakeholder groups and include those involved in the implementation process to identify potential differences in experiences and expectations.

The study took place at the start of an automation project, representing only a snapshot of the overall process. Investigating an automation project from beginning to end through action research could provide deeper insights into differences in expectations between the early and later stages of implementation.

Lastly, it is likely that participants were influenced or guided by the scenarios used in the study. These scenarios were designed to facilitate concrete discussions about expectations and the impact of automation. However, each scenario included an USV, which undoubtedly shaped participants' perspectives. A follow-up study could avoid pre-constructed scenarios and instead present individual system elements to prevent potential bias.

There is also a risk of a technology push in this study, as USVs were framed in future scenarios. It is essential to remain critical of whether these technologies genuinely add value in the current context. Additionally, this framing may have shifted discussions toward the technology itself rather than focusing on human experiences. As a result, participants may have been left to identify gaps where the technol-

ogy falls short. Despite this, the choice was made to include USVs in the scenarios, as the primary focus of this project was automation.

6.7 Conclusion

The aim of this study was to get insights into the attitudes and experiences of skippers, surveyors and VTS operators working in the Port of Rotterdam regarding USVs. In order to answer this question I created two possible future scenarios which included USVs and presented these to participants. The attitudes of participants towards USVs were mixed, with many expressing fears on the lack of desirability and feasibility of an USV in the port environment. Some fears were related to the idea that the implementation of an USV might result in more difficult work. The study also sheds light on workers expectations of qualities that an USV needs to possess to be successful in a port context.

In order to ensure the success of an USV in the port environments, it is important to address the lack of desirability by designing the USV to be in line with workers expectations and needs. In order to ensure the feasibility of an USV, the study recommends to balance the characteristics of the context of deployment with technical capabilities of an autonomous USV to achieve the right level of self-directedness and self-sufficiency.

6.8 Trade-offs of future scenarios with USVs

The future scenarios could be plotted on a horizontal axis, as shown in Figure 24. The horizontal axis would represent the willingness of the port authority to embrace beyond visual line of sight remote control within the port area. In this context, the current scenario would be the scenario in which the port authority is not willing to adopt this at all. The mothership scenario represents the case where the port authority does test with remote control and USVs but still requires a

human to be physically present. In the remote control scenario, there are no longer any humans physically present with the USV.

Below, I have outlined each scenario with a brief summary of the advantages and disadvantages of each option. The innovation team can use this to become aware of the potential pros and cons of each scenario based on the ideas expressed by skippers, surveyors, and VTS operators during interviews.

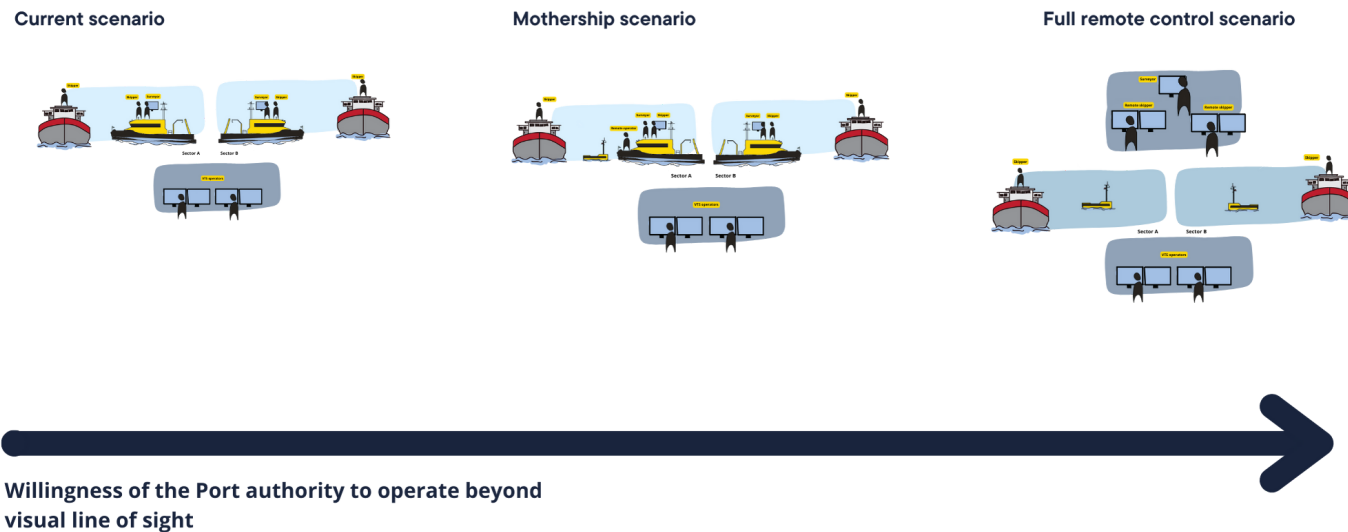


Figure 24: Three scenarios plotted on an axis based on the willingness of the port authority to embrace beyond visual line of sight operations in the port

6.8.1 Current Scenario

In the current operational scenario, the flexibility of survey equipment is very low. To conduct a survey, both a skipper and a surveyor must be available. They then need to travel to the vessel, which must dock before sailing to the survey location, a process that can take anywhere from one to several hours. This conflicts with the unpredictability of the port environment.

Operating a survey vessel is a specialized and intensive task, and temporary staff, who are increasingly employed to address labor shortages, are generally less proficient in handling it. Moreover, manoeuvring between small docks is time-consuming, while the process of sailing long survey tracks is considered monotonous. Lastly, VTS operators currently have little insight into the planned survey work or the routes the survey vessel intends to follow.

6.8.2 Mothership Scenario

While the mothership scenario provides a solution for transporting the USV to the survey location and ensuring a physical presence near the USV at all times, it does not appear to be the optimal approach for implementing an USV in the port.

The research indicates that surveyors and skippers see little benefit in the mothership scenario. An USV would primarily offer advantages in shallow parts with minimal vessel traffic or along docks and quays, but the current survey vessel is also able to achieve most of this. Additionally, launching and recovering the USV could be a time-consuming task, requiring extra personnel on board to operate the USV or monitor survey data. This would require an operator with both nautical training and survey expertise, two specialized skills that are already in short supply. While current port skippers are also trained to perform survey work, they would still be

needed to operate the conventional survey vessel.

Another limitation of the mothership scenario is the size of the USV, which is constrained to what can fit on the deck of the existing survey vessel. Stakeholders in the port area have expressed concerns regarding the USV's power, endurance, visibility, and stability.

Advantages

- Physical presence of personnel on-site to monitor the USV
- Potential time savings

Disadvantages

- Potential additional communication link required for VTS operators
- Limited time savings if USV launch and recovery are inefficient
- More personnel required instead of fewer, as multi-tasking is not desirable
- The USV is expected to provide benefits in only a very limited number of locations in the port area
- Added burden on the skipper to keep the USV in sight

6.8.3 Remote Control Scenario

Compared to the mothership scenario, the remote control scenario offers greater flexibility. However, participants expressed concerns about its technical feasibility and preferred working on the water rather than from an office. Since the USV no longer needs to fit on the mothership, there is greater flexibility in its design. However, a certain degree of flexibility will still be needed in the early stages, allowing the USV to be transported by both a vessel and a trailer.

Advantages

- Increased efficiency as personnel do not need to travel to the survey location
- Greater flexibility since skippers and surveyors do not need to be on board the vessel simultaneously
- Direct communication line between the skipper and the VTS operator

Disadvantages

- Potential delays in connection and control, which could be dangerous in high-traffic areas and with long stopping distances

- Unclear how the USV will reach the location
- Skippers and surveyors prefer working on-site rather than from an office
- Reduced situational awareness for skippers in fully remote control operations
- No personnel present on-site, making it difficult to intervene in case of malfunctions
- Likely the same number of personnel required, as multitasking is not desirable and maintenance staff will still be needed for the USV

6.9 Next steps

The expectations and attitudes of skippers, surveyors, and VTS operators regarding an autonomous ship have become clear. These interviews revealed that while there are opportunities to improve work quality, workers also expect that automation could make their jobs more challenging and provide little benefit over current work. In the next chapter, these insights will be combined with findings from previous context research to explore how automation can add value to work quality and the broader context.

7 Explore worker- technology fit

7.1 Introduction

In this chapter will be explored in what way a USV could be a positive contribution to the current work environment. This will be done by outlining the minimum requirements for a USV to be operational successfully in the port. Also workers' needs and pain points will be combined to create worker-technology fit.

7.2 Design requirements

During the previous steps, the requirements shown in Figure 26 were identified. These requirements represent the minimum conditions that must be met for an USV to operate successfully in the port environment. In order to have a successful design, the design must be viable, feasible, and desirable.

Desirability means that users want the product. The end users in this scenario are the workers. These workers will end up interacting with the USV on a daily basis and if they do not see the solution as desirable or as an improvement on their current work, automation acceptance will likely be low.

Feasibility means whether or not the concept can be created or not. Feasibility is important to consider to some extent, especially when designing for the near future, but for speculative design it should not become a limiting factor for creativity. However, it is important to mention that the port is a highly regulated environment and that legislation should

be taken into account as much as technical feasibility. Viability means that the design is viable from a business perspective. One of the main drivers for the deployment of a USV are reducing worker shortages by increasing the efficiency. If these benefits are not provided, an USV could not be economically viable for the Port of Rotterdam. When desirability, viability and feasibility are balanced, the "sweet spot for innovation" can be found (Figure 25).

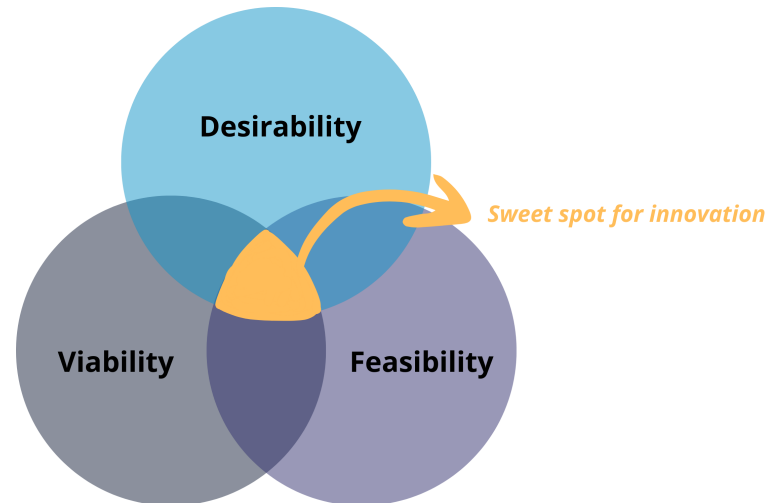


Figure 25: The balance of viability, desirability and feasibility leads to successful innovation

Trend research	Technical requirements	Business	Quality of work
Literature	Should be safe from AIS and GPS spoofing threats	Should align with local regulation	Should not make the job more boring or stressful
Context research	Should be able to navigate safely in areas with heavy maritime traffic, maintaining a sufficient distance from other vessels	Should not need more operators than the current situation	Should honor the skills and experience of skippers and workers
Interviews	Should be capable of detecting and avoiding obstacles, including the prop wash from passing ships	Should increase the efficiency of operations	Should decrease the number of times a survey needs to be broken off
	Behaviour should be predictable for VTS operators and other maritime traffic	Should increase data accuracy	Should limit technical disruptions on work
	Should be able to respond immediately to changing situations, such as sudden course changes by other vessels	USV should be flexible in deployment and serve as a supplement to manned vessels, operating from both water and land	Should limit the time surveying on busy intersections
	Should be clearly visible to other vessels with human operators	The launch and recovery of the autonomous USV should not take too long	
	Should be visible on radar and AIS		Human-machine collaboration
	Function of USV as a survey USV should be clear to other maritime traffic	Broader context	Remote operator should have sufficient situational awareness
	Should be visible on radar and AIS	Should not be a burden for other ecosystem stakeholders	System limitations and capabilities should be clear to operators
	Should have sufficient battery life	Should not lead to negative social effects	Should allow for the growth of a trust-based relationship between operators and technology
	Should be stable enough on the water to follow tracks despite wake waves or wind	Should have positive effects on the broader ecosystem	Human intervention must always be possible
	Should have enough force to be able to sail stable tracks, even with strong water flows and wind	Should not be an additional burden to VTS operators at busy times	There should be a stable and fast communication possibilities
		There should be a plan for physical intervention in case of malfunctions, ensuring that other waterway users are not inconvenienced	USV should be able to share live measurements with the surveyor to enable real-time monitoring
		The operator should be able to communicate via VHF with VTS operators and other maritime traffic	Should not require excessive multitasking

Figure 26: Requirements for the final design, identified through interviews, literature research, trend analysis, and contextual research.

7.3 Method

During the process, I obtained user insights from context visits, identified trends through a PESTEL analysis, and collected expectations and requirements for an USV from interviews with end users in the ecosystem. To base a final design of these insights, I made use of the value proposition canvas (Strategyzer, 2025). The value proposition canvas can be used to match user needs with solutions in order to create value for end users. First, I created insight cards from the context study and the interviews in Miro. I then used these insight cards to fill in a value proposition canvas for each group, which can be found in Appendix G. From this, several ways to alleviate the pains that workers currently experience emerged. However, many examples also surfaced where the implementation of a USV could make the work more challenging. Below, I will delve deeper into how an USV could impact the work of each group.

7.4 Results

7.4.1 Skippers

Figure 27 illustrates the benefits, risks, and possible risk mitigations of an USV, based on knowledge of their current work. It became apparent from observations that skippers can experience surveying long, quiet stretches as boring. An USV could take over this task and alleviate that "pain." Interviews also revealed that these areas are particularly suitable for USV implementation.

However, there is a risk: participants indicated that they find human oversight of the USV important. Supervising a USV that surveys long stretches is likely even more tedious than doing the task manually. A possible mitigation is for the surveyor, who is already monitoring the measurements, to also

keep an eye on the USV's tracks. The remote skipper would then remain responsible for communication with the VTS. Whether this is a viable solution or places too much pressure on the surveyor needs further investigation, as I would like to avoid stretching operational system too much (Bradshaw et al., 2013). Surveyors mentioned in interviews that they prefer to avoid multitasking, but when the environment is calm, this might be different.

Another insight from skippers was that they prefer working in the field. A major risk of implementing an USV is that a skipper would have to work from an office. While this risk cannot be entirely avoided in the case of remote control, it could be mitigated by alternating remote control with physical navigation in a hybrid setup. This could also help prevent skill degradation by up keeping manual control skills (Bainbridge, 1983).

Additionally, it became clear that skippers experience surveying in busy areas as intense. During observations, visible frustration arose when a skipper had to abort a measurement due to incoming traffic. A potential issue with the USV is that it would primarily survey in quiet areas, as indicated by interview participants. This would mean that human operators would be responsible for survey work in busy areas, as the USV would not be capable of handling these situations. As a result, the more complex tasks would remain with human workers. This aligns with one of the ironies of automation described by (Bainbridge, 1983). The final design aims to address this by deploying the USV when the port area is less busy. However, especially in the beginning, this will not always work seamlessly or be possible. Over time, the frequency of having to survey at busy intersections would be reduced as the USV becomes capable of surveying these intersections during periods of low traffic density.

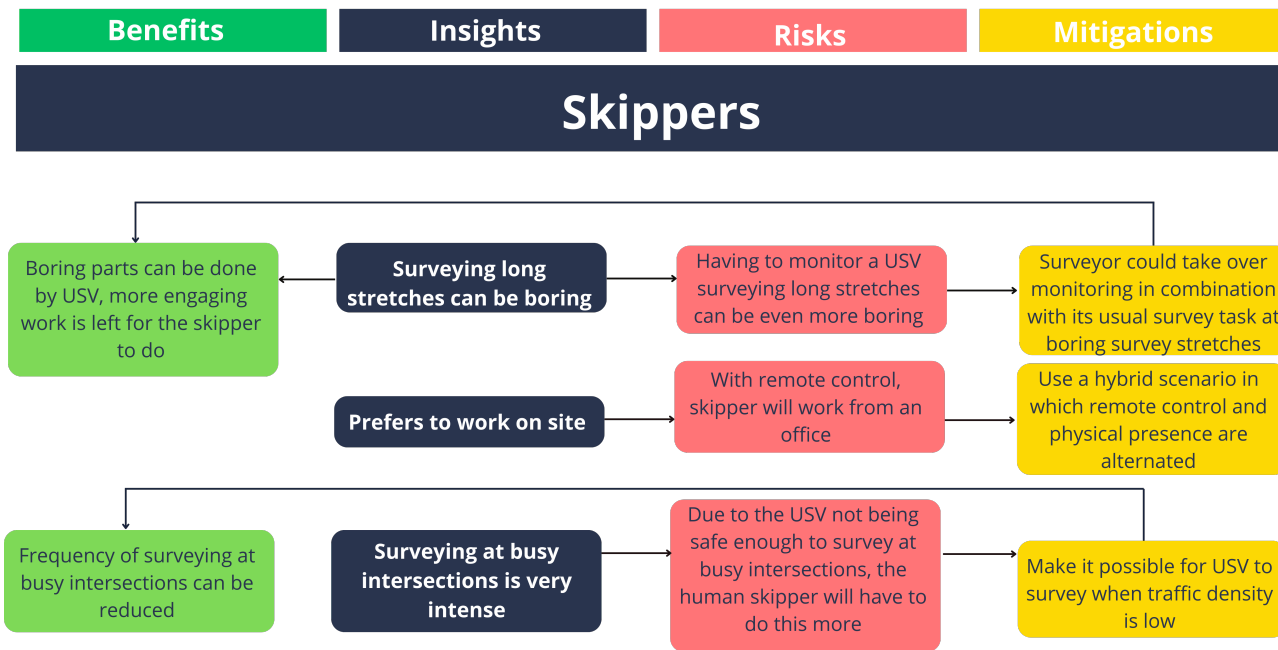


Figure 27: Benefits and risks based on user insights on skippers

7.4.2 Surveyors

The insights regarding surveyors, along with the associated risks and benefits, are shown below in Figure 28.

Surveyors expressed frustration with equipment failures and long repair times. A potential risk of implementing a USV is that the likelihood of technical malfunctions, especially in the early stages, may increase. This could be mitigated by fostering close collaboration between employees and technology providers, ensuring that technical issues are resolved quickly and effectively.

Additionally, surveyors find it problematic when prop wash interferes with measurements. Prop wash is caused by crossing traffic and frequently occurs at busy intersections. A risk of implementing the USV, besides the fact that, in the beginning, it may not yet be capable of avoiding prop wash on its own, is that surveyors might have to conduct more measurements at busy intersections because the USV is not yet able to do so. To prevent the same issue that arises for skippers, the USV must be capable of surveying busy areas during quiet periods.

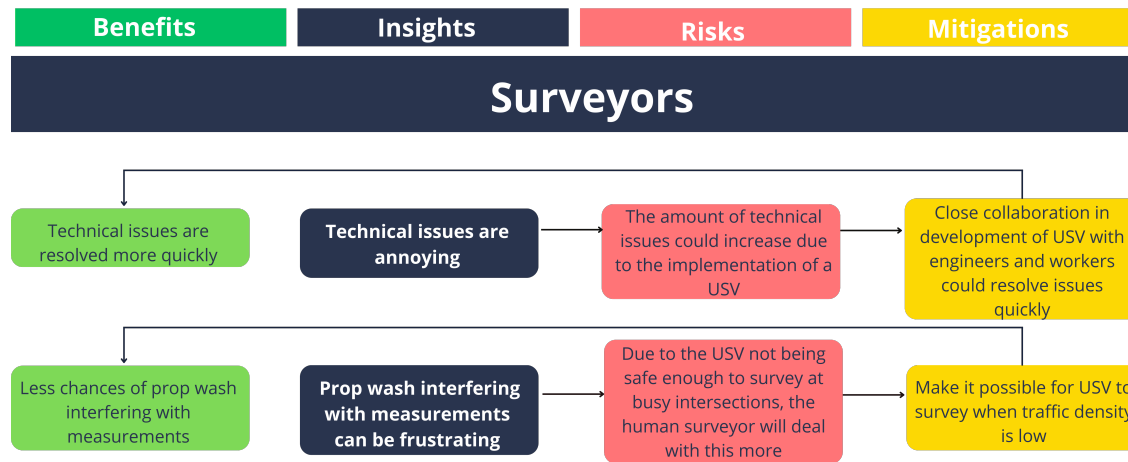


Figure 28: Benefits and risks based on user insights on Surveyors

7.4.3 VTS operators

The insights regarding VTS operators, along with the associated risks and benefits, are shown in Figure 29. VTS operators indicated that they often experience both overload and underload during their work, as traffic conditions can change rapidly. However, they also noted that some areas are frequently quiet, and at certain times, traffic remains low for extended periods. A potential risk of deploying a USV is that it could add an extra burden to VTS operators by requiring them to warn other vessels about its presence. This issue could be mitigated by deploying the USV during low-traffic periods, ensuring that it does not contribute to workload peaks. Many insights from observations with VTS operators were related to their limited insights on destinations of vessels. They mentioned that information was sometimes outdated or inaccurate and expressed a need for more insight into survey operations. Additionally, during shift handovers,

some traffic information can be lost. These issues could be alleviated if the USV shared its planned tracks live with VTS. However, a potential risk is that this could clutter the VTS operators' visual overview. VTS operators also emphasized the importance of fast and efficient communication, preferring to minimize repetition. This could be improved by visually sharing the USV's planned tracks, eliminating the need for VTS operators to repeatedly request the USV's intended location. Additionally, the need to repeat communications could be reduced if other vessels also had access to the USV's planned track. However, it is important to note that VTS operators prefer to receive confirmation from a vessel that the information has been acknowledged. This could become more challenging with an autonomous USV if there is no direct supervision. Currently, there are no clear guidelines for digital VTS communication. As a result, for now, a human skipper will need to continue handling communication with VTS.

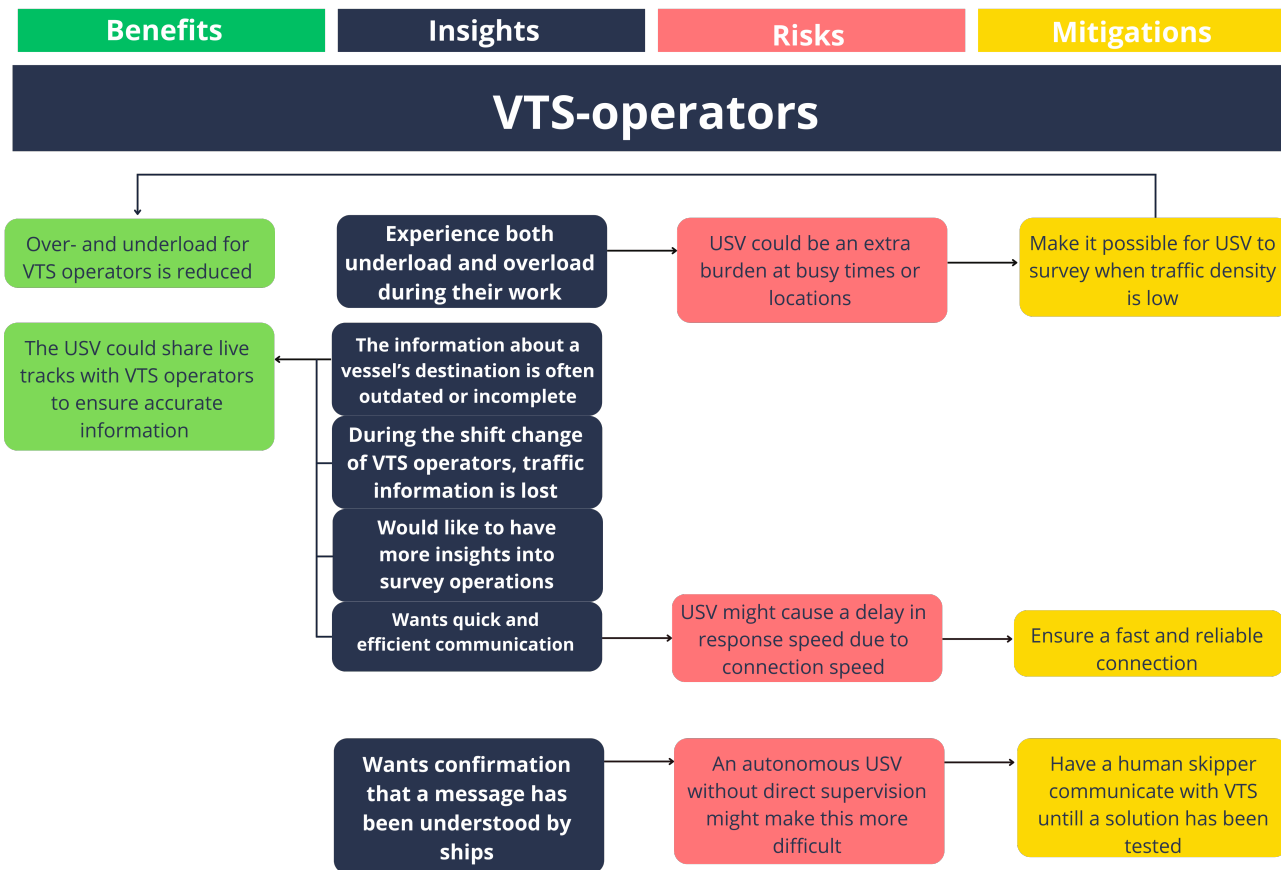


Figure 29: Benefits and risks based on user insights on VTS operators

7.5 Key insights

An often reoccurring value that could release pains of both surveyors, skippers and VTS operators was a more tactical deployment of survey vessels when traffic density is low (Figure 30).

This could be made possible by gaining better insight into current traffic situations and by having more flexibility in deploying survey equipment. Better insight into traffic situations could result from increased collaboration between VTS

operators, skippers, and surveyors during working groups on the implementation of an USV. Additionally, the planned tracks of the autonomous survey USV could be shared with VTS operators and other vessel traffic. This would enhance mutual understanding and allow VTS operators to anticipate traffic situations more effectively. More flexibility could be achieved through the use of remote control, which would eliminate the need for workers to physically travel to the survey vessel.

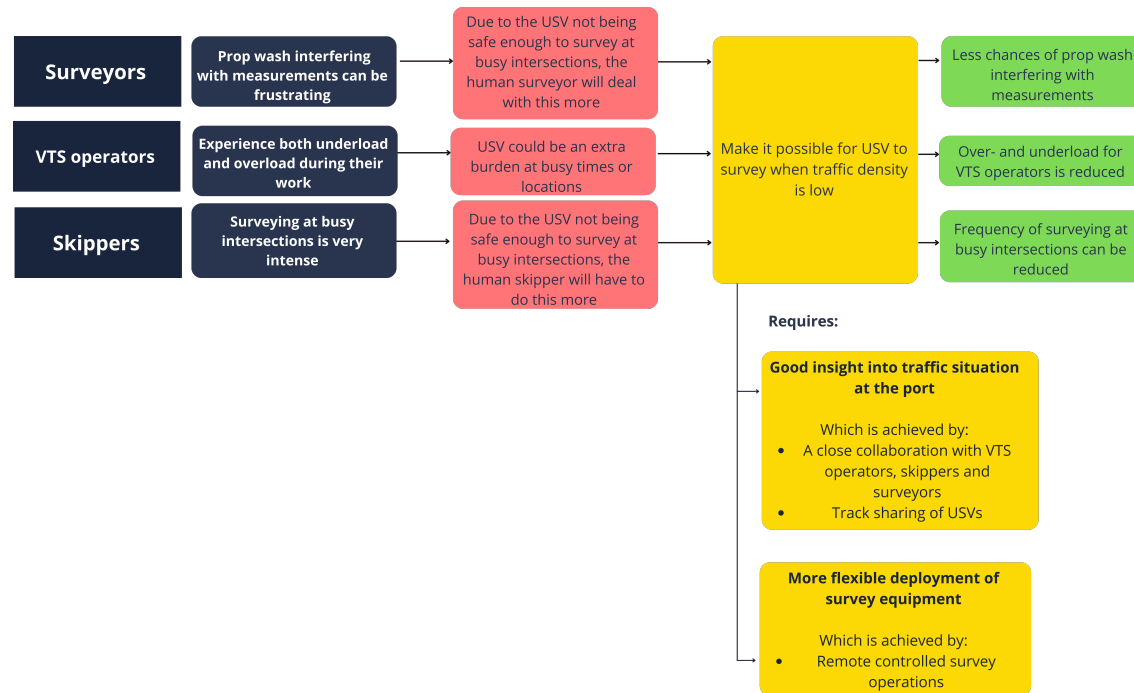


Figure 30: More tactical deployment of survey vessels

7.6 Conclusion

In this chapter, opportunities for a worker-technology fit were explored. At the beginning of the chapter, I discussed the importance of feasibility, desirability, and viability in creating a sustainable design. I then presented design requirements based on trend research, literature review, context analysis, and interviews. These requirements outline the minimum criteria a design must meet to be desirable, feasible, and viable.

Next, I explored opportunities for value creation based on insights into the current work of skippers, surveyors, and VTS operators. To do this, I documented insights from both the context research and interviews on insight cards. These insight cards were then used to complete the value proposition canvas for each group.

During this analysis, it became clear that the USV also had the potential to destroy value or negatively impact current work processes. These risks were identified, and strategies to mitigate them were proposed. The most valuable oppor-

tunity to both add value and reduce risks was deploying the USV at busy intersections, ideally during low-traffic periods. Additionally, for VTS operators, the ability to view the USV's planned tracks could provide value.

7.7 Next steps

From the scenarios in chapter 6 it became clear that an USV itself for surveying offers little advantage over the current survey vessel. The main operational advantage of an USV in the port is the possibility for more flexible deployment, which allows for surveying at quieter times. This would relieve the burden of surveying in high traffic environments for skippers and surveyors and help with over- and underload with VTS operators.

Therefore, I will design a system of human roles and USVs that will allow for a more flexible deployment of survey equipment, making it possible to survey on times in which there is less vessel traffic by 2035. This scenario should be in line with the design requirements presented in Figure 26.

8 Final design

8.1 Introduction

In this chapter, a possible scenario will be presented based on the opportunities for value creation and the requirements established in Chapter 7. Alongside the scenario, high level guidelines are presented that could be used during the implementation based on insights from interviews with workers. Finally the design and guidelines are validated with members from the innovation department.

8.2 Final scenario

A remote control scenario was chosen to allow future scalability and flexibility. A remote skipper is responsible for overseeing the USV and communication with the VTS and a surveyor is responsible for the measurement quality. Traditional survey operations will also continue to be carried out in parallel. The reason for choosing this hybrid approach, in which the current working method is combined with a fully remotely controlled USV, is based on the fact that skippers have expressed a preference for also working in the field. Additionally, interviews revealed that people need time to adapt to technological changes, making this the most logical scenario for now. According to (Hynnekleiv & Lützhöft, 2022) it is important to allow for a trust based relationship to grow between technology and human operators. It is also important for human operators to have a full understanding of system

capabilities and limitations to prevent over or under trust in the technology (Hynnekleiv & Lützhöft, 2022)(Calvert et al., 2024).

In the beginning it is important to grow get a feel for the technology in a safe to fail environment. Workers also emphasized the need for physical presence, in case of system failure. As many places in the port are not accessible by trailer, a conventional survey ship will tug the USV towards a survey location. However the remote skipper and surveyor will not be present at the survey ship. The remote skipper and surveyor will independently carry out surveys with the USV, but the conventional vessel will also be carrying out surveys in a nearby area. In case of system failure and at the end of the survey, the conventional survey vessel can pick up the USV. In order to achieve this, quick communication between the remote team and the physical team must be ensured. This might also require some extra planning beforehand. The remote team and the physical team must switch sides frequently, to experience working with the retrieval of the vessel and with remote control. For VTS operators, tests could begin by visually presenting planned USV tracks. In order to get more insight in when, where and for how long VTS operators experience underload during their work, a close collaboration between the surveyors and skippers testing the USV and VTS operators willing to think along in the implementation must be established. A visualization of the scenario is shown in Figure 31.

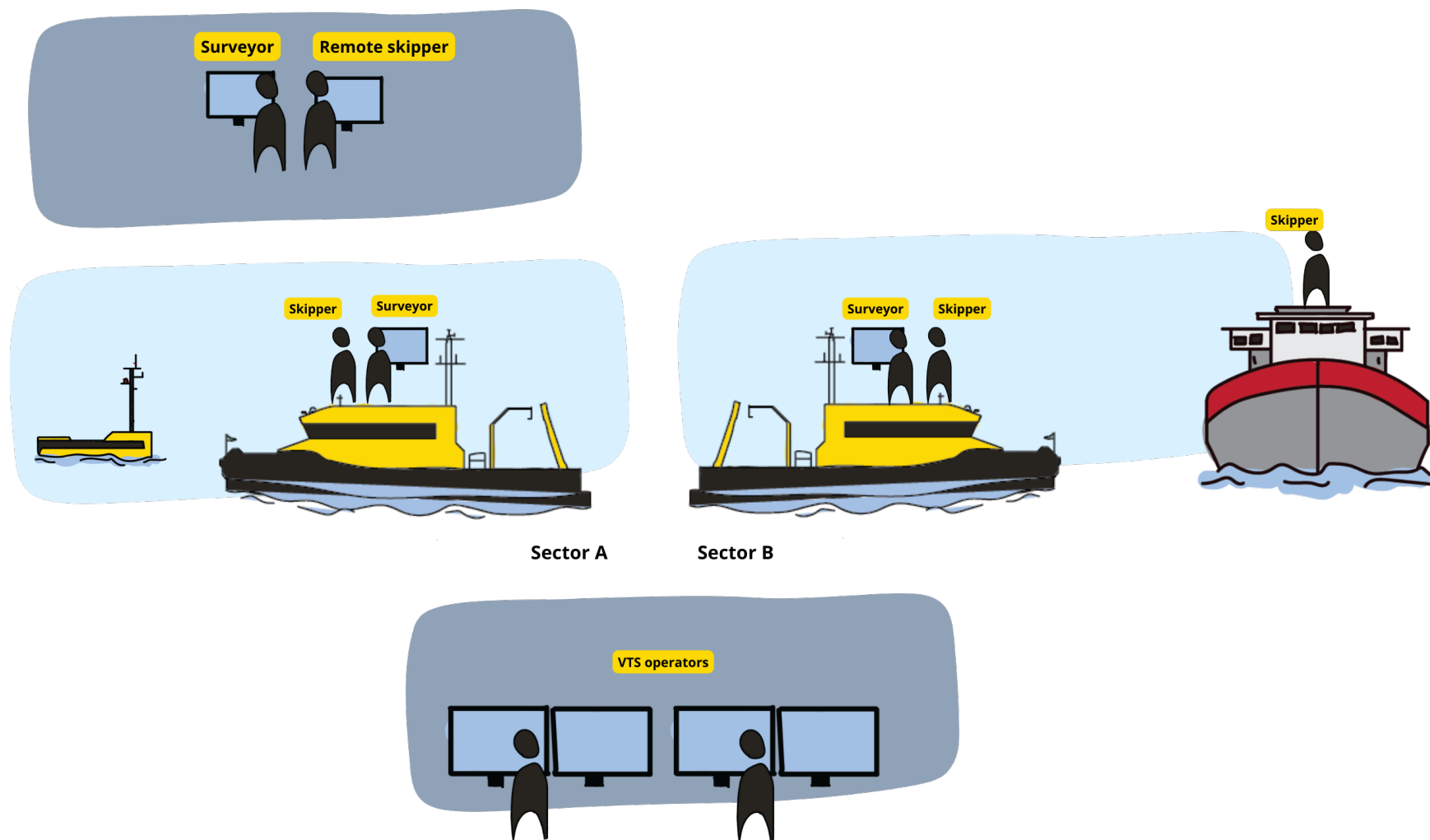


Figure 31: Hybrid scenario with physical human presence

If there is enough trust and understanding in the system to be self sufficient in case of a lost connection (which can happen frequently in the port), test with full remote control can start. This does require, remote docking and barging to be efficient. If this is successful, or if remote operators experi-

ence to much boredom due to monitoring the system, there could be try outs with multiple USVs. However, this should be up to the remote skipper and surveyor, as multitasking is currently undesired. A visualization of this scenario is shown in Figure 32.

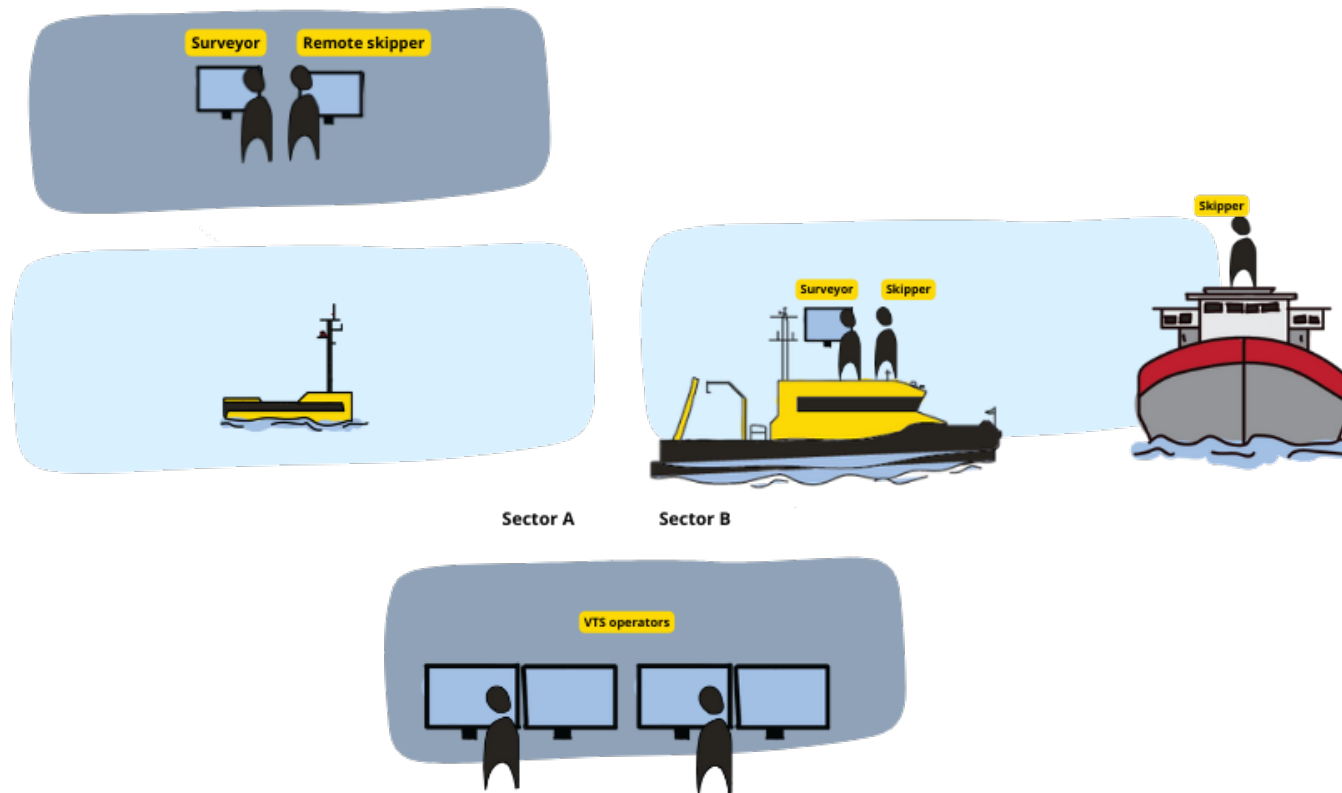


Figure 32: Hybrid scenario without physical human presence

If there is enough trust and understanding in the system to conduct unsupervised surveys, and achieve sufficient measurement quality, the USV(s) could be deployed around the clock. A surveyor could check the data afterwards remotely. The downside of operating, for example, at night is that no remote operator would be able to monitor the USV or ensure the quality of the measurements. However, a VTS operator would always be present to oversee the sector, though they

are not intended to be responsible for the USV. They would warn other traffic about the USV's presence. The port authority has initiated a digital VTS program this year, which aims to establish guidelines for digital communication. The USV would need backup systems and should be capable of handling unexpected situations independently while also maintaining communication with VTS operators. A visualization of this scenario is shown in Figure 33.

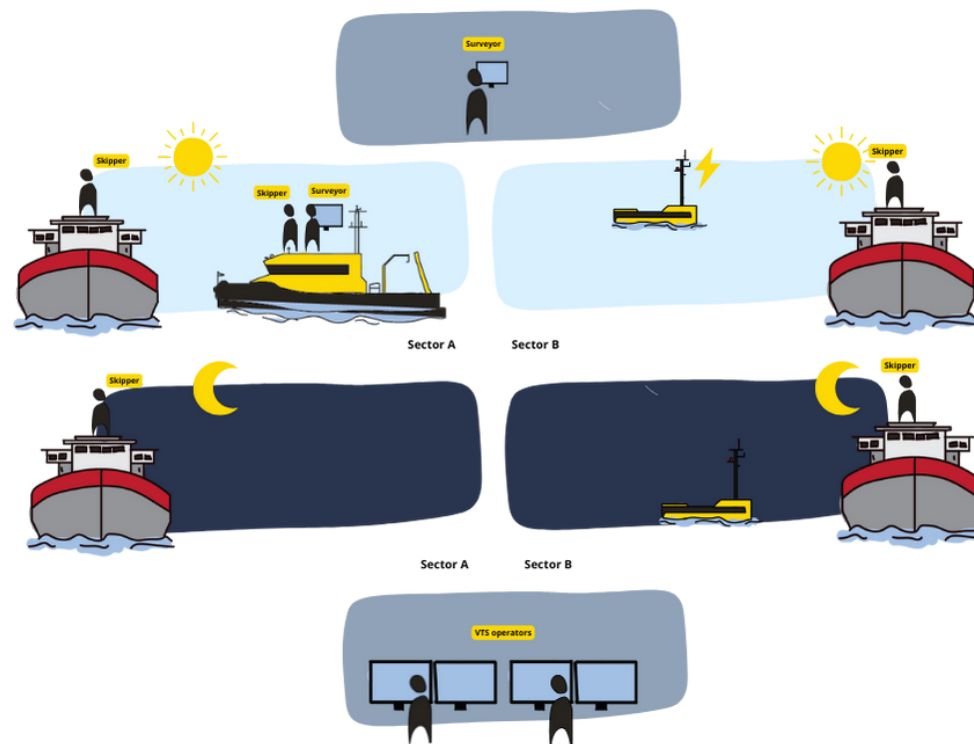


Figure 33: Hybrid scenario without physical human presence

An overview for the implementation is shown in Figure 34.

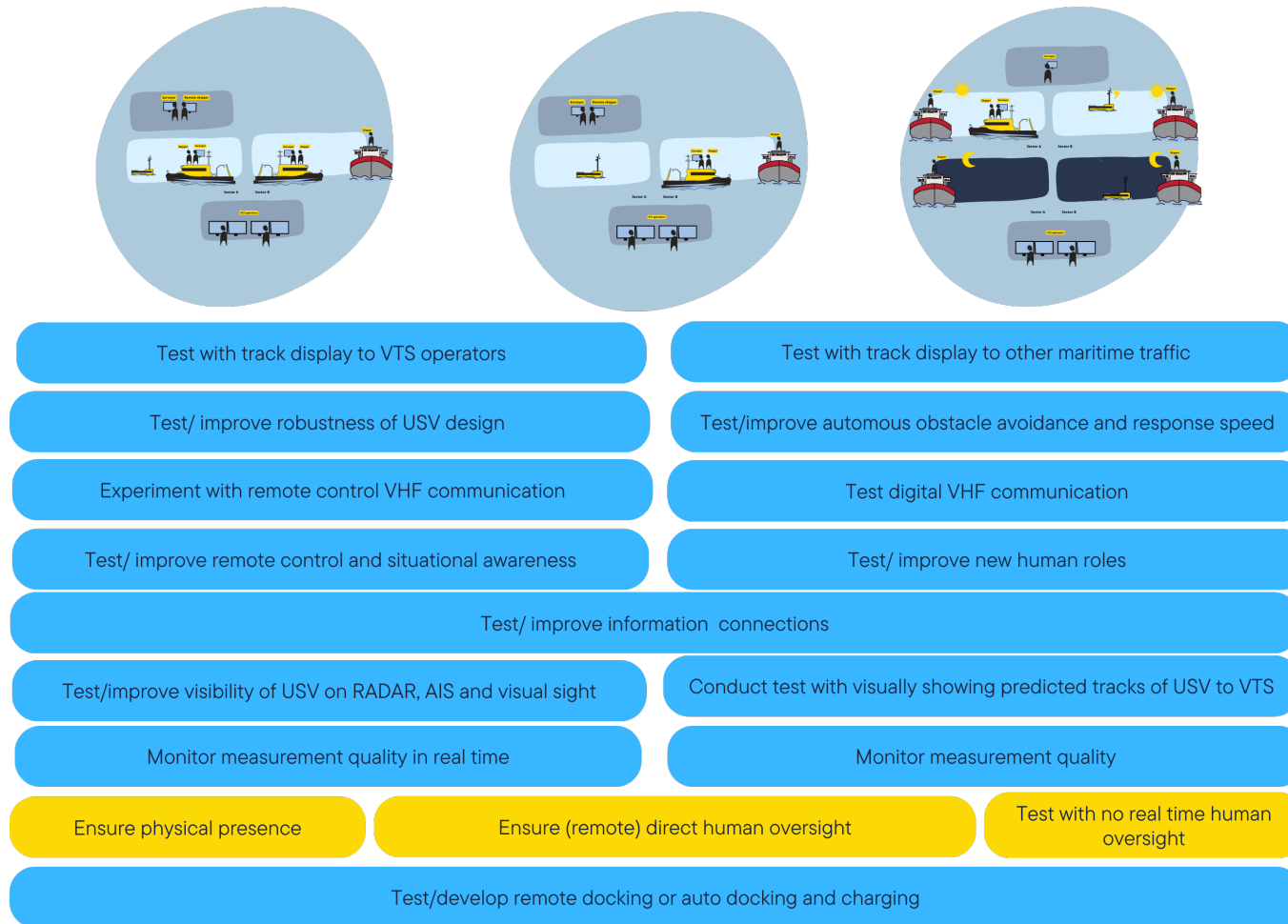


Figure 34: Implementation guide for USV

During the implementation, it is important that the following requirements that VTS operators, skippers and surveyors stated during the interview are met (figure 35)

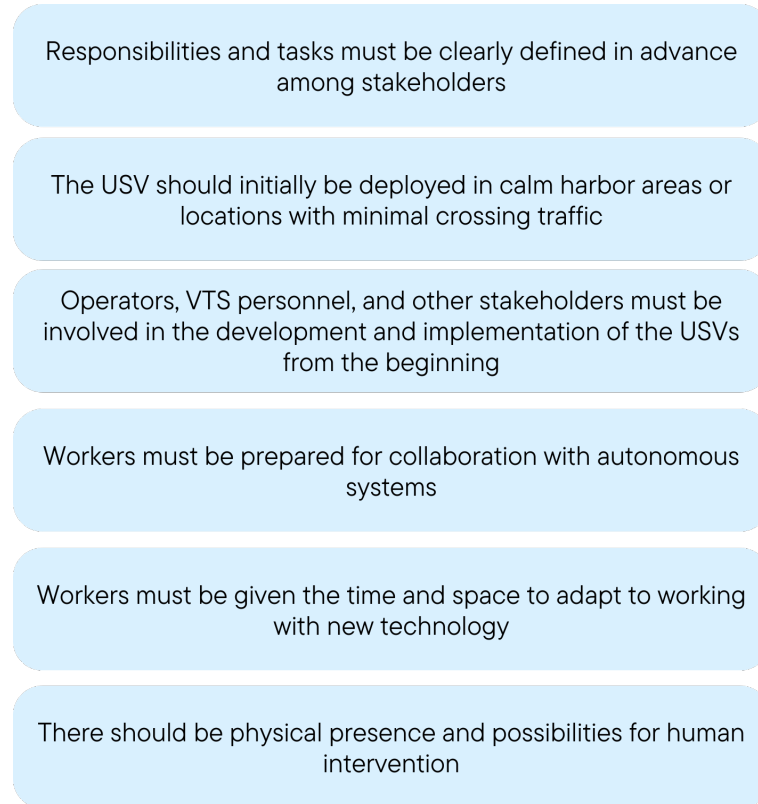


Figure 35: Workers requirements of the implementation of USVs

8.3 Validation

The project outcomes and guidebook were validated in one-on-one sessions with members of the innovation team. The purpose of these sessions was to determine whether the outcomes were valuable and if the approach is desirable, feasible, and viable for application in the early stages of automation projects in the port area.

8.3.1 Method

I will validate the guidelines and outcomes with different members from the innovation department through semi-structured interviews. Some members were involved with autonomous shipping, however this was not considered to be a requirement to participate in the validation, as they could encounter future automation related projects in their career. Table 5 shows the participants that have been interviewed and their titles.

Participant	Title
P1	Innovation lead
P2	Program manager
P3	Innovation lead
P4	Program manager

Table 5: Overview of participants

First, I wanted to validate the desirability of the results for the innovation department. In order to achieve this, I brought printed versions of the two future scenarios (Figure 21 and Figure 22) I had showed to participants of the interview study as well. I then asked the participant to write down what they would expect the advantages and disadvantages of each scenario to be from the perspectives of VTS operators, skippers, and surveyors. Additionally, I asked them to list what they thought surveyors, skippers, and VTS operators would

consider essential requirements for an USV in the port area. The reason for this was to reflect on how the insights from the study would be novel to the members of the innovation department.

Next, I shared the research findings and examined how well they aligned with the participant's expectations. This was followed by an open discussion with each participant, in which I explained the results in more detail. Afterward, I presented the final scenarios and assessed whether the innovation team members found these useful.

After this, I presented the guidebook that could be followed to achieve these results. Even if the outcomes are considered desirable, it is also important to assess whether the process used to obtain them is feasible and viable for practical implementation.

During the validation sessions, physical notes were taken. To analyse the insights, the notes were put into Miro and clustered based on meaning. This process is shown in Figure 36.

Step 1: All insights were put in Miro

Step 2: The Insights from each participant were clustered based on meaning

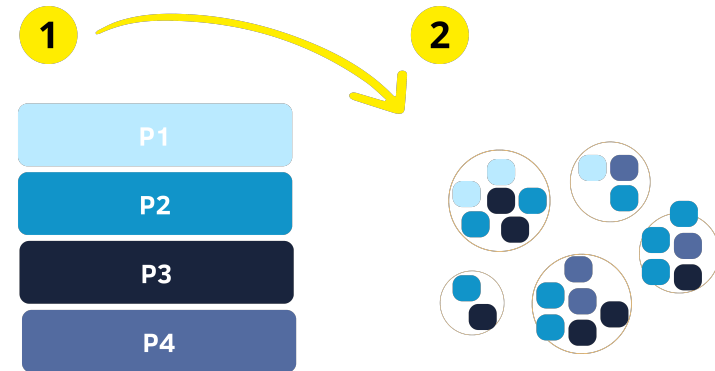


Figure 36: High level overview of the data analysis of the validation sessions

8.3.2 Results

Results related to project outcome

When presenting the scenarios, some participants questioned why VTS operators were involved in the scenario, as they were not considered relevant stakeholders since they are not direct end users of the USV. There were also questions about why other ships were included in the scenarios. Participants thought that the skipper would feel useless in the mothership scenario because a second boat would be deployed. Their expectations were that the surveyor would have a positive attitude toward the USV, as it would provide more data, allowing for better analyses. They expected that the VTS operators would be sceptical about the amount of work involved, as it would likely result in additional communication rather than added value.

Regarding the full remote control scenario, members of the innovation team expected the following reactions from workers: They expected that skippers would be more positive about this setup since their work would remain the same but be organized differently, preventing them from feeling useless. A potential drawback they anticipated was that the skipper would not be able to work on the water. They expected that surveyors would view this scenario positively, as remote control could improve the speed of data collection. For VTS operators, they expected this scenario to be more favourable as well, as it would establish a direct communication line.

From this, it became clear that the research provided new insights for members of the innovation department. Some insights, such as the skippers' preference for working on the water, were expected, but practical insights, such as the need for VTS operators to gain more visibility into the working area of survey ships, were new.

Members stated that the findings from following the guide-

lines were novel to them and important to consider during the implementation of the USV, as the needs of end users must be taken into account. Regarding the final design, members of the innovation department raised questions about what times the port could be quieter, given that the port operates 24/7, unlike a highway.

In the final scenario, it was mentioned that the additional surveyor might no longer be needed to validate the data, as this could be automated. An alternative implementation sequence was proposed in which the uploading and validation of measurement data would first be automated, followed by the deployment of the USV.

Furthermore, the first scenario of the final design received feedback. The hybrid use of the survey vessel and the drone could potentially create an additional burden for the surveyors physically present on the ship. It was suggested that, if this turned out to be the case, the issue could be resolved by using a completely separate vessel for the USV or by transporting the USV to the survey location by car during the initial phase.

Results related to guidebook

Members of the innovation team saw no reason not to refer to the guidelines when starting an automation project. Reasons for using the guidelines were that they outline step by step what needs to be investigated to determine desirability. As an improvement, they suggested that, in addition to desirability, they would also like to gain insights into feasibility and viability, as this aspect was currently lacking. The business model canvas was mentioned to achieve this.

Additionally, it was noted that the guidebook was theoretical. It was unclear from the guidebook who the intended user is. One suggestion to make the guidebook more practical was to include prompting questions.

Furthermore, there appeared to be confusion around the

meaning of automation, autonomous navigation, and robotization. Participants held different definitions, which led to confusion when interpreting the approach. For example, the implementation of a USV was seen by some as robotization, which they believed would lead to a fully autonomous port. According to others, automation referred more to the simplification of processes, the support of human work, and was more digital in nature. Still, there was uncertainty among other participants about the level of autonomy of the USV. It was noted that the USV was not fully autonomous, but rather a hybrid form, as full autonomy in a specific operational domain would mean no human involvement at all. These varying interpretations of automation or autonomous technologies among innovation team members could lead to miscommunication when using the guidebook.

For participants who had not previously been involved in the project, the visuals of the scenarios were unclear. Comments were made suggesting that a legend should be added, as the diagrams were otherwise difficult to understand. It was also confusing that the operator of the survey vessel was referred to as “skipper,” while operators of other ships were also called “skipper.” Additionally, one participant misunderstood the social network map, thinking it referred to digital data flows rather than the execution of survey mea-

surements.

8.4 Conclusion and limitations

In this chapter a final design for a future scenario alongside implementation guidelines according to insights from interviews with workers. The final design includes a hybrid scenario in which a remote controlled USV with autonomous functions is deployed with the regular survey vessel. The main advantage of the USV would eventually be a more flexible deployment of survey equipment which should make it possible to survey at more strategic times when vessel traffic is low. However in order for this to be achieved, auto docking will need to be developed and further research will need to be done to determine which locations are usually quiet on what times. This will have to be done in close collaboration with VTS operators as the USV should be deployed when they experience under load.

Finally the results are validated with members from the innovation department. From this it became clear that following the guidelines has brought new and valuable insights about the attitudes and experiences of VTS operators, skippers and surveyors on implementation of a USV. An overview of the insights can be found in table 6.

Feedback type	Feedback related to project outcome	Feedback related to guidebook
Positive feedback	Research resulted in novel and tangible insights.	- Guidebook was seen as useful for exploring desirability. - Provides a clear step-by-step approach to identify what should be investigated.
Improvements	- Concerns about feasibility due to 24/7 port operations. - Suggestion to automate easier tasks first, like data upload/checks. - Independent testing proposed instead of hybrid use.	- Lacks tools for assessing business viability. - Unclear target audience. - Scenario visuals unclear. - Terminology caused confusion.

Table 6: Feedback on project outcome and guidebook

A major limitation of the study was that, for some participants who were not directly involved in the project, the guidelines were not immediately clear. As a result, much of the feedback was based on misunderstandings and could not be used.

Additionally, a significant part of the conversations focused on explaining the terminology used, as participants often attached different meanings and interpretations to these terms, which caused further confusion.

Moreover, I did not send the guidebook to participants in advance, and each validation session lasted approximately one hour. This meant there was not enough time for participants to thoroughly read through the guidebook. Based on the feedback of members of the innovation department, the guidebook went through a final iteration. In this iteration, a clear definition of automation was included, a target audience was defined and prompting questions were added.

9 Discussion

9.1 Introduction

In this chapter a summary of insights will be given. After this, the academic and practical contribution of the project will be highlighted. I will also discuss the generalizability of the study, go over limitations and finally discuss future research directions.

9.2 Summary of insights

9.2.1 Analysis of the macro environment

A PESTEL analysis was conducted to get a complete picture of the factors influencing the adoption of autonomous shipping. This analysis shows the following: Efforts are being made to regulate autonomous shipping and digital VTS communication. From 2025, crewless navigation will be allowed in the Netherlands, likely accelerating the development of unmanned surface vessels (USVs). Technological advancements in autonomous shipping are moving fast. Many initiatives demonstrate that autonomous shipping is becoming a reality, for example the use of shore control centers. At the same time, there are (cyber)security risks, such as AIS and GPS spoofing. From a socio-demographic perspective, there is a labour shortage in the Netherlands. This can be seen as an opportunity for autonomous shipping, as it can contribute to more efficient operations. However, a potential barrier to adopting (semi-)autonomous vessels is the conservative nature of the maritime sector.

9.2.2 Literature research

Previous research shows "automation pitfalls" that can result in harmful outcomes, including reduced job satisfaction. These pitfalls are: The false idea that automation substitutes human work, an overemphasis on technology, and a disconnect between designers and workers.

When automation is adapted to a real world context, there are several factors that influence whether or not people accept the new technology. These factors are the perceived necessity, perceived risk and perceived benefits of the technology.

For complex and unpredictable environments like ports, a collaborative relationship between humans and ships with autonomous functions is desired over fully autonomous ships. As autonomous ships become more widely implemented, the literature expects a shift from offshore to on-shore work in which autonomous ships will be remote controlled or monitored from shore control centers. In this transition, operators' work is expected to shift from an active role to a backup role. In this shift it is important to take some direct factors into account, like situational awareness, engagement and trust that need to be taken into account. If these factors are not managed well, undesirable effects like job dissatisfaction and dangerous situations could arise. Besides direct factors, autonomous shipping also leads to ripple effects on its environment.

To avoid the pitfalls mentioned above, workers should be included early on, collaboration with workers should be prioritised over the substitution of workers and the impact of the technology on the broader context and social relations need to be considered. Multiple methods, like human-centered design and participatory design are mentioned to integrate human operators in the design process. To realize these methods effectively it is important to involve users early in the design process and to take into account ripple effects.

9.2.3 Identify key workers in the current process and understand the broadness of their work

A social network map of the broader ecosystem in which hydrographic survey operations take place was created. In this ecosystem, the skipper and surveyor have verbal communication with each other and communication through the interface of the survey software. The skipper sees other ships on the radar, navigational maps and through visual sight. He also hears other skippers talk through the VHF channel, but does not communicate directly with the other ships. Communication about incoming traffic, destinations and special manoeuvres is done through the VTS operator of the sector. VTS operators are constantly anticipating situations in which ships could come into conflict. In order to be able to predict the situation properly, the VTS operator needs to have reliable information on the destination of each ship and the confirmation from skippers that they have understood his instructions, which is often lacking. The VTS operator is in contact with the skipper through the VHF. Survey vessels are also marked as blue to not lose them out of sight, which can occur in hectic situations. The skipper of the survey vessel is responsible for navigation and complete coverage of the area that is to be surveyed. Because survey ships sail against the usual flow of traffic, it is important to stay alert for upcoming ships. If a ship is approaching, the survey work must be broken off and continued when the water is calm again. The work is experienced as intense at busy intersections with a lot of vessel traffic. The skipper is working closely together with the surveyor, which is present at the same ship. The surveyor is responsible for the quality of the measurements and decides what parts of the port are measured during the week, according to the ship planning. The surveyor dislikes it when issues with the data occur.

9.2.4 Understand workers expectations of automation

During the interviews, specific characteristics of the port area were mentioned, such as traffic density and complexity. It was also suspected that the implementation of a USV would change the work, with both positive and negative effects expected, depending on the scenario.

Additionally, Participants express concerns about the implementation of a USV related to limited benefits, the need for additional personnel, stability, traffic density, regulations, reduced control, and communication issues. At the same time, USVs could offer advantages such as compact size, better accessibility, and increased efficiency.

Finally, participants outline the requirements USVs must meet to operate effectively in the port. These include a certain degree of autonomy, a clear visibility for other traffic, clear communication, sufficient situational awareness with remote control, sufficient battery life, the importance of physical presence and a calm operating area.

For the Implementation participants voiced the need for collaboration, organizational culture, and a phased approach.

9.2.5 Explore worker-technology fit

From the value proposition canvas, it became clear that a hybrid scenario is necessary to allow skippers to also work in the field. Additionally, it is important that workers closely collaborate with development teams to quickly resolve technical issues with the USV. Since there is currently no digital VTS, a human skipper must remain in direct contact with a VTS operator for now. Here, communication delays must be prevented. A potential advantage for VTS operators is that the USV could share its tracks in the future, but to make this effective. The USV must also be able to operate in areas with high traffic density. One way to achieve this is by leveraging the flexibility of remote control, ensuring that the USV

is deployed in these areas only when vessel traffic is low. This would prevent VTS operators from being overloaded by the USV during peak times. It would also ensure that skippers do not have to conduct surveys mainly in busy areas because the USV cannot do so, and that surveyors do not receive poor-quality data due to prop wash disturbances from other vessels.

9.2.6 Final design

The implementation of USVs in the port will follow a hybrid approach. Which will combine remote operation with physical human presence. This phased transition aligns with stakeholder preferences to work in the field and to have physical oversight. It also allows for gradually building trust and understanding of the capabilities and limitations of the USV. In the initial phase, a remote skipper will oversee the USV and handle communication with VTS, while a remote surveyor ensures measurement quality. Traditional survey vessels will continue to operate alongside the USVs to keep physical presence in case of emergencies and to transport the USV. Effective communication between remote and physical teams is essential. And frequent role-switching is desired. As confidence and understanding of the system grows, full remote control tests can begin. In a further scenario, USVs could operate round-the-clock without direct human oversight. To achieve a successful transition, responsibilities and tasks must be clearly defined, workers must be prepared for working with the USV and, workers must be given time and space to adapt and workers must be involved in the development of the USVs.

9.3 Contribution

The research has an academic contribution, as well as a practical contribution.

9.3.1 Academic contribution

Contribution to human-centered design research

This study contributes to academic literature on human-centered automation by providing a four step approach to including worker perspectives in automation projects from the start. By doing this, it contributes to the current understanding of how human-centered design methods can be operationalized in complex, multi-stakeholder environments like ports. Another academic contribution is the use of speculative scenarios to understand workers expectations about the future of work. By doing this, the study provides an example of how speculative design can serve to uncover expectations and experiences while doing design research. By doing field observations and using these insights to uncover potential value creation for workers, the study demonstrates how contextual knowledge of work can guide design decisions in multi stakeholder systems. Lastly, the thesis contributes on how technological or business ambitions are to be balanced with workers needs.

Contribution to human computer interaction research

The thesis provides a practical example of what human-robot collaboration can look like in a real-world, multi-stakeholder context. For example, the study provides insight into how workers, a group often under-represented in the development of autonomous technologies, perceive the value, risks, and trade-offs of USVs. Additionally, the thesis contributes empirical insights by exploring what workers expect

from automation before it is implemented. Whereas previous studies mostly looked at the effects of automation after deployment, this study shows how workers anticipate its impact during the early stages. This is particularly relevant for socio-technical design, where human needs must be explored alongside technological development. It also shows how robots like USVs need to adapt to existing human work, highlighting the requirements for integrating automation into existing socio-technical environments.

9.3.2 Practical contribution

The innovation team has gained insight into how the negative consequences of automation on the broader ecosystem and the quality of human work can be avoided. At the same time, it has become clear how automation can actually add value for key actors within the ecosystem, such as skippers, surveyors, and VTS operators, by addressing the challenges they face in their work.

In addition, the innovation team has developed a better understanding of what workers consider important for an USV to operate successfully in the port area. These insights are based on interviews with workers who have hands-on experience in this work environment. There is also a clearer picture of what they find important when implementing automation.

To ensure that this approach can be replicated in the future, the innovation team has received a guidebook with a concrete approach. The guidebook offers a practical translation of human-centered design principles that can guide innovation teams at the start of automation projects. This will enable them to consider workers perspectives and the effects of automation on the broader context.

9.4 Generalizability

The findings of this research are relevant for organizations looking to automate in complex, multi-stakeholder environments such as ports.

The approach is applicable in the early stages of an automation project when automation seems desirable and may even be seen as an end goal. This is especially relevant if automation has not yet been implemented in the specific context and the technology to automate the process is available but may not yet be fully developed.

9.5 Limitations

Due to time constraints, it was not possible to fully immerse in the work of the involved professionals. Observations were limited to a single day or afternoon, and there was no opportunity to collaborate further with users and the innovation team in a joint session, even though this could have been highly valuable. Additionally, only a limited number of people could be interviewed, not only due to time constraints but also because there were few available respondents. Hydrographic surveying is a niche field, which meant that finding interview participants was challenging.

As a designer, I had a bias during the interviews and observations, partly because I knew in advance that my research would focus on automation. For this reason, I find it important to emphasize that it is always crucial to critically assess whether automation is truly necessary in a specific context. This is especially relevant because, in this case, the perceived value of automation was primarily in mitigating potential negative impacts on work rather than in direct improvements.

Additionally, at times, the research felt like a 'technology push.' Initially, I conducted trend research, which led me to discover that an USV would likely be implemented. Based

on this, I developed scenarios that incorporated this USV. As a result, it felt as though the technology was once again placed at the center, and the human roles were designed around it, which sometimes felt somewhat misaligned.

No official expert interviews were conducted, as the focus of this research was on incorporating the perspectives of human workers in the early stages of automation projects. However, involving more experts could have been beneficial in gaining a better understanding of the actual feasibility of USVs. Consequently, the final scenario may not fully reflect the technical and practical feasibility of USVs.

Finally, the research consisted of a single case study within the port area. As a result, the generalizability of the study is limited.

9.5.1 Reflection on project approach

To arrive at the final scenarios, I followed a four-step process. Afterwards, I documented these steps as a project approach and developed them into a guidebook. In this reflection, I will discuss how I arrived at these steps and how things could have been done differently. According to validation sessions with members of the innovation team, the guidelines could be made more practical by adding probing questions. Additionally, by incorporating the Business Model Canvas, the approach could consider not only desirability but also viability.

In the first step, I could have chosen a more methodical approach to identifying stakeholders. There are several methods available to assess which stakeholders are most affected by the change and which hold significant influence or opinion. This is a crucial step that I primarily carried out based on intuition. A more structured approach would have benefited both my own process and the applicability of the guidebook. Furthermore, I did not investigate what effect involving other stakeholders might have had on the outcomes.

In the second step, I visited workers. In practice, this step overlapped with the first, as I validated my information flow with the workers during these visits. At the same time, I observed their work. While this yielded many insights, it did not provide the depth of understanding that could be achieved by shadowing workers over multiple full workdays. As a result, the findings may still present a simplified version of their actual work. During validation, I sent my results to participants. Although they confirmed the accuracy of the findings, they also noted that it did not yet fully capture the complete picture of their work. It would be interesting to shadow workers over a longer period to gain deeper insights.

Additionally, I chose to use journey mapping to present the results. However, other methods could also have been used, such as personas. I have not yet explored these alternatives within my research.

In the interviews, I aimed to uncover workers' expectations of automation using fictional scenarios. In the literature, exploring workers' expectations of automation is not explicitly described as a formal method. While the interviews did reveal expectations, they did not lead to a co-created vision of a desired future with the workers. This could be a valuable method to try. Moreover, the scenarios I created may have been too guiding. For example, many comments were about the size of the USV. In the scenarios, it was depicted as fairly small, although this does not necessarily have to be the case.

In the fourth step, I looked at how value creation could be added or taken away through the implementation of a USV. To do this, I used parts of the value proposition canvas. However, there are other approaches that could have been used as well, such as a future wheel workshop. Due to time constraints, I carried out this step on my own, while it could have been very valuable to do this together with workers.

9.6 Future research directions

It would be interesting to validate the final scenario not only with the innovation team but also with technology providers, experts, and workers. Based on their insights, an additional iteration could be conducted, followed by pilot tests to further assess practical applicability.

This project specifically focuses on the early phase of automation projects. A valuable next step would be to explore

in a long term study how workers' perspectives can be incorporated throughout all phases of a project and which methods are most suitable for each phase.

Additionally, it would be interesting to apply the approach to other complex multi stakeholder environments, such as large airports. This would not only help address the limited generalizability of the current findings but also refine and expand the approach based on new insights from different sectors.

10 Conclusion

The aim of this thesis was to explore how a human-centered transition to a more automated work environment can be ensured at the start of automation projects. To investigate this, a case study was conducted in a major Dutch seaport. In this port, the transition towards a more automated work environment is planned but has not yet taken shape.

According to the literature, several pitfalls can hinder successful automation. First, automation is often perceived as a substitute for human work, leading designers to overlook how automation impacts the overall functioning of the system and neglect human factors in the design process. However, in practice, human work will always coexist with automation. Second, there is often too much focus on technical aspects, which causes the broader implications for the surrounding environment to be ignored and results in a failure to design for human work. Third, there is a gap between designers and workers, leading to an oversimplified understanding of human work and the implementation of technolo-

gies that do not align with workers' needs.

To address these issues, workers must be involved in the design process from the beginning through human-centered design methods. Additionally, the broader implications of automation must be understood.

This thesis translates these principles into an approach consisting of four practical steps and applies them to the case study. First, the ecosystem and information flows must be mapped out. Next, designers must gain an understanding of the full scope of human work through context research. Then, workers' expectations regarding automation in their specific context must be explored, which can be achieved through interviews and the presentation of fictional future scenarios. Finally, research should be conducted to determine how automation can add value for workers compared to their current tasks. The value proposition canvas serves as a valuable tool to visualize this value creation.

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Appendix A

In this appendix, the initial (anonymous) stakeholder maps can be found.

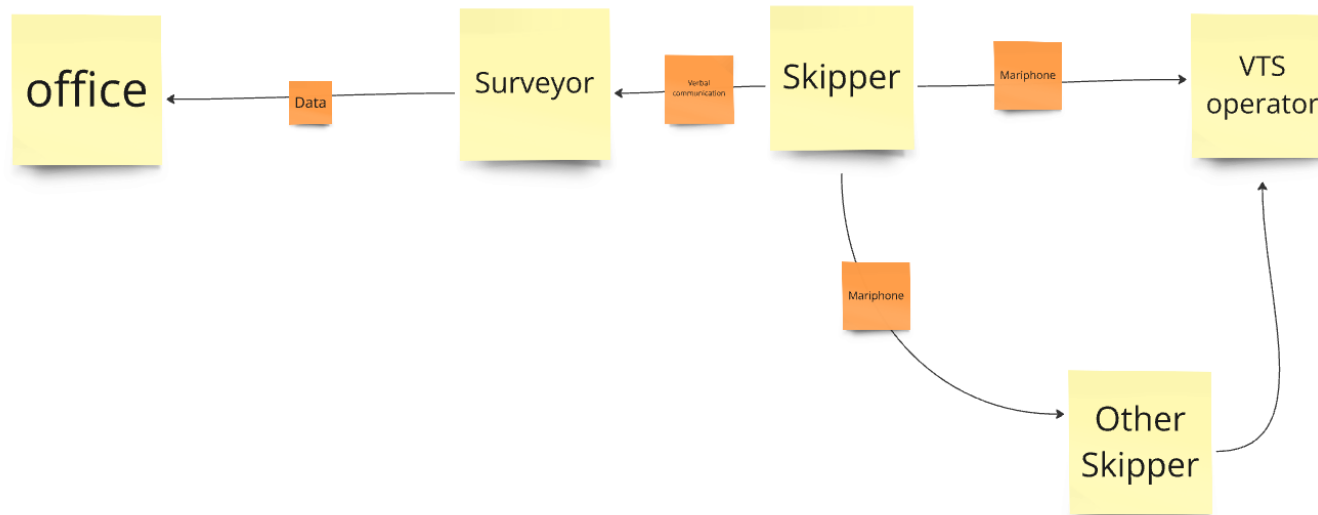


Figure 37: Initial stakeholder map of hydrographic survey operations

Appendix B

Hydrographic surveying

Hydrographic surveying is a process in which the port's seabed is mapped. Based on this information, it can be determined whether the port needs dredging.

In total, the port authority has three survey vessels, one of which is owned by an external skipper who has been carrying out survey tasks for the port authority for several years. Pictures of a survey vessel can be seen in Figure 39. The survey work is divided into two sections of the port. In the port, 500km² are surveyed every year through +/- 1500 individual surveys (Port of Rotterdam, 2024c).

One survey vessel is stationed at Maasvlakte and operates from Maassluis to the sea, while the second survey vessel is stationed at Botlek and operates from Maassluis to the Brienenoord Bridge. The area where the survey tasks are carried out is partially monitored by two VTS centers. One center is located at Hoek van Holland, and the other is at Botlek.

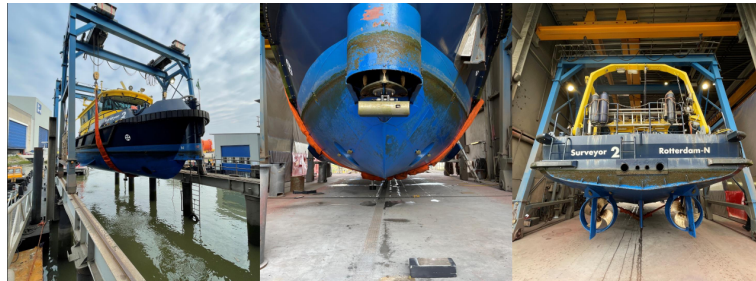


Figure 39: Survey vessel out of the water from different angles

Types of surveywork The survey work is divided into 3 types of tasks: Depth measurements (Snoek, 2024c), density measurements (Snoek, 2024a), and flow measurements

(van Reenen & Rotsaert, 2024).

These tasks have varying levels of priority and are organized into the weekly schedule called the "shipplanning". In this schedule, periodic surveys 40 (which are based on the siltation rates of specific areas) and special tasks are combined by a scheduler. The surveyors must complete the weekly schedule by the end of the week.

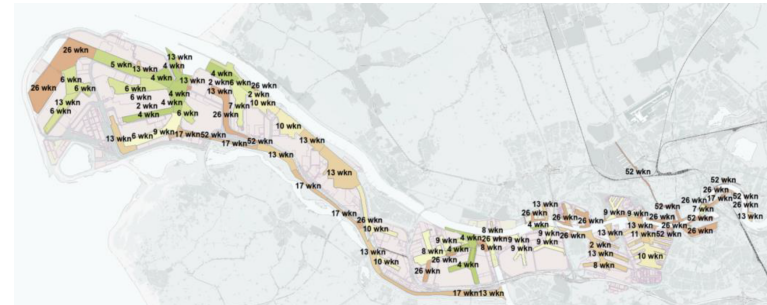


Figure 40: Frequencies of surveyed areas in the port. Taken from (Port of Rotterdam, 2024c)

At the beginning of the week, the empty berths of ships are sounded. Later in the week, the berths can be re checked to see if previously occupied places are now empty. Some critical locations are sounded at a frequency of once every two weeks. It may also be the case that the surveyors are called upon by the duty officer in the event of an emergency. Furthermore, the soundings are dependent on the water level. Shallow harbors are only surveyed at high tide. The banks are sounded using both a laser and a multibeam. At high tide, the survey vessel sails along the bank, and the bottom is mapped using the multibeam. Then, at low tide, the vessel sails along the bank again to map the part that is above water using a laser.

There are other tasks carried out by the survey vessels and

their crew, there may be salt measurements, current measurements, and silt measurements. Finally, the vessel may be used for sounding to detect potential damage or for surveying before, during, and after construction projects. Finally there are quality control tasks that need to be done: The depth needs to be checked every year in the lock (which has fixed depth) and the multibeam needs to be calibrated every three months.

Measurement Equipment and Software

Various types of equipment and software are used to conduct the measurements. For each depth measurement, a sound profile must be taken with the sound velocity profiler (SVP). This measurement should be repeated approximately every hour or whenever the survey area is more than one kilometre away from the previous measurement (Port of Rotterdam, 2024c)(Snoek, 2024c).

A key measuring instrument is the multibeam, which is mounted at the front of the ship. The multibeam is used for depth measurements and calculates the distance to the seabed using sound waves (Snoek, 2024c). This is done in a two-dimensional line. An image of the multibeam is shown in Figure 41.

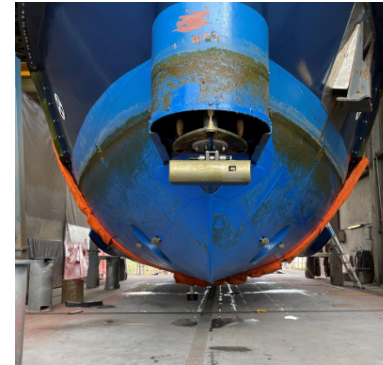


Figure 41: Multibeam at the bottom of the ship. Taken from (Port of Rotterdam, 2024c)

For depth measurement, the positioning of the ship is also important. There are various global navigation satellite systems (GNSS) with increasing levels of accuracy. Standard GNSS does not provide vertical positioning and has an accuracy of five meter. Differential GPS (DGPS) has a horizontal accuracy of one meter and also lacks vertical positioning. The most accurate satellite system is GNSS with a virtual reference system (VRS), which provides the highest accuracy with vertical positioning accuracy of less than 0.02 meter (Port of Rotterdam, 2024c).

Additionally, it is important to compensate for the ship's movements during measurements. For this purpose, each survey ship is equipped with a motion sensor that measures the roll, pitch, heave, and heading of the ship and can compensate for these movements (Port of Rotterdam, 2024c). The motion sensor and the parameters it measures are shown in Figure 42

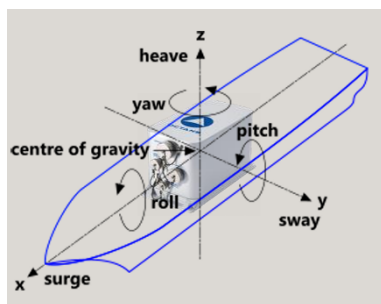


Figure 42: Motion sensor. Taken from (Port of Rotterdam, 2024c)

The survey vessels are also equipped with a Riegl laser scanner mounted on the mast of the vessel. This laser scanner is used for three-dimensional measurements above the water surface, such as constructions and embankments (Port of Rotterdam, 2024c). Sample measurements from the laser scanner were found in the document analysis and are shown in Figure 43.

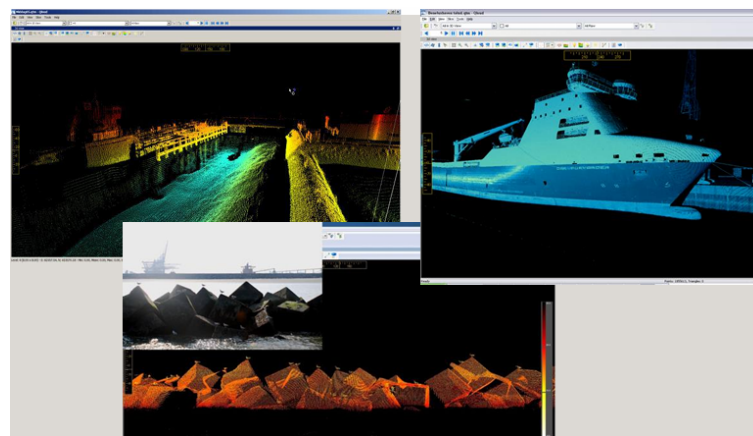


Figure 43: Laser data. Taken from (Port of Rotterdam, 2024c)

Qinsy is software used for data acquisition. Qinsy enables the collection and processing of spatial data, integrating inputs from various sensors (Port of Rotterdam, 2024c)(Snoek, 2024c). A visualization of a survey in Qinsy is shown in Figure 44.

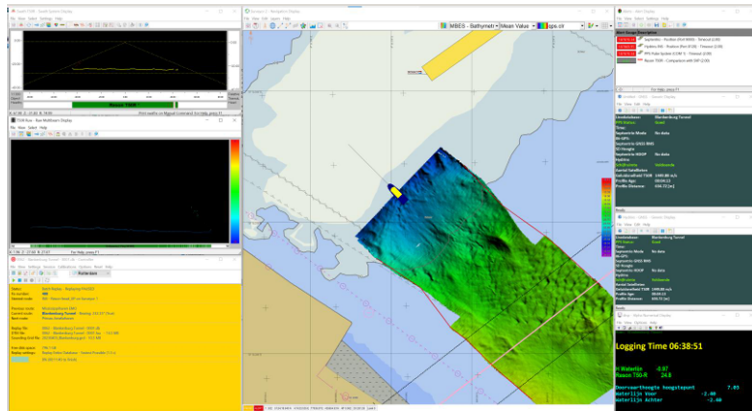


Figure 44: Qinsy software. Taken from (Port of Rotterdam, 2024c)

Autoclean is a software program used to clean raw data. A large portion of the data can be cleaned using filters in the program, while the remaining parts must be manually checked (Port of Rotterdam, 2024c). A visualization of the Autoclean program can be found in Figure 45.

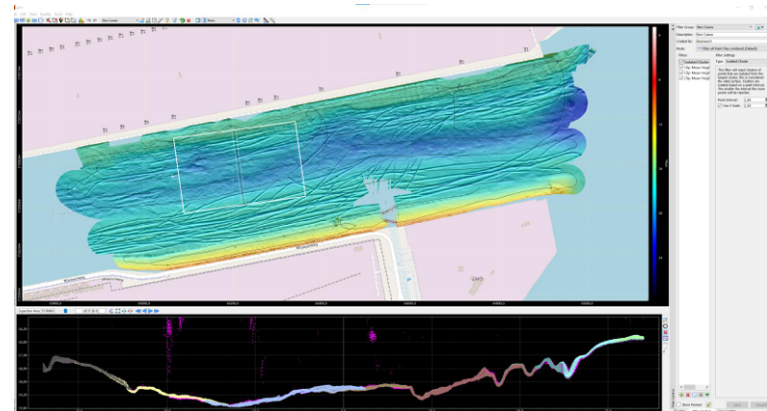


Figure 45: Autoclean software. Taken from (Port of Rotterdam, 2024c)

The data is saved in a BIS (Bathymetric Information System) database with ESRI Arcmap. This allows the map of the ports depths to be multilayered and fully up to date. Which can be used for Electronical Navigation Charts (ENC). The production of ENCs (Electronic Navigation Charts) takes place automatically according to the S-57 standard, issued by the IHO (International Hydrographic Organisation) (Port of Rotterdam, 2024c). ENC's are used by skippers to navigate and many other applications.

Point measurements using a density meter are performed in areas where a silt layer thicker than 25cm is present (often Beercanal, Maasmond and Calandcanal) (Snoek, 2024a). These density measurements are performed using a Rheo-Tune, a measuring instrument that determines properties such as shear stress, sludge density, and the sensor's depth (Port of Rotterdam, 2024c). The sampler is put in the ground underwater and measures the density of the ground. A visualisation of this beaker sampler is shown in Figure 46.



Figure 46: RheoTune. Taken from (Port of Rotterdam, 2024c)

These measurements are supplemented with Singlebeam echo sounder readings, which is shown in Figure 47. The single beam data is used to measure the density of the silt through SILAS software. This combination ultimately determines a layer thickness, which can be used to adjust the

Multibeam measurement (Port of Rotterdam, 2024c).



Figure 47: Single beam. Taken from (Port of Rotterdam, 2024c)

This approach calculates layer thickness, allowing for adjustments to the Multibeam measurements (Snoek, 2024a).

Appendix C

In this appendix, the other scenarios that were ideated, but not chosen to use in the interview are presented. Some alternative scenarios contained an emergency response vessel in some form. In figure 48, an scenario is presented in which an air drone operator could lift the autonomous drone from the water in case of a system failure.

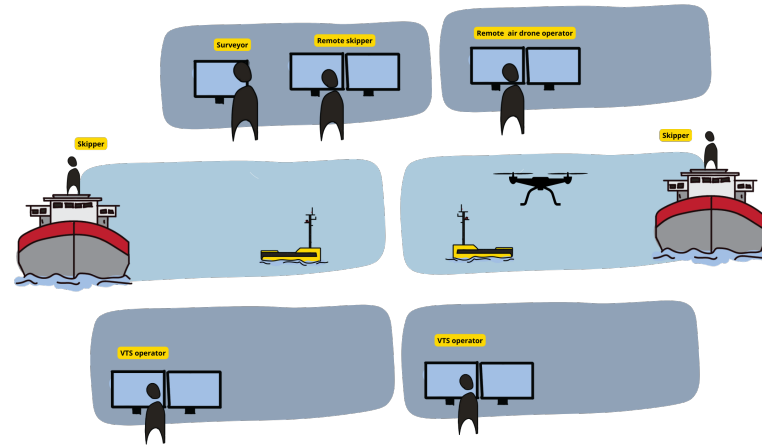


Figure 48: Scenario with an air drone

Another option for an emergency response vessel would be an regular vessel, with an captain and a technician that could physically reach the destination of a faulty drone, as is seen in figure 49.

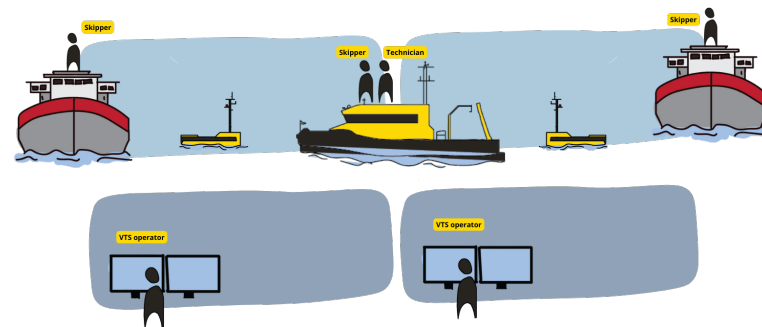


Figure 49: Scenario with emergency vessel

I chose not to include these scenarios, because they might be to steering that an emergency vessel needed to be present. Also the mothership scenario already contained some form of physical human presence, which could be discussed during the interviews.

Other scenarios were expansions of either the mothership or remote control scenario. Expansions of the mothership scenario included one mothership, with multiple autonomous drones accompanying it (figure 50), or each survey vessel having its own autonomous drone (figure 51).

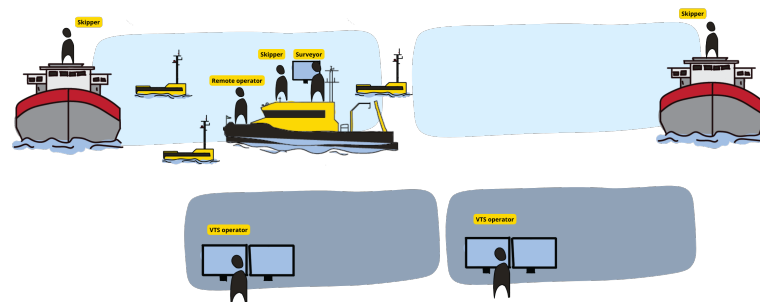


Figure 50: Scenario one mothership and multiple drones

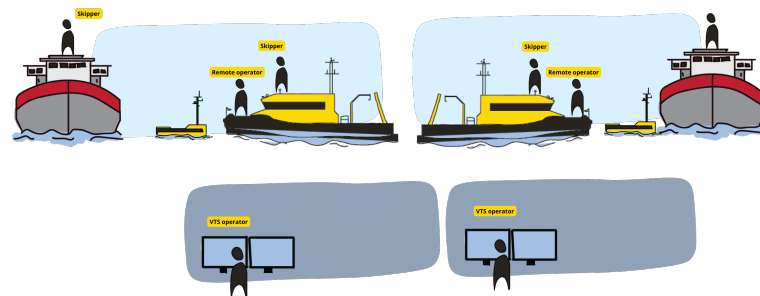


Figure 51: Scenario with two motherships and drones

The expansions of the remote control scenario included a larger swarm of autonomous drones (figure 52).

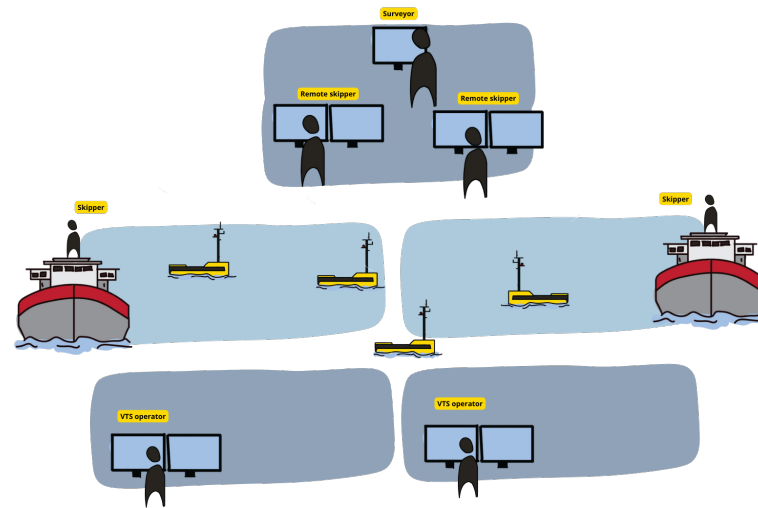


Figure 52: Scenario with swarm of remote controlled drones

Other scenarios included different configurations of human operator roles. In one configuration. Only one remote operator would oversee two autonomous drones (figure53). This scenario was not chosen, because according to the literature research this situation would have a high probability to cause mental overload for the remote operator.

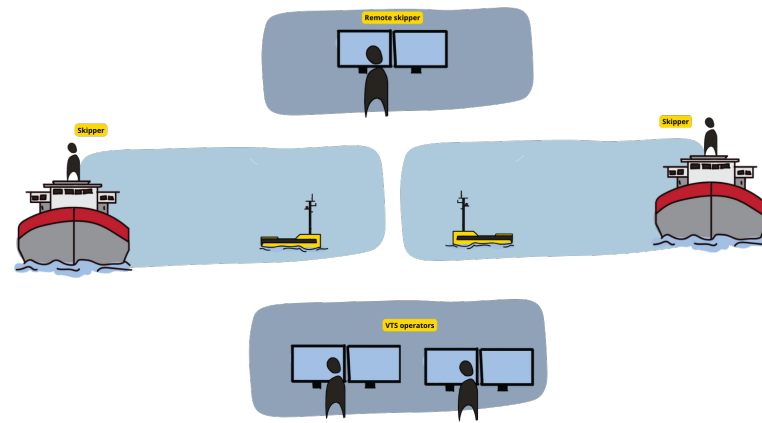


Figure 53: Scenario with one remote operator

Appendix D

In this appendix. The protocol for the interview study can be found. The interviews were held in Dutch, but for readability, the protocol has been translated to english.

Introduction script

"Hello, my name is Maureen and I am a student at TU Delft and working on my thesis. My research focuses on automation in the port of Rotterdam, specifically in the field of hydrographic research. "In this interview I want to understand your views and ideas on how (semi-)autonomous ships would impact your work experience." I will ask you questions about your current work, how your work has changed in the past and how you see the future" "The data I collect remains anonymous and confidential. It will only be used for my research." "You can stop the interview at any time; participation is completely voluntary. (Make sure the consent form is signed!) You can also interrupt me at any time." "There are no right or wrong answers – I'm interested in your opinions and personal experiences." "Finally, can I record this interview?"

Opening question

"Can you briefly describe your role in your current work?"

Step 1: current work experience and tasks

I created the scenario below. This is a simplified version of the current operational situation. I asked you to think about the things you like about your job and the things you don't like.

- 1.1.2 "Which tasks do you enjoy?"
 - "Why do you like these tasks?"
- 1.1.3 "What tasks do you not like?"
 - "Why do you like this one less?"

Reflection on changes

I've asked you to think about the ways your work has changed.

- 2.1 "What changes have you experienced in the years you have worked here?"
 - "Which of these changes were an improvement?"
 - "Which of these changes had a negative effect on your work experience?"

'Autonomous ships' have been a hot topic for quite some time. I'm curious about your ideas about this.

- 2.1 "What do you envision when you think of a semi-autonomous ship within your field?"
- 2.2 "What are your feelings about the idea of (semi-)autonomous ships?"
 - 2.2.1 "What opportunities do you see for your work with this technology?"
 - 2.2.2 "What threats do you foresee in your work with this technology?"

Future scenario of autonomous ships

I would like to show you two fictional future scenarios in which (semi-)autonomous ships play a role. I would like to emphasize that the scenarios are purely fictional and are intended to gather your input during the interview. It is not a concrete plan for the future.

Fictional mothership scenario

In the first fictional scenario, one of the two research ships carries a semi-autonomous ship. This drone can be controlled remotely by a remote skipper. The ship can simultaneously perform measurements and sail with the mother ship. The surveyor checks the measurement data from both the drone and the mother ship.

- 3.1 "How would this scenario change your current tasks?"
- 3.2 "How would your collaboration with other users in the ecosystem (such as VTS operators, skippers and researchers) change?"
- 3.3 "Can you think of a top for this scenario?"
- 3.4 "Can you also think of a tip for this scenario?"
- 3.5 "What would you change about this scenario? Feel free to customize it as you like"

Lay out the cards with possible additional people/ships so they can be easily customized. Also put pens on the table.

Remote control scenario

In this scenario, the skippers and surveyors are no longer present on the ship, but control the ships remotely. The remote skippers can put the ships in automatic or manual mode. In automatic mode the skipper can view the vessel's surroundings, just as a VTS operator can see. When one skipper steers a ship manually, the other can keep an overview of the situation and vice versa. The surveyor remotely checks and monitors the information from both ships. The surveyor checks the incoming measurements from the drones and communicates with the skippers remotely which measurements should be taken where.

- 3.1 "How would this scenario change your current tasks?"
- 3.2 "How would your collaboration with other users in the ecosystem (such as VTS operators, skippers and researchers) change?"
- 3.3 "Can you think of a top for this scenario?"
- 3.4 "Can you also think of a tip for this scenario?"
- 3.5 "What would you change about this scenario? Feel free to customize it as you like"

Lay out the cards with possible additional people/ships so they can be easily customized. Also put pens on the table.

General questions

Keep the future and current scenarios visible as a reference point. This allows the participant to build on or critique the previous scenario.

"Now that we've seen the screenplay and discussed your current work..."

- 4.1 "If autonomous ships are implemented, what responsibilities would you like to retain, and why?"
- 4.2 "Which tasks would you leave to the autonomous system, and why?"
- 4.3 "What properties should the autonomous ship have to have a positive impact on your work?"
- 4.4 "What barriers do you foresee in the implementation of autonomous ships?"
 - 4.4.1 "How can these be addressed?"
- 5.3 "What could be your contribution to the implementation of (semi-)autonomous ships?"

Close

Thank the participant.

- 5.1 “Is there something I forgot to ask that you would like to share?”
- 5.2 “Do you know anyone else I could talk to?”

Appendix E

In this appendix, the informed consent forms used in the interview study can be found.

Informed consent form

Onderzoeker: Maureen Boers

Email: [REDACTED]

Je wordt uitgenodigd om deel te nemen aan een onderzoek met de titel: 'Envisioning the role of human workers in increasingly autonomous work environments: A case study in the port'. Dit onderzoek wordt uitgevoerd door Maureen Boers van de TU Delft in samenwerking met het Havenbedrijf Rotterdam.

Het doel van dit onderzoek is om de behoeften en wensen van schippers, VTS-operators en surveyors met betrekking tot toekomstige hydrografische surveyoperaties in kaart te brengen. Het interview zal ongeveer 60 minuten duren. De verzamelde data zal worden gebruikt voor een masterthesis in Strategic Product Design. Tijdens het interview wordt u gevraagd om te vertellen over uw huidige rol in het hydrografische surveyproces, uw mening over een voorgesteld scenario, en uw visie op een ideaal toekomstig hydrografisch surveyproces.

Het interview kan online plaatsvinden (via het platform Teams) of in persoon. De sessie wordt opgenomen, en de opnames worden opgeslagen, getranscribeerd en geanonimiseerd voor verdere analyse. Zoals bij elke online activiteit bestaat er een risico op een datalek. We doen ons uiterste best om uw antwoorden vertrouwelijk te houden. De risico's worden geminimaliseerd door gegevens veilig op te slaan in met wachtwoorden beveiligde digitale bestanden. Alleen de onderzoeker en haar team aan de TU Delft hebben toegang tot de data; het Havenbedrijf Rotterdam krijgt geen toegang tot deze informatie om te waarborgen dat de identiteit en meningen van deelnemers vertrouwelijk blijven. Audiobestanden worden vernietigd zodra ze zijn omgezet in geanonimiseerde transcripties. Persoonlijk identificeerbare informatie (zoals namen van deelnemers, afdelingen of e-mails) wordt alleen gebruikt voor administratieve doeleinden en verwijderd zodra deze doeleinden zijn vervuld. Namen van deelnemers zullen nooit worden gekoppeld aan de onderzoeksdata. Ten slotte wordt commercieel gevoelige informatie geabstraheerd of verwijderd uit het eindrapport.

Uw deelname aan dit onderzoek is volledig vrijwillig, en u kunt zich op elk moment terugtrekken zonder een reden op te geven. U bent vrij om vragen over te slaan. Zodra de onderzoeksresultaten echter zijn geaggregeerd en gebruikt voor verder onderzoek of publicaties, is het mogelijk dat uw individuele (geanonimiseerde) data niet meer uit de studie kan worden verwijderd. Houd er rekening mee dat uw antwoorden op de vragen of uw bereidheid om deel te nemen geen invloed hebben op uw werk en niet met anderen buiten de interviewsessie zullen worden gedeeld.

Dit onderzoek wordt begeleid door assistent professor Achilleas Psyllidis

[REDACTED] en PhD student Garoa Gomez

Beldarrain [REDACTED]

GELIEVE DE JUISTE VAKJES AAN TE VINKEN	Ja	Nee
A: ALGEMENE TOESTEMMING – ONDERZOEKSDOELEN, TAKEN VAN DE DEELNEMER EN VRIJWILLIGE DEELNAME		
1. Ik heb de studie-informatie gelezen en begrepen, of deze is aan mij voorgelezen. Ik heb vragen kunnen stellen over het onderzoek en mijn vragen zijn naar tevredenheid beantwoord.	☐	☐
2. Ik geef vrijwillig toestemming om deel te nemen aan dit onderzoek en begrijp dat ik vragen mag weigeren te beantwoorden en op elk moment uit het onderzoek mag stappen, zonder een reden op te geven.	☐	☐
3. Ik begrijp dat deelname aan het onderzoek inhoudt dat er een audio-opname wordt gemaakt van het interview, waarvan de audio zal worden getranscribeerd naar tekst en geanonimiseerd voor verdere analyse. De audio-opnames worden na voltooiing van het onderzoek verwijderd.	☐	☐
4. Ik begrijp dat het onderzoek bestaat uit een eenmalig interview met een duur van 60 minuten.	☐	☐
B: MOGELIJKE RISICO'S VAN DEELNAME (INCLUSIEF GEGEVENSBESCHERMING)		
5. Ik begrijp dat deelname aan het onderzoek de volgende risico's kan inhouden, aangezien het binnen een organisatie wordt uitgevoerd: 1) deelnemers kunnen zich verplicht voelen om deel te nemen; 2) antwoorden kunnen mogelijk commercieel vertrouwelijke informatie onthullen; 3) deelnemers kunnen zich geremd voelen om hun mening te uiten. Ik begrijp dat deze risico's worden geminimaliseerd door de identiteit van deelnemers anoniem te houden, een vertrouwelijkheidscontrole uit te voeren voordat het onderzoek wordt gepubliceerd, en deelnemers op elk moment de mogelijkheid te bieden zich terug te trekken.	☐	☐
6. Ik begrijp dat deelname aan het onderzoek ook inhoudt dat specifieke persoonlijk identificeerbare informatie (zoals naam, e-mailadres en afdelingsnaam) en bijbehorende onderzoeksdata (zoals een beschrijving van mijn huidige rol) worden verzameld, met het potentiële risico dat mijn identiteit wordt onthuld of mijn imago wordt geschaad.	☐	☐
7. Ik begrijp dat de volgende stappen worden ondernomen om het risico op een datalek te minimaliseren en mijn identiteit te beschermen bij een dergelijk lek: transcriptie van de audio-opnames naar geanonimiseerde tekst, vernietiging van de opnames, veilige gegevensopslag zonder toegang voor de organisatie, en vertrouwelijkheid met betrekking tot de identiteit en afdeling van de deelnemers.	☐	☐
8. Ik begrijp dat persoonlijke informatie die over mij wordt verzameld en mij kan identificeren, zoals naam, e-mailadres of afdeling, niet buiten het onderzoeksteam wordt gedeeld.	☐	☐
9. Ik begrijp dat de (identificeerbare) persoonlijke gegevens die ik verstrek, zullen worden vernietigd na de voltooiing van de masterthesis (in april 2025).	☐	☐
C: ONDERZOEKSPUBLICATIE, VERSPREIDING EN TOEPASSING		
10. Ik begrijp dat na het onderzoek de door mij verstrekte, geanonimiseerde informatie wordt gebruikt in de gepubliceerde masterthesis.	☐	☐
11. Ik ga ermee akkoord dat mijn antwoorden, meningen of andere bijdragen anoniem kunnen worden geciteerd in onderzoeksresultaten.	☐	☐

Handtekeningen

Naam deelnemer

Handtekening

Datum

I, as researcher, have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

Naam onderzoeker

Handtekening

Datum



Appendix F

In this appendix, the final code tree can be found below

Table 7: Codebook

Theme	Theme Description	Code	Example Quote
Characteristics of the port area	This theme addresses the specific characteristics of the port area mentioned by participants, such as traffic density, the multitude of factors, and unpredictability. It also covers what distinguishes survey work in the port area from survey work elsewhere.	Survey vessels must yield to other traffic	<i>"I was conducting a survey in a specific spot, and we were highly visible, right in the middle of the port area. Then a ship came sailing in, and at some point, we simply had to leave our position." (P9)</i>
		The port area is unpredictable	<i>"You have high tide, low tide, headwind, ebb, flood. So all these factors. There is always a plan. And as soon as the plan starts, deviations begin. Within 10 minutes, everything can be different." (P1)</i>
		The port area is very busy	<i>"Look at the Waalhaven or the Eemhaven, it's essentially one big ant nest. The intersections, like the Botlek and the Oude Maas, are very busy as well." (P8)</i>
		Local knowledge is important	<i>"You don't learn from a book, especially not in Rotterdam." (P8)</i>

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Theme	Theme Description	Code	Example Quote
		Survey areas can be difficult to access	"You can hardly launch that drone from the shore anywhere. At least, that is possible, but that is very difficult, because of course you have all kinds of sites that surround the port area, industries that all have extremely strict regulations with permissions. That is required by the government, but also by the companies themselves, so going through those sites of the tenants and/or owners is simply very difficult. You do not have the ideal view there either." (P9)
Future of work with autonomous drones	This theme examines how participants expect autonomous drones to impact their work, with both positive and negative changes anticipated. It covers general work changes and those specific to different operational scenarios.	General changes due to autonomous drones	"It does become a kind of extra caution for me as a VTS all of a sudden that I have to pay attention to it." (P5)
		Changes in the mother-ship scenario	"If you are on the big boat, you have to carefully plan your courses because you want to survey the whole area in one go with the small boat. This means more space is required, impacting navigation." (P3)
		Changes to work specific to the remote control scenario	"No matter how small the vessel is, it's still influenced by currents and wind. Here, you see what your ship is doing, you feel how it moves, and you react instantly. The question is to what extent you can compensate for that. You would have to read that from your equipment." (P3)

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Theme	Theme Description	Code	Example Quote
Implementation process of autonomous drones	This theme explores participants' expectations and attitudes toward implementing autonomous drones in the port, emphasizing collaboration, organizational culture, and a gradual transition.	Changes to work in the context of advanced autonomous navigation	<i>"With full automation, a ship would send a signal within a 400-meter radius, saying, 'I'm here, working.' And another ship would respond, 'I'm leaving the dock, oh yeah, that thing is still there, let me send a quick ping to check its location. There. I'm departing,' it says to the smaller vessel. The smaller vessel responds, 'Okay, I'm here now. No collisions.'" (P1)</i>
		The port is digitalizing	<i>"I believe they will come anyway. It is a development in the market that simply cannot be stopped." (P4)</i>
		People need time to adapt	<i>"It's the same as autonomous driving; it requires time. A significant investment is needed." (P6)</i>
		The transition phase from the current situation to a fully autonomous port is challenging	<i>"So imagine you have an autonomous cargo ship, but there are also inland vessels. How do they interact? I think that is the biggest question. A human has emotions and a sense of humanity, whereas a computer does not. So how will that work in the future?" (P6)</i>
		A fully autonomous environment operates smoothly	<i>"If everything were fully autonomous, I think it would be easier than having half of the ships operate autonomously while the others have to navigate around them." (P5)</i>
		Initial issues with new technology are resolved over time	<i>"You only really find out when you actually try it." (P7)</i>

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Theme	Theme Description	Code	Example Quote
Concerns about autonomous drones	This theme captures participants' concerns regarding autonomous drones, including stability issues, regulatory uncertainties, reduced human control, and connectivity problems.	Need for collaboration	<i>"If there are developments related to our field, then they should be handled by us." (P2)</i>
		Importance of culture	<i>"I do think you need delicate, skilled people to set it up." (P9)</i>
		A gradual process	<i>"It simply has more advantages than disadvantages, but there is always some resistance. You should not push too hard against it but rather let it slide off." (P1)</i>
		No advantages of USVs	<i>"It costs a lot, and people don't do it either. If someone owns a cargo ship and sailing is profitable, they are not going to invest 4 million just to avoid touching the controls." (P6)</i>
		Additional personnel required for USVs	<i>"It really is not feasible. You would still have to work with the same crew. I see no advantage in that at all." (P3)</i>
		Concerns about the stability of USVs	<i>"A huge push-boat produces a wake that lifts such a thing up. You can hit it against the quay. I think it immediately gets mangled." (P2)</i>
		Concerns related to vessel traffic	<i>"In very specific situations. For example, along the Gloringer, in smaller ports where your survey vessel is already fully occupied. I would think that an autonomous drone wouldn't be a problem there. But in busy intersections, I think there will be more drawbacks." (P8)</i>
		Concerns about regulations	<i>"Legally, you always have to be cautious because you can't sue a computer. If operations become autonomous, who is responsible? That's a big dilemma." (P1)</i>

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Theme	Theme Description	Code	Example Quote
		Concerns about the lack of human control	<i>"Because you can intervene more easily if you are on board." (P4)</i>
		Concerns about communication and connectivity	<i>"Whether you are in the office or on the boat and see nothing, that doesn't matter much. It is only the delay, the quality of the connection... I don't know if it is sufficient yet." (P6)</i>
		Concerns about visibility	<i>"Sometimes we don't even see some of the yachts on the radar because they are so small that they are not visible." (P7)</i>
Advantages of autonomous drones	This theme highlights the benefits of autonomous drones, such as their smaller size, ability to access areas where conventional ships struggle, and increased efficiency.	USVs can access difficult areas	<i>"Areas where you currently can't go might be useful. But other than that, I actually don't see any advantages." (P2)</i>
Expectations of autonomous drones	This theme covers all expectations and requirements that an autonomous drone must meet to operate within the port context.	USVs increase efficiency	<i>"The side from which the wind comes measured by the smaller vessel, so that you finish a few hours earlier." (P9)</i>
		Autonomy of USVs	<i>"The autonomous drone navigates by itself. You only need to be present when it is finished, when it needs to be taken back on board." (P4)</i>
		USV operating area	<i>"Autonomous navigation could work very well in areas where it is certain that no vessels will be entering or leaving." (P5)</i>
		Visibility of USVs	<i>"If they are equipped with AIS, others can see it on their maps. Then it stands out a bit more. I think that is the most important, especially if it is very small." (P7)</i>

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Theme	Theme Description	Code	Example Quote
		Communication of USVs	<i>"What happens if it suddenly receives other orders? Does it suddenly turn? Then there must be a system that indicates this, so vessels can take it into account." (P1)</i>
		Remote control of USVs	<i>"You must always have a wide view around you." (P3)</i>
		Physical presence near USVs	<i>"You must be present. So you would rather have a small boat with you." (P2)</i>
		Lifespan of USVs	<i>"It should be able to cover both the larger areas and the smaller, more inland areas. The drone needs to be able to operate continuously for at least 5 to 6 hours. And also, if it could be quickly recharged from the vessel." (P9)</i>

Appendix G

In this appendix, the value proposition canvas for each group can be found.

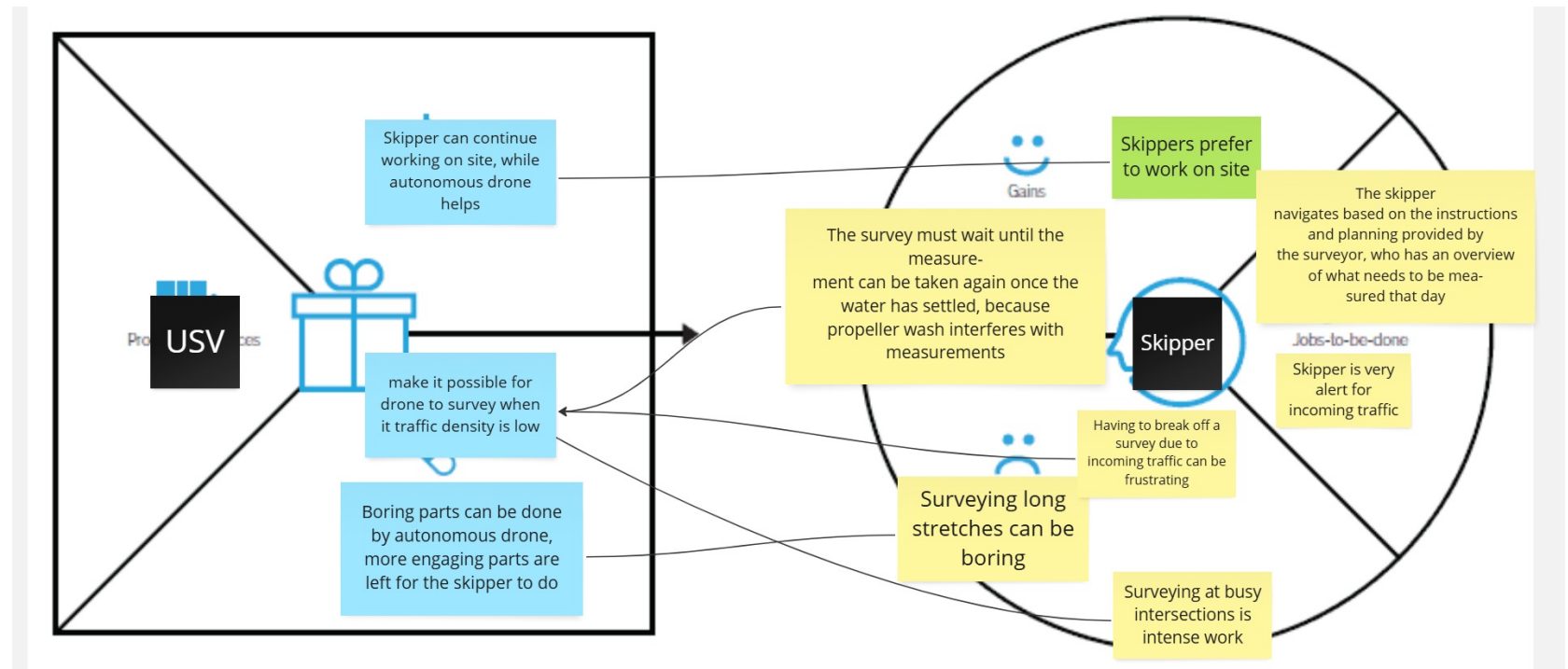


Figure 54: Filled in value proposition canvas for skipper

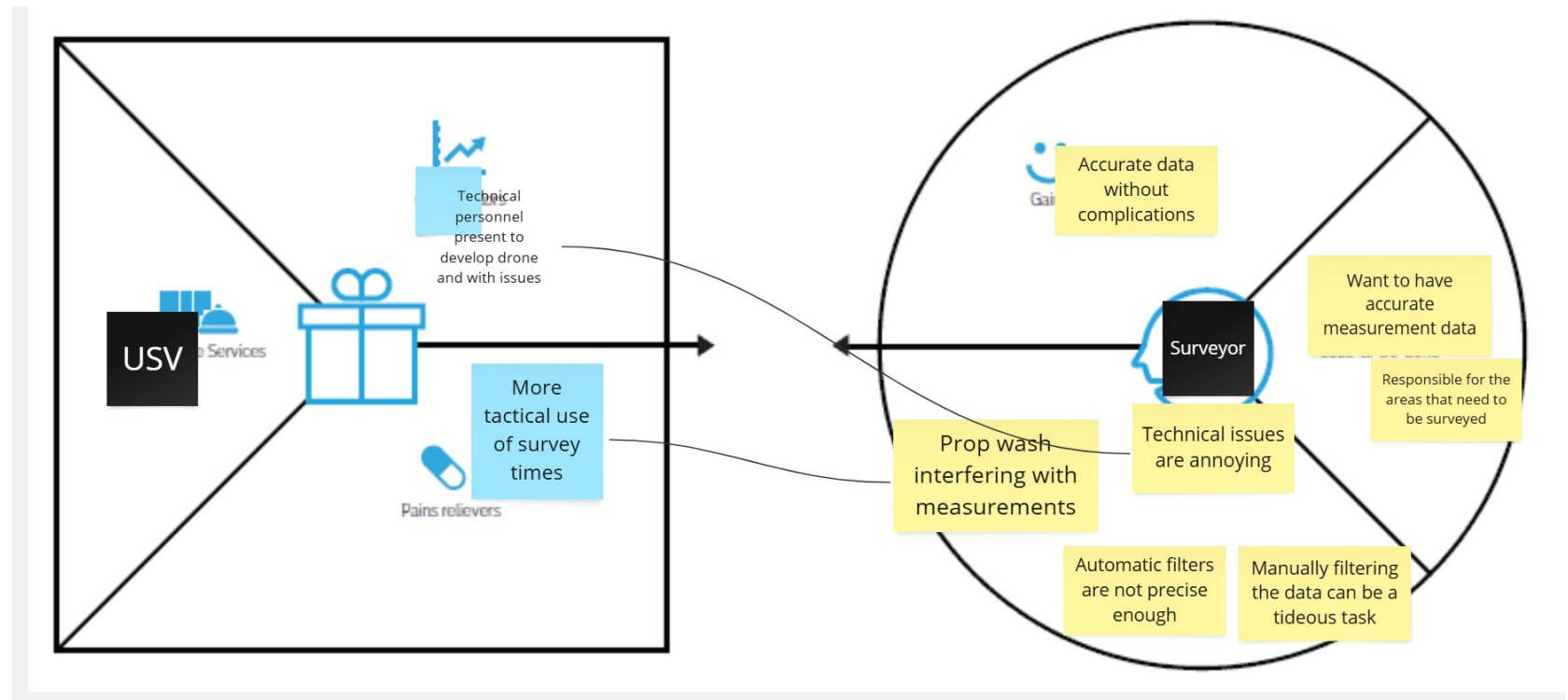


Figure 55: Filled in value proposition canvas for surveyor

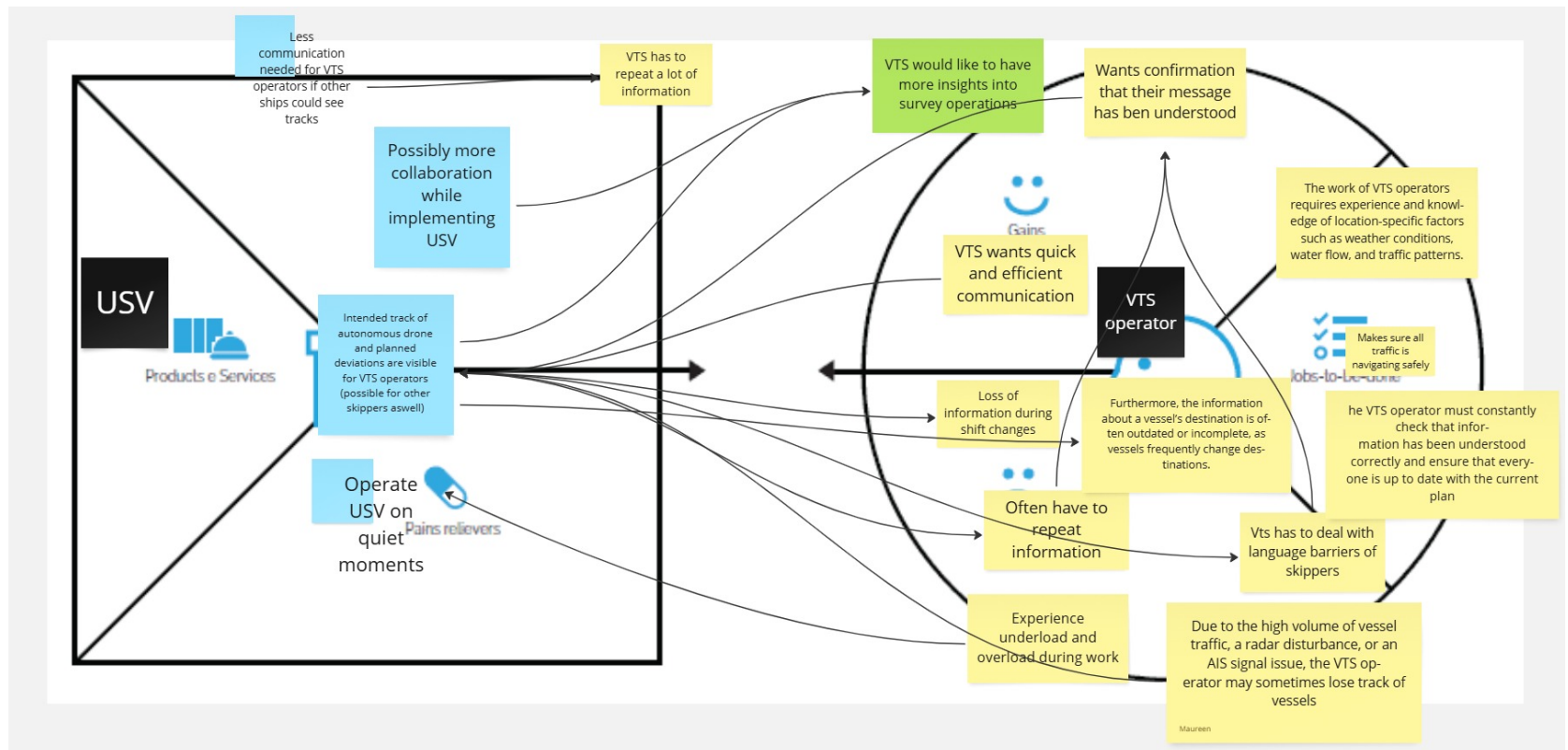


Figure 56: Filled in value proposition canvas for VTS operator