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Enhancing Terminal Tractor Operations

A User-Centered Approach to Digital Interface Design in off-highway vehicles

Master's thesis in Computer science and engineering

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CHALMERS UNIVERSITY OF TECHNOLOGY
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Cover: Illustration of a Terminal tractor in operation (Authors contribution)

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Abstract

This masters thesis explores how a digital interface for terminal tractor operators can be designed to improve operational efficiency and safety while reducing cognitive and ergonomic strain. The project was conducted in collaboration with Volvo Penta and followed a user-centered design process inspired by methods from Interaction Design and Human-Computer Interaction.

To understand operator workflows and challenges, the study combined video analysis, heuristic evaluation, interviews, and a focus group. Early insights guided the development of a conceptual prototype, which was iteratively refined and evaluated using scenario-based testing inside an actual terminal tractor. Particular attention was given to balancing intuitive interaction with non-negotiable safety procedures and deciding when to rely on physical versus digital controls.

Key features such as a central Task View and integrated camera system were prioritized based on frequency of use and risk level. The findings underscore the importance of critically defining what is "essential" from an operator's perspective and how assumptions made early in the process can shape the outcome.

Although limited by the lack of system integration and live driving tests, the study presents valuable insights for designing future operator interfaces in off-highway vehicles. It concludes with suggestions for broader user testing, integration of live data, and the need for cultural adaptation in safety practices.

Keywords: terminal tractor, interface design, usability, ergonomics, operational safety, off-highway vehicles

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Additionally, we are grateful to NTEX and Göteborg RoRo for facilitating contact with terminal tractor operators, enabling us to carry out important observations and interviews essential to our study.

David Boman & Otto Ekelund, Gothenburg, 2025-06-03

Contents

List of Figures

List of Tables

1
Introduction

As digitalization progresses within the motor industry, the interaction between operators and off-highway vehicles is undergoing improvement regularly [1]. These machines, ranging from forestry harvesters to mining trucks (see figure 1.1), must perform in demanding conditions where quick decisions can impact efficiency, safety, and productivity. Yet, despite their complexity, the interfaces that operators rely on to control and monitor these machines often fall short. Critical information is often buried in cluttered displays, making it difficult for operators to quickly identify and act on key data. Interfaces can misalign with workflows and not be opted for the actual usage scenarios increasing cognitive load and the risk of errors. Complex interfaces across machine types require users to relearn layouts, leading to inefficiencies and steep learning curves [2].

Cognitively, operators must interpret disorganized data, remember complex sequences, and navigate poorly structured interfaces, this can result in reduced situational awareness and increase mental strain [3]. Ergonomically, many systems use fixed displays where poor interface placements can contribute to physical discomfort and workload [4].

Figure 1.1: Examples of off-highway vehicles. (left: Forestry harvester from Pixabay, Right: Dump truck from Unsplash).

Volvo Penta, a division of the Volvo Group specializing in engine systems for marine vessels and off-highway applications, recognizes these challenges and the need for smarter, more intuitive digital interfaces [5]. Operators require clear, accessible, and contextually relevant information to optimize performance and ensure safety.

This thesis explores how intuitive Human-Machine Interfaces (HMIs) can address operational needs for terminal tractors, providing a seamless and efficient user experience.

User experience (UX) design is the central part of this challenge. By analyzing existing interface solutions (see figure 1.1), identifying usability gaps, and developing a prototype, this research aims to bridge the gap between operator needs and interface design. The central question guiding this study is: How can an intuitive interface be designed for terminal tractors to enhance operational efficiency and ensure safety, while reducing the cognitive and ergonomic workload.

Figure 1.2: Existing cock-pit solution for a terminal tractor [6]. Copyright by Kalmar

The methodology consists of a staged, qualitative process designed to identify usability challenges and inform interface design improvements. It begins with a heuristic evaluation of existing terminal tractor interfaces to identify preliminary design issues. This is followed by a pilot study involving a UX expert to refine the evaluation framework. An in-depth interview with a professional operator is then conducted to gather task-specific, practical insights. Finally, a focus group with multiple operators is held to validate and expand upon the findings. The study results in two primary contributions: a set of usability insights derived from expert and user input, and a prototype interface aimed at enhancing intuitiveness, operational efficiency, and reducing cognitive and ergonomic workload.

Conducted as part of the M.Sc. Interaction Design and Technologies program at Chalmers University of Technology, this thesis is in collaboration with Volvo Penta. Through user research, iterative prototyping with tools like Figma and usability testing, the study will contribute to the development of digital interfaces that enhance operational efficiency and improve user experience. By tackling these challenges, this research assists Volvo Penta in enhancing the usability and effectiveness of their display solutions, ensuring operators have the tools they need to work efficiently and safely in demanding environments.

1.1 Research Problem

This research explores how intuitive interfaces can be developed to effectively convey critical information and enhance operational efficiency for terminal tractors. By focusing on operational needs, the study aims to design a user-centric interface that prioritizes the most critical tasks for operators working in demanding environments, which leads to the following research question:

Main research question:

How can an intuitive digital interface be designed for terminal tractors to enhance operational efficiency and ensure safety, while reducing the cognitive and ergonomic workload?

Subordinate questions:

- What methods can be used to identify and evaluate operational needs for heavy off-highway vehicles?
- How can the most critical operational tasks be identified and prioritized?
- What category of controls should remain physical and what works better in digital form?

While these challenges are broad and related to each other, this thesis will primarily focus on the main research question stated above. While other aspects such as the physical layout of the cockpit, balancing generic versus tailored solutions, and considering user needs and environmental factors are important, the core investigation will revolve around developing a user-centric display interface that enhance operational efficiency.

1.2 Stakeholders

The thesis is as a part of M.Sc. Interaction Design and technologies at Chalmers University of Technology. The project accounts for 30 credits and will be realized in the spring semester of 2025. Sjoerd Hendriks, the academic supervisor from Chalmers, will provide guidance and feedback on the projects academic aspects. Johan Eriksson, the industrial supervisor from Volvo Penta, will ensure the project aligns with Volvo Pentas requirements. Morten Fjeld, serving as the project examiner, will be responsible for grading and approving the thesis.

The thesis is in collaboration with Volvo Penta, a division of the Volvo Group specializing in engine systems for off-highway solutions. Secondary stakeholders include operators of off-highway solutions, whose daily interactions with Human-Machine Interfaces (HMIs) provide critical insights into usability requirements. Other stakeholders include machine manufacturers and maintenance teams, who influence the technical feasibility and implementation of display solutions.

1.3 Expected Deliverables

The goal of this study is to develop a user interface tailored specifically for terminal tractors, aimed at enhancing operator efficiency and safety. This section outlines the key deliverables that are expected to result from the research and design phases, including both a functional prototype and the insights that will inform future interface development. These deliverables are anticipated to showcase a user centered design approach and provide considerations for improving human machine interaction in off-highway machinery.

1.3.1 Prototype

The primary deliverable of this study is a functional prototype of a user interface tailored to terminal tractors. This prototype will demonstrate a clear, user-centered design that integrates the insights gathered during the research phase, particularly around data prioritization and task-specific requirements.

To create this prototype, we will utilize design and prototyping tools such as Figma [7]. Figma will be used to develop wireframes, high-fidelity mockups, and interactive design elements, supporting a collaborative and iterative design process. These interactive designs will simulate key aspects of the user experience, allowing us to explore functionality and usability early in the development phase.

Additionally, a test rig may be constructed to allow for the physical simulation of the user interface in a controlled environment. This rig will facilitate the testing of the prototypes usability by integrating the display and input mechanisms, enabling the evaluation of the interface design and the prioritization of critical operational tasks. While it will not attempt to replicate real-world conditions such as vibrations, glare, or varying operational environments, it will provide a practical setting for assessing the interfaces effectiveness inside the cockpit where ergonomic aspects can be considered.

These deliverables will serve as the foundation for the final recommendations on display design for terminal tractors and will help demonstrate how user-centered interface design can contribute to improved operational efficiency.

1.3.2 Findings and Design Considerations

Beyond the development of the prototype, this study is expected to generate key findings that will contribute to user-centered interface design for off-highway vehicles. One anticipated outcome is a reflection on the research methodology, evaluating the effectiveness of various approaches such as user studies, prototyping, and testing. This will help identify strengths and limitations, offering insights into how future research can better capture operator needs and assess usability.

Additionally, the study is expected to identify specific pain points in the user journey of terminal tractor operators, inefficiencies in task execution, or difficulties in accessing critical information. These insights will help highlight where current interface solutions fall short and guide the development of more intuitive and efficient interaction patterns. Particular attention will be given to identifying which types of information such as trailer identification, coupling status, yard navigation, and system alerts are most critical to display in real time to support safety and decision-making.

Furthermore, the knowledge gained through this research will have practical implications for the design of future interfaces in terminal tractor environments. By understanding the challenges operators face during daily operations, designers and engineers will be better equipped to create user-centered systems that improve task flow, reduce cognitive load, and enhance overall situational awareness. These anticipated findings will serve as a foundation for ongoing development and innovation in the field of industrial vehicle interface design.

1.4 Delimitations

A primary limitation is that the project emphasizes the conceptualization and prototyping of a user interface, utilizing tools such as Figma. While the prototype will demonstrate the functionality and usability of the design, the actual implementation of the interface into hardware and software systems falls outside the studys scope. Consequently, the projects deliverable will remain at a conceptual stage, with technical integration left for future development.

Another constraint involves the testing process. Due to time and resource limitations, full-scale testing in real-world operating environments will not be possible. Instead, the study will rely on usability testing conducted with a test rig designed to simulate the operational environment of off-highway vehicles as realistically as possible. While this method provides valuable insights, it cannot fully replicate the complexities of real-world conditions, such as long-term operation or extreme environmental influences.

The study further prioritizes functionality and usability over aesthetics, particularly regarding the test rig. The primary objective is to create a prototype and testing environment that is intuitive, effective, and user-friendly, rather than focusing on achieving a visually polished or aesthetically pleasing design. This practical approach underscores the projects' commitment to operator efficiency and usability over superficial considerations.

Finally, environmental factors, including glare, vibrations, and extreme temperatures, are acknowledged as significant challenges for off-highway vehicle interfaces. Although the study will take these factors into account and propose design recommendations, it does not aim to deliver fully tested solutions to address these challenges comprehensively. Developing robust solutions for such issues would require additional resources and testing beyond the scope of this project.

1.5 Terminal Tractors and Their Operational Context

Terminal tractors, also known as yard trucks, shunt trucks, or yard spotters, are specialized vehicles designed for moving semi-trailers and containers within confined environments such as ports, distribution centers, and terminals. Unlike conventional road trucks, terminal tractors are built for efficiency in low-speed, short-distance operations involving frequent trailer transports.

A defining feature of terminal tractors is their use of a fifth wheel coupling system, which connects to the kingpin of a trailer, see figure 1.3. The kingpin is a robust vertical steel pin located underneath the trailers front end. When docking or coupling, this pin locks into the tractors fifth wheel, a horseshoe-shaped plate mounted above the rear axle. Terminal tractors are often equipped with a hydraulic fifth wheel, which can lift and lower trailers, allowing operators to hook up and move trailers. This saves time and reduces the physical burden on the operator.

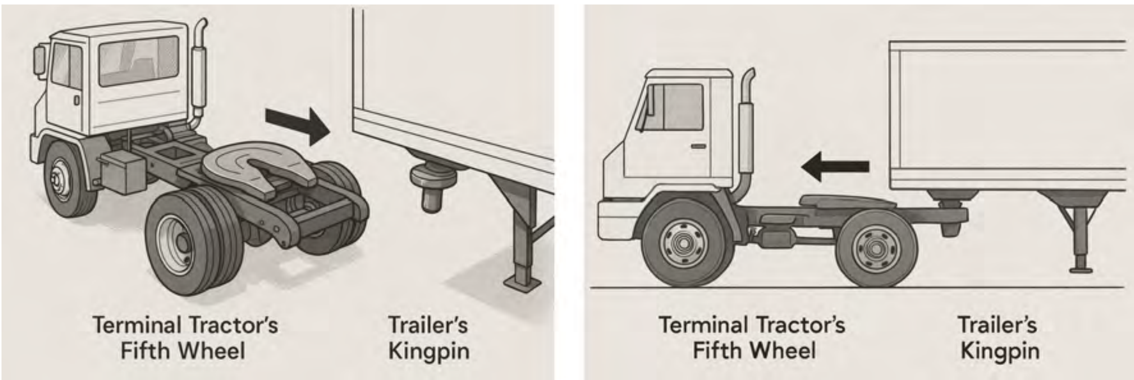

Figure 1.3: Terminal tractor's fifth wheel connecting to a trailer's kingpin.

1.5.1 Terminal Environments

Terminal tractors operate in highly dynamic and space-constrained environments. These include:

- Container ports and harbors, where terminal tractors shuttle containers between ship berths and storage yards or rail loading points.
- Logistics and distribution centers, where trailers are constantly moved between loading docks and parking areas for efficient staging and turnover.
- Rail intermodal terminals, where cargo is transferred between trains and trucks, requiring precise alignment and tight scheduling.
- RoRo (Roll-on/Roll-off) ferry terminals, where vehicles, machinery, and trailers are moved on and off ships. In these areas, rapid loading and unloading are crucial to maintain tight shipping schedules.

These environments often feature tight corridors, limited visibility, and a high density of moving equipment, such as forklifts, reach stackers, and other terminal tractors. In addition, operations can be further complicated by weather conditions, such as rain, snow, or fog, which reduce traction and visibility.

1.5.2 Cognitive and Physical Strain on Operators

Although terminal tractors are optimized for maneuverability and efficiency, the nature of the work imposes considerable cognitive and physical stress on operators. A typical task, such as loading a trailer in a loading bay, requires the operator to frequently look back over the shoulder to monitor the alignment of the trailer with the dock while also being aware of potential surrounding obstacles or people in the way. This motion, repeated over long shifts, can cause physical discomfort, particularly in the neck and shoulders.

In addition to physical strain, operators can face high cognitive demands. They must continuously process a variety of sensory inputs: monitoring the position of their own vehicle, watching for pedestrians and other vehicles, and responding to radio or on-screen instructions. In busy terminals, trailer assignments can change rapidly, requiring operators to adapt quickly and navigate under time pressure. This continuous mental load can lead to fatigue, errors, and slower reaction times, all of which have implications for safety and efficiency.

2

Background

This chapter examines the role of interaction design in off-highway vehicles, focusing on its impact on user experience through digital interfaces. As vehicles adopt advanced systems like digital dashboards and automation, effective design is crucial for operators in complex environments. It also highlights key players, including Volvo Penta, a leader in off-highway engines, and CPAC Systems, known for embedded systems and automation, as well as NTEX and Göteborg RoRo, which use terminal tractors and helped provide valuable user insights.

2.1 Interaction design in off-highway vehicles

Interaction design, rooted in Human-Computer Interaction (HCI), focuses on shaping digital artifacts-including products, services, and environments with an emphasis on user experience [8]. In off-highway vehicles, it plays a crucial role in enabling operators to interact with advanced vehicle systems efficiently, even in demanding and unpredictable environments.

Interactive systems transmit, display, store, or transform information that users can perceive [9]. This is especially relevant as off-highway vehicles increasingly integrate digital dashboards, touch interfaces, automation, and connectivity features, requiring thoughtful design for effective interaction.

Operators in off-highway environments often face high cognitive demands when having to maneuver the vehicle and its tools while at the same time having high awareness of the vehicles surroundings. Having cognitive resources being occupied argues for making intuitive and efficient interfaces essential [10]. Interaction design can help mitigate cognitive overload by aligning system functionalities with users natural behaviors and eliminating unnecessary complexity [11]. Additionally, advances in haptic feedback, adaptive interfaces, and multimodal interaction offer more intuitive ways for operators to engage with technology.

Prior research underscores the importance of designing the right thing in the right way [12][13]. In off-highway vehicles, this means developing user-friendly, context-aware interfaces tailored to operators needs. Key benefits of interaction design in this domain include [14]:

- Improved Task Efficiency: Streamlined dashboards and voice-controlled interfaces can help operators manage vehicle functions quickly and effectively.

- Reduced Operator Fatigue: Ergonomic design reduces cognitive strain and physical effort, leading to safer and more comfortable operations.
- Enhanced Situational Awareness: Well-designed information displays ensure that critical data (e.g., terrain conditions, fuel levels, system alerts) is easily accessible.
- Personalized User Experience: Adaptive systems that learn user preferences can improve ease of use and overall efficiency.

Beyond usability, investing in interaction design offers economic advantages. Companies prioritizing design achieve 200% higher valuations and 30% increased revenues [15][16]. For off-highway vehicle manufacturers, this underscores the competitive edge of user-centered design.

2.2 Digitalization in off-highway vehicles

Digitalization is rapidly reshaping industries worldwide, including agriculture, construction, and mining, by integrating advanced technologies to improve efficiency, productivity, and decision-making [17]. A key element of this transformation is the evolution of digital displays and user interfaces, which are playing an increasingly important role in enhancing human-machine interaction and streamlining operational workflows. An example of this evolution in agriculture vehicles can be seen in figure 2.1.


Figure 2.1: Examples of digitalized agriculture vehicle. (left: Old agriculture vehicle from Wikimedia commons, Right: Modern acriculture vehicle from Flickr).

The growing adoption of digital technologies has enabled the development of more sophisticated displays, providing operators with real-time access to critical data. This is particularly important in sectors such as agriculture, construction, and mining, where operators often work in complex and challenging environments. Modern digital displays incorporate features such as intuitive data visualization, touch controls, and customizable layouts, allowing operators to monitor performance metrics, troubleshoot issues, and optimize their operations with ease [18].

One of the primary factors behind the rise of digital displays is the ability of digital systems to gather and process large volumes of data. Sensors embedded in machinery collect real-time information on everything from engine performance to environmental conditions, feeding this data into displays that help operators make quick, informed decisions [19]. For example, in agriculture, a harvester might display real-time yield data, soil conditions, and machine diagnostics all in one user-friendly interface, ensuring operators can adapt to changing conditions and maintain high productivity.

Digitalization enables greater customization in display solutions, moving away from static interfaces to modular systems that can be tailored to specific tasks or user preferences. This adaptability is particularly beneficial in off-road vehicles, where operators may require different types of information based on the task at hand. For instance, digital screens can be configured to provide real-time, customizable information, ensuring that users receive updates that are relevant to their specific needs. Customizable displays allow operators to prioritize the most important data, ultimately improving usability and operational efficiency. As Hartwich, Hollander, Johannmeyer, *et al.* [20] emphasize, user-adaptive Human-Machine Interfaces (HMIs) that adjust to individual user needs can significantly enhance usability, trust, and system effectiveness by providing tailored interactions.

2.3 Related Works

Some examples of related research projects are described below and compared to the scope and domain of this project. These are used to provide context of what is currently known and designed in the field, but it also helps to contrast our work to theirs, or to build upon. The similar nature of the projects can also help inform and inspire decisions regarding similar stages of the process. With this, a more streamlined process can be achieved where potential limitations or problems along the way can be identified early and guided through the related works.

2.3.1 Slag Hauler User Interface Design [21]

This research project in collaboration with Kiruna Vehicles focused on designing a digital user interface (UI) for a SH60 slag hauler (see figure 2.2). The aim of the project was "...to create a basis for an interface with good user experience for the drivers, service personnel and manufacturer." through the use of a human-centered design approach. The project resulted in a safe and efficient UI concept with improved user experience (see figure 2.2).

Figure 2.2: The user Interface Concept and the SH60 Slag Hauler (Adapted from Rondahl and Larsson [21])

The project relates closely to this thesis project in its human-centered design approach for creating a digital user interface for a heavy off-highway vehicle. Some useful insights and methods from this work involve the iterative prototyping and user testing methods for evaluation. Insights from their user testing that are not vehicle specific will also be incorporated into our design process.

2.3.2 Analyzing online videos: a complement to field studies in remote locations [22]

This research paper presents a complementary method for conducting field studies through the use of online videos. It covers the difficulties in accessing users in remote locations or with limited availability to perform user studies. The paper targets forest machinery specifically to test the method of analyzing online videos. By resorting to analysis of online videos on platforms such as YouTube, a good understanding of the field can be achieved. Advantages mentioned in the report are presented below:

- Easy to obtain a large and diverse set of samples.
- Diverse samples provide a broader set of results.
- Adaptability and flexibility.
- Time saving for collecting the videos compared to doing field visits.
- Safer option for the researcher in terms of risks when being around heavy machinery.
- Less ethical issues because of the public availability of the videos.
- Lack of intrusiveness when not engaging directly with the user.

The paper also states a set of disadvantages that are presented below:

- Lack of multi-sensory experience of being on-site.

- Prior domain knowledge is recommended although not critical.
- Limitations for custom setups.
- Lack of interaction with the operator.
- Difficulties digging into details in terms of interaction.
- Reduced situation awareness.
- Lack of information regarding the operator .

This research paper brings great value for the process and execution of this masters thesis because of the limited access to terminal tractor operators. Because of the similarities in field this paper has provided a valuable alternative for user studies. Even though it might not be sufficient to have as a sole data collection method, it serves as a complementary method for gaining an understanding of the users workflow and potential pain points alongside real field studies to help gather the required data to further analyze and base decisions on.

2.3.3 User Interface Supporting Forest Machine Operators: Improve User Experience and Adaptability through Accessibility and Personalization [23]

This research focused on designing a user-friendly interface for the MaxiXT control and information system used in forest machines. The goal was to ensure that operators receive the right information at the right time, improving efficiency and promoting a better working environment. Using a design thinking methodology, the study placed emphasis on user research, iterative prototyping, and user testing to develop an intuitive interface that meets operator needs. The final prototype (see figure 2.3), tested in both Mid-Fi and Hi-Fi versions, received positive feedback, highlighting the importance of clear and accessible information.

Figure 2.3: Hi-Fi prototype of the drive view (Adapted from Krantz [23])

This project closely relates to this thesis in its human-centered approach to designing a digital interface for heavy off-highway vehicles. Valuable insights from this work include the importance of user research in identifying key operational needs, as well as the iterative testing methods used to refine the interface. Additionally, findings regarding operator preferences and the potential for interface personalization offer useful considerations for this research.

While MaxiXT was designed for forestry machines working in logging areas, this thesis focuses only on terminal tractors in ports and yards. Forestry machines need features like timber tracking and terrain stability warnings. Terminal tractors, on the other hand, need task management and reliable coupling status.

2.3.3.1 Investigating the Design Process of Developing a Dashboard Interface for an Electric Terminal Tractor [24]

This masters thesis explores the design of a digital dashboard interface for an electric terminal tractor, focusing on user experience during the transition from fossil-driven to electric vehicles. Using a user-centered design approach, the study examines how this process impacts the final interface concept and identifies key factors to ensure a smooth shift from traditional to new interfaces. Despite challenges such as limited user availability, alternative design methods were employed, and three design iterations were completed. The final concept, developed with the help of legacy bias to ease the transition, showed improved user experience while maintaining familiarity of previous interface solutions for operators.

This thesis is closely related to our project in terms of both field and objectives, as both focus on developing digital interfaces for terminal tractors. It provides valuable insights into methods used and helps us better understand the operator's workflow. However, key differences exist since their project specifically addresses the transition from fossil-fueled to electric terminal tractors, which is not a major focus of our thesis. Additionally, while their project aimed to create a dashboard screen behind the steering wheel to display vehicle data such as speed, fuel levels, and pressure, our thesis goes a step further by exploring how an interface can enhance the overall efficiency and safety of operating tasks.

2.4 Problem

While digital display technologies present significant opportunities to enhance industrial operations, their success largely depends on overcoming key challenges in design and application. A central challenge lies in creating user-friendly interfaces that show just the right amount of information in the right way at the right time and effectively conveying critical information. This research aims to explore how these interfaces can be optimized for terminal tractors, improving usability and operational efficiency

A central challenge in designing digital displays for terminal tractors is delivering operators the exact information they need for each task. Trailer identification, navigation, and coupling all demand different data, so the interface must dynamically adapt to those contexts. The goal is to display critical details precisely when required, enhancing efficiency and safety while preventing information overload [25]. Customizable interfaces that change based on the task can reduce cognitive load by displaying only the most relevant information [26].

The digitization of interfaces for off-highway vehicles presents a balancing act between providing more data and avoiding distractions. On one hand, digital systems can display a wealth of information, offering operators real-time data on machine performance, environmental conditions, and task-specific metrics. However, this increase in available data can become a double-edged sword. While it can be beneficial, there is a risk that too much information on the screen could overwhelm the user, leading to distractions that impair decision-making or reduce operational efficiency.

Furthermore, ensuring that the interface is intuitive and easy to use, regardless of setting or operator experience, is crucial. Operators may use a variety of machines, and the interface must remain consistent and easy to navigate across different contexts. To achieve this, the design should strike a balance between flexibility and simplicity. A unified interface across machine categories should allow operators to quickly interpret essential data without unnecessary complexity, minimizing the risk of errors and maintaining focus on critical tasks. As noted by Blackler, Popovic, and Mahar [27], applying principles such as using familiar symbols, metaphors, and consistent design can facilitate intuitive interaction, thereby enhance usability and reduce cognitive load.

The focus of this thesis is to explore how to design an intuitive, user-centered interface that enhances operational efficiency within terminal tractor operations. By developing a solution that adapts to varied tasks and yard environments such as trailer handling, navigation, and coupling this research aims to deliver insights for creating digital displays that optimize performance and safety in terminal tractor contexts.

2.5 Expected Findings

Through this study, we anticipate uncovering several key findings that will impact the design and development of user-centered display solutions for off-highway vehicles, more specifically; terminal tractors. These findings will focus on three primary areas: data prioritization, identifying gaps and problems in current systems, and understanding task-related data requirements.

2.5.1 Data Prioritization

A key objective of this study is to identify the most critical types of data that users rely on and determine how this information should be prioritized within the interface. Efficient and intuitive data presentation is essential for ensuring the smooth operation of off-highway vehicles, as well as for enhancing usability and safety. A study investigated driver preferences for the location and prioritization of in-vehicle information. The findings suggest that organizing and displaying information according to driver expectations can reduce distraction and improve driving performance [28].

Monitoring critical engine-related data such as fuel levels, engine temperature, RPM, and fault alerts is essential for assessing a vehicles health and performance. Real-time insights into these metrics empower operators to make quick, informed decisions when issues arise. By pinpointing which metrics need continuous monitoring, operators can take a proactive approach to address potential faults, minimizing downtime and ensuring the vehicle operates at its best [29]).

The relevance of specific information in an interface is closely tied to the operational context in which it is used. In terminal tractor operations, for example, drivers may prioritize different types of data depending on the task at hand such as identifying trailers, coordinating yard locations, or monitoring coupling status. These contextual variations underscore the importance of designing interfaces that support task-specific demands. As Gullà, Ceccacci, Germani, *et al.* [30] emphasize, adaptive interface design should accommodate these varied requirements, ensuring that users are presented with the most relevant information to perform their tasks safely and efficiently.

In addition to task-specific data, environmental factors such as terrain type, weather conditions, and proximity to obstacles play a crucial role in operational safety and situational awareness. As noted by Park, Xing, Akash, *et al.* [31], environmental complexity including elements like road type and lighting significantly affects drivers situational awareness, influencing their ability to perceive and respond to critical information effectively.

2.5.2 Gaps and Problems

Through this project, several key gaps and challenges in current terminal tractor display systems are expected to emerge. In particular, the research anticipates identifying limitations in how existing Human-Machine Interfaces (HMIs) support the varying needs of operators during different tasks. These may include insufficient flexibility in adapting to shifting workflows, a lack of support for task-specific information, and poor alignment with real-world operator behavior. By uncovering these issues, the project aims to highlight where current systems fall short and provide a foundation for proposing improvements that enhance usability, safety, and operational efficiency in terminal tractor environments.

2.5.3 Task-Related Data Insights

The study expects to identify the variations in data needs based on the operational context. Since different steps in the workflow serve a unique function, the data displayed must be aligned with the operators immediate requirements for efficient operation. The project will focus on how task-specific data, such as navigation, maneuvering, system performance, or load distribution, can be optimized for terminal tractors vehicles to improve operational safety and effectiveness in various environments.

2.6 Volvo Penta

Volvo Penta is a global leader in developing power solutions, specializing in engines rather than entire vehicles. Unlike manufacturers that produce off-highway vehicles, Volvo Penta focuses exclusively on delivering innovative and reliable engines that power a wide range of industrial, marine, and off-road applications. Their expertise ensures that they meet the demands of various industries while prioritizing efficiency, durability, and sustainability [5]).

A key area of Volvo Pentas operations is the design and production of off-highway engines, which serve industries such as agriculture, mining, forestry, material handling, and construction. These engines are known for their power, versatility, and fuel efficiency, making them essential for heavy-duty machinery operating in demanding environments. By focusing solely on engines rather than complete vehicles, Volvo Penta positions itself as a trusted partner for original equipment manufacturers seeking high-performance and dependable power solutions.

Volvo Penta is also deeply committed to innovation, particularly in the fields of electrification and renewable energy. They offer modular and custom-built electric power systems, enabling the electrification of vehicles such as fire trucks and forklifts. Their battery energy storage subsystems (BESS) provide scalable, energy-dense solutions that enhance efficiency and support energy transition. Additionally, Volvo Penta is exploring renewable fuels, including hydrogen dual-fuel engines and Hydrotreated Vegetable Oil (HVO), to reduce emissions while maintaining exceptional performance [5].

Volvo Penta adopts a partnership approach in their line of business [32]. They collaborate closely with Original Equipment Manufacturers (OEMs), companies that produce machinery or vehicles using Volvo Pentas engines. This collaboration allows Volvo Penta to deliver tailored solutions that meet specific industry requirements. With a global network of over 3,500 dealers spanning 130 countries, Volvo Penta ensures that their customers receive unparalleled support, including spare parts, compliance assistance, and service coverage.

2.7 CPAC Systems

CPAC Systems, a member of the Volvo Group, brings over 25 years of expertise in developing advanced systems for Marine vessels, Offroad machinery, and Commercial Vehicles. The company is particularly renowned for its work in Embedded Systems, where it specializes in designing custom user interfaces that simplify complex operations across various industries. These interfaces are central to CPAC's solutions, whether for autonomous vehicles, advanced automation, or control systems. In addition to their interface expertise, CPAC Systems excels in Vehicle Automation, developing autonomous solutions for mining and agricultural applications, and Electromobility, where they integrate electrical motor control systems for marine and industrial vehicles. [33].

CPAC, being a part of this project, has provided this masters thesis with their previous work and their future visions for the terminal tractor during the discover phase of this project, this information has helped in gaining a base understanding of what can be done and what is being done in the field of terminal tractors.

2.8 NTEX

NTEX, a leading logistics company in Scandinavia, was founded by Thomas Ström with the goal of providing a regional alternative in the logistics market. Through both strategic acquisitions and organic growth, NTEX has become one of the largest companies in its sector in Scandinavia, with an impressive turnover of over 3.8 billion SEK. The company operates a fleet of approximately 1,300 trailers for freight transport, complemented by a robust network of transshipment and logistics terminals. These terminals play a crucial role in NTEXs operations, serving as key hubs for the efficient movement of goods, with their own fleet of terminal tractors helping to streamline the handling and transfer of cargo between trailers and warehouses. [34]

NTEX has played a significant role in this masters thesis by providing terminal tractor operators for the user studies, observations and evaluation.

2.9 Göteborg RoRo Terminal

Göteborg RoRo is a key part of Sweden's logistics network, specializing in RoRo (Roll-on/Roll-off) operations for vehicle handling and other cargo that can be rolled on or off ships. The terminal offers tailored solutions for specialized cargo and load carriers, ensuring efficient logistics operations. In addition, Göteborg RoRo provides rail solutions through its combined terminal and uses terminal tractors to optimize the transfer of goods across different transport modes. With over 400 professionals, the terminal operates year-round, supporting Swedens import and export chain [35].

Göteborg RoRo has provided the project with a meeting with a terminal tractor operator during the discovery phase of the project for conducting user studies and observations of the terminal tractors in use.

3

Theory

In this chapter, important theoretical subjects and concepts are described, as well as how they relate to this thesis.

3.1 Interaction Design

3.1.1 Wicked problems

The field of design is dynamic and flexible, meaning there are no defined foundations for how design thinking is structured. As Buchanan [36] states, "No single definition of design, or branches of professionalized practice such as industrial or graphic design, adequately covers the diversity of ideas and methods gathered together under the label." Despite lacking a unified foundation for the various design disciplines, they share common ground in their approach to addressing wicked problems.

Wicked problems are a concept first introduced and described by Horst and Webber [37]. It aims to describe problems that are complex, ill-defined, and not fixable with straightforward solutions. These problems often arise in design and planning contexts where traditional linear problem-solving methods are inadequate. This concept challenges the step-by-step models of the design process that assume problems can be fully defined and then solved analytically. Rittel and Webber [37] mention ten key properties that define wicked problems where six principles that applies and aligns to this masters thesis are described below:

1. **No definitive formulation:** The issue being solved in this thesis (creating an intuitive and efficient display interface for terminal tractors) does not have a single clear definition. What makes a display interface free from issues depends on the user, the context, and the operational needs.

2. **No stopping rules**: With the design process being of iterative nature and that this thesis will not reach full implementation in vehicle, there is no clear point in which the interface is "done".

3. **Good or bad solutions, not true or false**: The design of the interface will not have a single "correct" answer. Rather, the answer will be related to its usability, efficiency, and user satisfaction.

4. **Subjectivity in explanations**: The project incorporates several stakehold-

ers (e.g., drivers, operators, UX/UI experts) that may define the problem and solution differently. What one user finds intuitive and satisfactorily, another might find confusing.

5. **Interconnected problems**: The design of the display is interconnected to broader system challenges, such as safety, vehicle automation, and operational efficiency. This can result in a situation where one aspect is improved at the cost of another, creating new challenges elsewhere.

6. **No definitive test for solutions**: The validation that the design solution is the best will not be apparent until it has been implemented under real-word conditions for a longer period. Simulations and user testing will help, but the unpredictability of the real world remains.

By recognizing the nature of these challenges, the approach of the design process will be iterative, and user centered. Since no definitive solutions exist, the thesis will rely on prototyping, user feedback, and iterative refinements to navigate through the complex nature of designing an intuitive and efficient display solution. The absence of stopping rules puts responsibility on balancing usability, efficiency, and adaptability rather than seeking a "correct" answer. Lastly, by engaging with stakeholders and user testing, the project aims to address the subjective nature of framing problems and ensuring a result that is well integrated and has been thoroughly evaluated.

3.1.2 Human computer/machine interaction

Human computer interaction (HCI) is an area of research and practice that emerged in the early 1980s, initially as a specialty area in computer science embracing cognitive science and human factors engineering [38]. With the rapid pace of digitization, the field of HCI has grown and evolved greatly since the 1980s, and with this growth, users' needs and demands change. Carroll explains that "HCI is about understanding and critically evaluating the interactive technologies people use and experience. But it is also about how those interactions evolve as people appropriate technologies, as their expectations, concepts and skills develop, and as they articulate new needs, new interests, and new visions and agendas for interactive technology."

With regards to this thesis of digital interfaces in terminal tractors it is highly relevant to consider the drawbacks it can bring. According to Li, Vaezipour, Rakotonirainy, *et al.* [39], ...an in-vehicle HMI introduces additional information to drivers to guide their behaviors, which may lead to an overload of mental and visual workload.. This argues for carefully considering the workload that comes with introducing a new source of information in the vehicle and balancing the amount of information and how it is displayed. Concepts of usability and UX will play an important role in justifying what will be regarded as an appropriate solution without introducing cognitive strain for the user.

3.1.3 Usability

Usability can be defined as how easy a product is to use and its level of intuitiveness. Where the word intuitiveness is understood in this report as described by Blackler, Popovic, and Mahar [40] "intuition is a cognitive process that utilizes knowledge gained through prior experience. Intuitive use of products involves utilizing knowledge gained through other products or experience(s). Therefore, products that people use intuitively should be those with features they have encountered before.".

More formally, the International Standards Organization (ISO) defines usability as ... the effectiveness, efficiency and satisfaction with which specified users can achieve specified goals in particular environments (ISO DIS 9241-11) [41].

The formal definition is broken down into the three aspects described below:

- **Effectiveness:** Effectiveness refers to the ability in which how well a goal or task is achieved. In some cases, its a simple success or failure, such as successfully opening a new file in a word processor. In other situations, it can be measured as a percentage, such as producing 80 out of a desired 100 components in a day, representing 80% effectiveness.
- **Efficiency:** Efficiency refers to the effort required to achieve a goal the less effort, the higher the efficiency. Effort can be measured by time taken or errors made. For example, creating a new file in a word processor is more efficient if done instantly and correctly on the first attempt, compared to taking minutes or making multiple errors. Unlike effectiveness, which focuses on achieving the goal, efficiency considers how smoothly the goal is reached.
- **Satisfaction:** Satisfaction measures how comfortable and acceptable a product feels to users, focusing on subjective factors such as design and user experience. This is a more subjective aspect of usability and can be more difficult to evaluate. An example of how satisfaction can affect usability can be that users might prefer a visually appealing TV interface even if another is faster. Satisfaction is crucial for voluntary-use products, where poor usability can lead to rejection, while in mandatory-use contexts like professional tools, effectiveness, and efficiency may take priority.

A valuable note regarding the ISO definition of usability is that it makes it clear that usability is not just a single property of a product. The usability factor is dependent on the user of the product, the goal they are trying to achieve and in which environment the product is being used. Therefore, usability is a property regarding the interaction of the product with the user and the set of tasks the user is trying to complete which is largely relevant for this thesis project.

3.1.4 User experience

User experience is the sum of the effect, or the effects felt by a user after interacting with a system, device, or product. This includes the influence of usability, usefulness, and emotional impact during interaction [42]. While usability focuses on effectiveness, efficiency, and satisfaction, user experience goes beyond these parameters and focuses on the holistic overall journey of the user.

In the context of this thesis, UX is especially relevant because designing an intuitive interface for various machine categories requires more than functional efficiency. It involves creating experiences that feel natural, seamless, and supportive, regardless of the users background or the specific machine in use. Taking the usability and UX factors into consideration for this project can aid in reducing cognitive and ergonomic workload by offering a solution that offers just the amount of information and functionalities at the right time. This will minimize the risk of creating an overly cluttered, complicated and/or complex interface that puts more stress on the users cognitive resources resulting in a solution that introduces an aid instead of another stress factor.

3.1.5 User centered design

User centered design (UCD) can be described as "...a practice, field, craft, framework, philosophy, discipline, or method of designing tools for human use by involving humans in the design process."[43]. This does not mean that the users are the ones producing the final design deliverables and should not be considered as such. Nielsen states in his book "Users are not designers and designers are not users"[44]. While users may engage in design activities as participants in design research, their role is to provide reflections and insights that the designers can use to base and shape their work. In this regard, UCD practitioners such as user experience architects or interaction designers can profile users, study their behaviors, and define their preferences for various aspects of a product or application. By understanding these insights, designers can make informed design decisions.

Furthermore, UCD is not about asking users directly what they want, as doing so introduces risks for bias. Instead, it is a collaborative process where the designer provides materials for users to reflect upon and then uses the insights gathered to craft solutions that meet user needs effectively. This collaboration between designer and user ensures that design outcomes are both functional and user centric.

The approach of UCD will be highly relevant for this thesis project since the deliverable is an interface that will be used and interacted with by humans.

3.1.6 Ideation

Ideation is described by Knight, Fitton, Phillips, *et al.* [45] as "...replicating creative cognitive processes and structuring activity to optimize the fuzzy challenge of developing ideas.". The term ideation is used when facilitating activities to generate a variety of ideas. There are many ideation activities and methods, an example of this type of activity is "Crazy-8" [46].

Conducting ideation can aid in increasing the quantity as well as the quality of ideas in the design process when done by multiple people. As Knight, Fitton, Phillips, *et al.* [45] states "Ideation is usually done in groups, on the basis that cohort size correlates with quantity and quality of outputs."

Different means of ideation will be used for this project to generate large sets of ideas and to explore alternate solutions.

3.2 Digital Vehicle Interfaces (DVI)

The design of interfaces for vehicles comes with many parameters to consider. Having the interface not distracting the user in their work is essential since it is closely related to safety considerations. The report "Human Factors Design Guidance for Driver-Vehicle Interfaces" [47] covers a wide range of design guidelines for digital vehicle interfaces derived from research. An example of one of these guidelines from the report regarding display location in heavy vehicles is that it should be "...compatible with normal visual scanning behaviors that heavy-vehicle drivers are trained to perform." other types of guidelines and principles regarding communicating messages from the system auditory or visually can be seen in table 3.1.

The guidelines provided in the report are mainly intended for on-highway vehicles; however, since they are both moving vehicles where attention should be focused on the driving and maneuvering of the vehicle and that the guidelines we incorporate are mainly regarding presenting information in a moving vehicle it is relevant to use as an instrument when conducting heuristic evaluations for this thesis; see Subsection 4.2.4.2 for a description of the method.

Use Auditory When	**Use Visual When**
The message is simple.	The message is complex.
The message is short.	The message is long.
The message will not be referred to later.	The message will be referred to later.
The message deals with events in time.	The message deals with locations in space.
The message calls for immediate action.	The message does not call for immediate action.
The visual system is overburdened.	The auditory system is overburdened.
The receiving location is too bright or dark.	The receiving location is too noisy.
The user must move about.	The user can stay in one place.

Table 3.1: Table of Principles for System Messages

3.3 Conclusion

This chapter has outlined key theoretical concepts relevant to this thesis. These theoretical frameworks provide the foundation for addressing the research question:

" How can an intuitive digital interface be designed for terminal tractors to enhance operational efficiency and ensure safety, while reducing the cognitive and ergonomic workload? "

Based on the discussed theories, an intuitive interface can be understood as one that uses users prior experiences, minimizes cognitive load, and aligns with both usability principles (effectiveness, efficiency, satisfaction) and the broader holistic UX considerations. Intuitiveness emerges from familiarity, clear information hierarchy, consistent design patterns, and responsiveness to user feedback. In addition, it is shaped by the context in which the interface is used, the emotional responses it evokes, and the extent to which it supports users in achieving their goals seamlessly. Through iterative design, user involvement, and continuous evaluation, this thesis aims to create an interface that not only functions effectively but also provide a meaningful and satisfying user experience.

4
Methodology

This thesis adopted research through design approach, which was particularly well suited for addressing complex challenges within user experience and interface design. The process followed the stages of discover, define, develop, and deliver, providing a structured yet flexible framework for developing user-centered solutions. By involving terminal tractor operators throughout the design process, the research sought to identify pain points in key operational workflows.

The primary objective of the study was to develop an intuitive and adaptive display that presented critical information precisely when it was needed. Although tasks like coupling confirmation and container coordination differed in nature, they shared fundamental requirements for prompt updates and clear, actionable feedback. Addressing these shared needs was essential for enhancing both operational efficiency and safety in terminal tractor environments.

4.1 Research through design

The methodology of Research through Design (RtD) was integral to this thesis. Research through design involves generating knowledge and insights through the design process itself, rather than through traditional methods like experiments or literature reviews alone [48]. In this thesis, RtD was used as a means to explore and refine the design of the interface in terminal tractors.

The core idea of RtD is that the design process itself contributes to research by testing, experimenting, and iterating on various design solutions. This iterative process enabled the creation of design artifacts (such as prototypes) that provided valuable insights into the problem and helped evolve the solution over time [49]. Through RtD, the interface designs not only served the functional needs of the machines but also contributed to the broader field of UX/UI design for off-highway vehicles.

4.2 Double Diamond

The thesis used the double diamond framework, which originates from the design problem-solving process. The double diamond framework consists of four main phases: Discover, Define, Create, and Deliver. The first phase, Discover, aimed to explore the problem space. The second phase, Define, sought to define the problem based on the previous findings. The third phase, Create, diverge the solution space to explore possible solutions for the defined problem. The fourth phase, Deliver, evaluated the potential solution(s) that emerged from the previous step.

- **Discover**: The first phase involves exploring the problem space by studying the terminal tractor, the current interfaces, and identifying areas where they fall short. This phase focused on gathering insights from various stakeholders.
- **Define**: In this phase, the gathered data was analyzed to define the specific challenges in the current operational workflow, identifying the most critical tasks that need to be prioritized and addressed in the interface design.
- **Create**: The third phase explored potential solutions by diverging into various design ideas, prototypes, and concepts that could address the identified challenges. These solutions were then refined through iterations.
- **Deliver**: The final phase involved evaluating the best solution(s) to address the defined challenges and selecting the most effective approach for a digital interface inside the cockpit of terminal tractors.

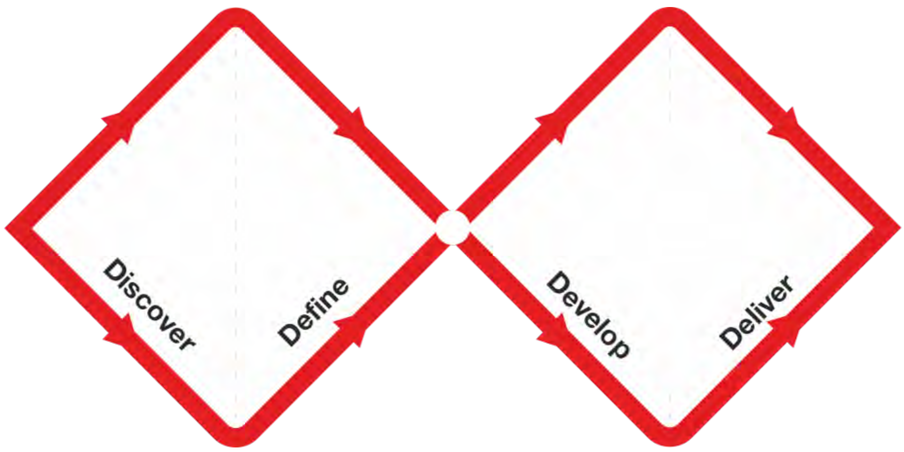

Figure 4.1: The double diamond framework visualized [50].

4.2.1 Discover

The Discover phase focused on conducting preliminary research to gain a comprehensive understanding of the operational environment, user needs, and behaviors of terminal tractor operators. Key activities included engaging with stakeholders, viewing video material, observing workflows, and identifying the functional requirements and interaction patterns that shaped daily operations in port and yard settings.

4.2.1.1 Digital observations

Digital observation is a qualitative method that involves analyzing publicly available online content to study behaviors and practices in naturalistic settings. This approach is grounded in digital ethnography, which recognizes online platforms as valid environments for research [51]. For this project, digital observation offered a practical and valuable complement to field studies by providing access to detailed examples of operators workflows, including task execution, vehicle interaction, and movement patterns. It enabled a contextual understanding of daily operations that might not have been fully observable in person, thereby supporting a richer, more comprehensive analysis of the user journey.

4.2.1.2 Interviews

Interviews were conducted with key stakeholders at Volvo, including:

- **UX/UI Designers:** The team currently working on the interface design for the terminal tractor, to gain insights into their current design process and challenges.
- **Engineers:** Experts who are familiar with the technical functions and operational needs of terminal tractors. Their input will be crucial in understanding the most important operational tasks that need to be represented in the interface design.

These interviews were conducted in a semi-structured manner to ensure a balance between gathering detailed insights and allowing flexibility for open discussions. Following *The Mom Test* guidelines, the goal was to avoid leading questions and obtain unbiased feedback to inform the design direction. According to Rob Fitzpatricks principles in *The Mom Test*, the key is to ask about real-life experiences rather than hypothetical situations, ensuring that the feedback was grounded in actual user behavior [52](Gamble, n.d.).

4.2.2 Define

In the Define phase, qualitative analysis methods were employed to analyze the data collected from stakeholder interviews. The goal was to gain a deeper understanding of the unique needs for terminal tractors and further define the scope of the project. The research focused on:

- Identifying common operational needs across the terminal tractor.
- Prioritizing critical tasks that should be represented in the interface.
- Defining user requirements to ensure the interface enhances operational efficiency and usability for operators.

4.2.2.1 Affinity analysis

Affinity analysis was employed to analyze the interview data and uncover key patterns and insights. This qualitative approach proved ideal for exploring participants perceptions and experiences, particularly in identifying recurring themes related to operational needs and interface design[53]. The process proceeded through several stages to ensure a systematic and focused analysis:

- Becoming familiar with the data.
- Identifying recurring themes relevant to the research focus, such as operational needs and interface priorities.
- Reviewing and refining the identified themes for accuracy and consistency.
- Defining and naming the themes for clarity and relevance.
- Verifying themes with concrete examples that directly inform interface design.

4.2.2.2 Fishbone diagram

The Fishbone Diagram, or Ishikawa diagram, is a tool used to identify the root causes of issues within a system. It visually organizes potential contributing factors, helping teams analyze underlying causes. In this project, the Fishbone Diagram was used to analyze user data collected during field studies, complementing the affinity diagram in categorizing insights. This method allowed for the identification of operational, technical, and environmental factors that affected the usability of the terminal tractors, ensuring a comprehensive understanding of the challenges users faced [54].

4.2.2.3 User Journey

A User Journey is a visual tool that maps the steps a user takes to achieve a specific goal within a system, highlighting key interactions, emotional responses, and potential pain points along the way. In this project, it was used to trace the terminal tractor operators experience from the initial system interaction to task completion, allowing the team to identify critical touchpoints and improve the user experience. By centering on the user's perspective, the User Journey revealed important usability challenges and opportunities for improvement [55].

4.2.3 Create

This phase focused on generating and prototyping solutions based on the defined challenges.

4.2.3.1 Ideation

Various brainstorming activities and ideation techniques were employed to generate a wide range of concepts aimed at addressing the identified operational needs of terminal tractor operators. This phase is built on insights gathered during the Discover phase, where user needs, workflows, and functional requirements were established.

The outcome of the ideation phase was a set of preliminary concepts, sub-concepts, or interface ideas. These were heuristically evaluated and, where appropriate, synthesized to form a final concept that aligned as closely as possible with the identified requirements and supported efficient, safe operation in terminal tractor environments.

4.2.3.2 Crazy 8

Crazy 8s is an ideation technique used to quickly generate a variety of design ideas. Participants are given eight minutes to sketch eight distinct solutions to a specific design challenge, promoting creativity and pushing beyond initial, obvious concepts. In this project, Crazy 8s was applied to explore different interface concepts for the terminal tractor system. This method encourages divergent thinking early in the design process, helping identify directions before refining selected ideas[56].

4.2.3.3 Prototyping

Low-fidelity prototypes were developed early to test initial ideas from the ideation and gather feedback. The low level of fidelity helped in gathering feedback regarding the fundamentals of the concept, instead of specific design details, in a quick manner [57]. These prototypes then underwent iterative refinement to optimize the design of the interface, ultimately leading to a high-fidelity prototype as the final concept deliverable.

4.2.4 Deliver

The final interface design was developed and prepared as a deliverable, incorporating insights from all previous phases to ensure a cohesive and user-friendly solution for terminal tractors.

4.2.4.1 Evaluation

The final solution underwent usability testing with stakeholders, including UX/UI designers and operators. In addition to this, heuristic evaluations were performed to assess how the interface performed in relation to established design principles in digital vehicle interfaces. The feedback from the evaluative studies was used to ensure the interface effectively met operational needs and usability requirements for the terminal tractor.

4.2.4.2 Heuristic evaluation

Heuristic evaluation is a type of usability evaluation method in which designers evaluate a user interface against established principles, also known as heuristics, to identify usability issues [58]. The heuristics are mainly based on results from research of what good usability factors are, making them reliable. However, heuristic evaluation should not replace testing with real users, instead, it should complement user testing and be integrated early as well as later stages in the design process.

4.2.4.3 Think Aloud

The Think Aloud protocol is a qualitative usability method in which participants verbalized their thoughts while interacting with the interface, providing valuable insights into their decision-making and uncovering usability issues. In this project, Think Aloud sessions involved UX/UI designers, engineers and operators discussing scenarios related to terminal tractor operations. The feedback collected was analyzed to inform design improvements and ensure the interface met user needs [59].

4.2.4.4 The Wizard of Oz

The Wizard of Oz method is a usability testing technique in which users interact with a system that appears fully functional, while a human operator simulates the systems responses. This method allows designers to test the user experience and interface functionality without needing a fully developed system. In this project, the Wizard of Oz technique was used to simulate the behavior of the terminal tractor interface, enabling UX/UI designers and engineers to observe how users interacted with the interface and identify potential usability issues. This method was particularly useful in the early stages of design when testing a prototype or exploring complex interactions that were not yet automated [60].

4.2.4.5 Focus Groups

Focus groups is a qualitative research method used to gather diverse user opinions, experiences, and expectations through guided group discussions. In this project, focus group were conducted with UX/UI designers to explore perceptions of the terminal tractor interface and gather feedback on usability, functionality, and design. This method encouraged participants to build on each others ideas, revealing insights that may not have surfaced in individual testing. The discussions helped identify common usability concerns and informed design decisions [61].

5

Planning

This chapter presents the planning of the master's thesis. It includes the time plan and planned result.

5.1 Time Plan

The thesis was carried out for 20 weeks, starting on January 20th, and included the following main areas of work: planning report, user research, ideation, prototype & evaluation, and thesis report. Throughout the project, consultations with both the supervisor from Chalmers University of Technology and the advisors from Volvo Penta were held weekly. For the complete time plan with all sub-sections, see Figure 5.1.

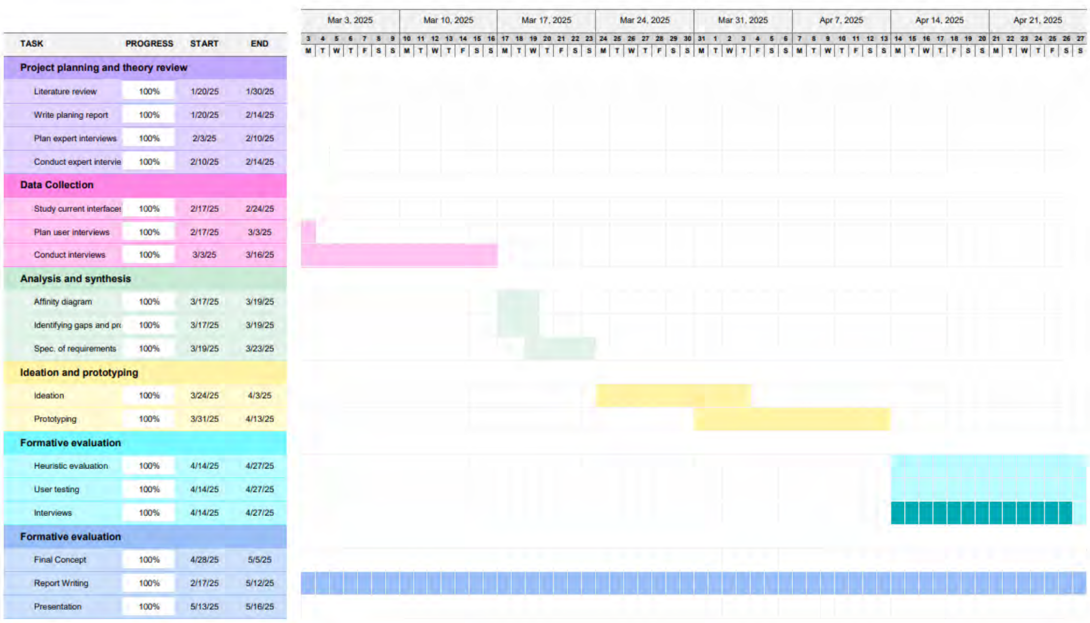

Figure 5.1: Cutout from the Gantt-chart of the projects timeplan.

6

Ethical Considerations

6.1 Data Privacy

When utilizing systems that involve Artificial Intelligence (AI), it is essential to prioritize data privacy to protect users sensitive information. Clear guidelines should be established to avoid sharing sensitive information with AI systems unnecessarily. For example, anonymizing user data before processing or excluding it altogether can reduce privacy risks. Organizations must also inform users how their data will be used and obtain explicit consent, empowering individuals with control over their personal information.

6.2 Accessibility

Accessibility should be a central consideration when designing products to ensure inclusivity for all potential users, regardless of ability. This involves designing systems and interfaces that are usable by individuals with diverse needs, such as those with visual, auditory, cognitive, or physical impairments. Incorporating universal design principles and conducting accessibility testing during development can help eliminate barriers to use. By prioritizing accessibility, the product can cater to a broader audience, enhancing usability and equity in access.

6.3 Environmental Impact

The production and operation of systems, particularly those involving digital technologies, have an environmental impact due to energy consumption and material usage. For example, manufacturing hardware often relies on resources that contribute to greenhouse gas emissions and e-waste. Ethical development requires assessing the carbon footprint and sustainability of the materials used. Choosing eco-friendly alternatives, optimizing energy efficiency, and designing systems that are durable, or recyclable can mitigate environmental harm. Developers should also consider whether the products environmental cost is justified by its utility.

6.4 Meaningful Interaction

Before investing in the development of a new product or system, it is critical to evaluate its necessity and purpose. If the product does not provide meaningful value or serves only a marginal purpose, it may contribute to overconsumption or create unnecessary waste. Ethical development should involve assessing whether the product addresses a genuine need or problem. Engaging stakeholders and conducting research during the ideation phase can ensure that resources are allocated to projects that create meaningful, positive impacts rather than producing redundant or superfluous solutions.

7

Process and Execution

In this chapter, the design process and methods executed during the project will be described. The process was structured around four key phases: Discover (research and insights gathering), Define (problem definition and requirements), Develop (concept generation and iteration), and Deliver (finalization and presentation). Each phase contributed to the overall success of the project, helping to shape the final design.

7.1 Discover

The Discover phase focused on gathering insights through literature review, domain understanding, prototype exploration, and user research.

7.1.1 Literature Review

To establish a solid understanding of the terminal tractor and related fields relevant to this master's thesis, a comprehensive literature review was conducted, See section X. This review focused on the design of user interfaces in off-road vehicles, with the aim of improving usability, efficiency, and safety for operators. As this area is relatively novel, the review involved investigating interface solutions applied to off-road vehicles more broadly, with the goal of drawing insights that could be applied to terminal tractors.

Given the limited research specifically on interface design for terminal tractors, the literature review primarily focused on available studies related to off-road vehicle interfaces. Keywords such as "off-road vehicles," "interface design in off-road vehicles," "usability in vehicle interfaces," "human-machine interaction," "safety in vehicle design," "efficiency in vehicle operation," and "operator interface" were used to search for relevant studies. These searches were conducted primarily through Google Scholar.

Due to the emerging nature of the field, particularly the integration of interfaces in terminal tractors, much of the research conducted for this thesis relied on methodologies like the Double Diamond and Research Through Design (RtD). These methodologies were chosen to structure the exploration of the problem space and guide the design process, especially when tackling complex, or "wicked," problems within the interface design process.

While most of the literature reviewed focused on general interface design, usability principles, and efficiency in off-road vehicle contexts, fewer studies specifically addressed how to integrate interface solutions within terminal tractors. However, insights drawn from research on interface design for similar off-road vehicles were adapted to understand potential user needs and challenges in terminal tractor operations. The importance of user-centered design and ergonomics in vehicle interfaces was emphasized throughout the literature, highlighting the critical role that interfaces play in enhancing operator performance and safety.

The findings of the literature review mainly addressed strategies for conducting research in contexts where access to users is limited, such as industrial or transportation settings. One key insight was the value of video analysis as a method for observing user behavior and identifying usability issues without requiring constant user participation. These findings directly influenced the approach taken in Chapters 2 (Background), 3 (Theory), and 4 (Methodology), where methods such as remote observation and task analysis were emphasized. Together, these insights provided a foundation for understanding the practical and methodological challenges of designing effective user-centered interfaces in a specialized domain.

7.1.2 Understand the Domain

To design an effective interface for terminal tractors, the operating environment was studied, industry experts were consulted, and existing prototypes were reviewed.

7.1.2.1 Understanding the Terminal Tractor at Volvo Penta

As part of the research, the collaboration with Volvo Penta experts provided valuable information on the architecture of the system and the design of the interface for terminal tractors. A comprehensive walk-through of the terminal tractor was carried out, including an introduction to its machine controls and the vehicles functions within its operational environment (see Figure 7.1). During this session, information about the various systems integrated into the vehicle was gathered, informing the understanding of how the interface would need to interact with these components.

7.1.2.2 Exploring the CPAC Test Rig

As part of the research, collaboration with CPAC provided access to a test rig developed for integration into a terminal tractor. The test rig, located at CPACs facilities, featured an interface capable of displaying various types of information and controls. Although the interface was in the early stages of development, it provided valuable insights into how information could be managed and customized to meet operator needs. The flexibility of the system demonstrated how different data could be presented in a user-friendly manner, enabling efficient operator interaction.

7.1.2.3 Reviewing Previous Interface Prototypes

During the collaboration, two low-fidelity interface prototypes designed for terminal tractors were introduced. One prototype was developed by Volvo Penta and

Figure 7.1: Image of the terminal tractor during the walkthrough at Volvo Penta, showcasing the machine controls and operational systems.

the other by CPAC. Both prototypes were created in Figma, and although not fully functional, they provided an important starting point for understanding the interface context. These prototypes focused on basic interface elements and were instrumental in exploring early design concepts, helping to identify key user interaction principles. Review of these low-fidelity prototypes provided insights into the visual and functional aspects necessary to improve operator safety and efficiency.

7.1.2.4 Leveraging the Roadmap for Design Direction

To guide the development of the interface, a detailed roadmap document outlining Volvo Pentas vision for the terminal tractors interface and the required features was provided. This roadmap served as a crucial reference throughout the early stages of the design process. The document clearly outlined essential functions, including vehicle diagnostics and operational controls, and highlighted anticipated future developments.

7.1.2.5 Prototyping Our Interface to Test Assumptions

After exploring existing interfaces and analyzing system requirements, the decision was made to create a custom interface to better understand the functions and their potential integration. This approach enabled visualization of different features and identification of essential versus non-essential functions. As a result, more informed questions could be formulated for the user interviews.

In this phase of the design process, conceptual ideas were translated into tangible visual representations through wireframes, which served as structural blueprints outlining the layout and user interaction flow of the interface. The foundation for these concepts was a roadmap provided by Volvo Penta, developed during an initial visit to Göteborg RoRo, where specific operator needs and workflow challenges were identified. These insights guided the design direction, ensuring that the interface addressed operational requirements.

The act of prototyping played a central role not only in visualizing solutions but also in deepening the understanding of the vehicles functions and the operators workflows. Decisions about the placement and functionality of UI elements required active engagement with the system's context, reflecting a Research through Design approach. Additional inspiration was drawn from earlier conceptual interfaces developed by Volvo Penta and CPAC, which provided valuable references for design principles and best practices in the domain.

The wireframes focused on six critical features: machine controls, CarPlay integration, battery status, camera view, task management, and navigation. Each wireframe was designed with the unique needs of terminal tractor operators in mind, incorporating considerations such as screen size, control systems, and workflow to ensure the interface was both intuitive and efficient. Although initially conceptual, the wireframes provided a foundation for envisioning how the interface could look and function within a terminal tractor environment (see Figure 7.2).

To further refine the design, the process transitioned from wireframes to more detailed drafts. This progression was guided by Volvos design principles and specific aesthetic guidelines, ensuring consistency with Volvos established branding. The drafts expanded upon the wireframes by incorporating additional details for each feature, including machine controls for managing the fifth wheel, GPS-style navigation, camera view options, real-time performance data, and task management tools (see Figure 7.3).

The resulting interface served as a hypothesis regarding the systems functional requirements. The primary objective at this stage was to include as many functions as possible, rather than focusing on user experience, to determine which features were most crucial for operators. This approach enabled the development of relevant user test questions, guiding subsequent user research to gather critical information for refining the interface based on real-world feedback and operational needs.

7.1.3 Change of Scope

As an initial milestone in the design process, the thesis began with a broader objective: to explore how a unified interface could be developed for multiple types of off-road vehicles, particularly focusing on forest harvesters and terminal tractors. This early approach was based on the assumption that many interface challenges such as usability, safety, and efficiency would be shared across vehicle types. While this exploration helped build foundational understanding and context, it is not directly aligned with the final research question.

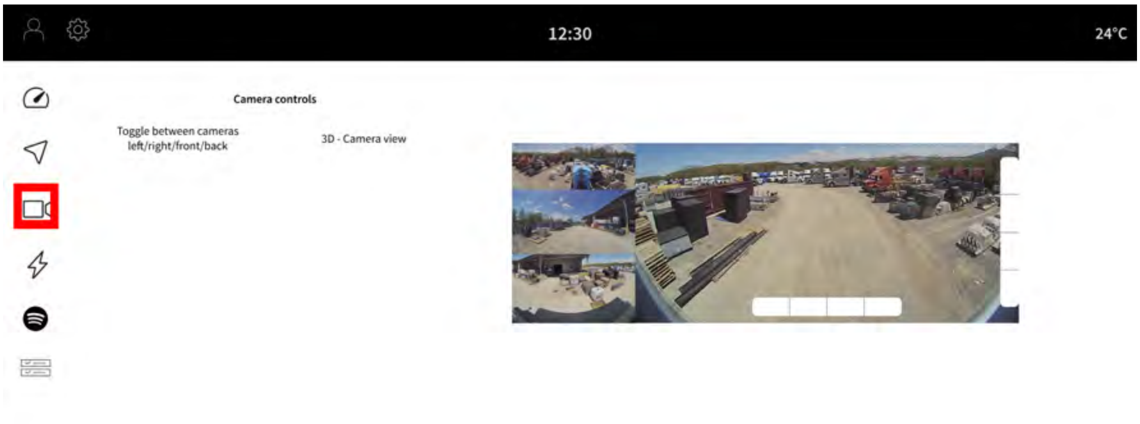

Figure 7.2: Wireframe of the terminal tractor interface showcasing the key features and layout

Figure 7.3: Higher-fidelity draft of the terminal tractor interface, incorporating additional details and design elements.

As the research progressed, it became evident that the operational environments and requirements of forest harvesters and terminal tractors were fundamentally different. Forest harvesters operate in forests, performing complex tasks such as felling trees, navigating rough and uneven terrain. In contrast, terminal tractors are primarily used in controlled environments, such as harbors, where their main function is the transport of shipping containers. The terrain, operational tasks, and cockpit layouts differ significantly between the two vehicles, making it challenging to create a one-size-fits-all interface.

Furthermore, it was found that forest harvesters had more advanced technology and interface solutions, leaving less room for meaningful improvements in this area. Given these differences and the fact that more data was available on terminal tractors, along with a better understanding of their design, the scope of the research was narrowed to focus exclusively on terminal tractors. This decision also aligned with the projects time constraints. By concentrating on terminal tractors, the research was able to focus on interface solutions tailored to the specific needs and challenges of terminal tractor operators, leading to a more focused study.

7.1.4 User Research

7.1.4.1 Digital Observations

One of the main challenges in reaching terminal tractor operators was the specialized nature of these vehicles. Terminal tractors are not widely used across various industries, with their primary application in ports and harbors, often restricted areas due to security concerns. This limited direct access to operators made observations and interviews difficult to arrange.

Sitompul and Wallmyr (2019) highlight the challenge of conducting user research in environments where operators are difficult to access, such as in the forestry or heavy machinery sectors. To address this, they propose the use of online video analysis as a complementary method to traditional fieldwork. Their study demonstrates how publicly available videos on sites such as YouTube can offer valuable insights into user workflows and behavior without requiring direct contact with the users. Given the similarity in context, this approach was adopted in this study to better understand the workflows and pain points of terminal tractor operators.

Searching with keywords such as "working terminal tractor" and "terminal tractor walkthrough," multiple videos were found in which yard jockey operators of terminal tractors filmed their daily routines and shared their experiences on platforms like YouTube.

The analysis of these videos involved taking separate notes on each observation. Afterward, the notes were compared and discussed, allowing for a clearer understanding of the workflow. This method proved to be effective, providing valuable insights into the tasks and challenges faced by operators.

7.1.4.2 Visit at NTEX

An interview was conducted with one of the operators, guided by a set of prepared questions. The questions aimed to understand the operator's experience with the current interface and their overall workflow. Topics discussed included the usability and accessibility of the terminal tractor's controls, as well as the operator's views on efficiency, safety, and task management. For example, the operator was asked which dashboard functions they use most while driving, how they ensure the fifth wheel is properly coupled, and which controls they feel should remain physical versus digital. Additional questions explored whether they find any functions unnecessary, what type of information is most critical during various stages of operation, and how they experience physical comfort and control placement throughout a typical workday.

The operator provided detailed insights into daily challenges, offering a clearer picture of how the existing interface both supports and hinders their tasks. Key pain points included difficulties with task management, locating trailers that had been placed in incorrect locations, and coordinating pick-up and drop-off activities. The operator emphasized the importance of simplicity in the interface, pointing out that dashboards often include unnecessary features that add clutter and make the system harder to navigate. The full set of questions and responses from this interview can be found in Appendix A.

In addition to the interview, another terminal tractor operator was observed while carrying out a task involving the pickup and drop-off of a trailer at one of NTEXs operational locations. During the observation, attention was focused on the sequence of tasks the operator performed (see Figure 7.4 and 7.5), including hooking and unhooking the trailer, maneuvering the vehicle. The interaction with the current dashboard was also noted, with particular emphasis on aspects such as the visibility of important data and the cognitive load required to interact with the system while performing physical tasks.

Figure 7.4: Photos showing the operator connecting break cables

Figure 7.5: Photos showing the operator maneuvering the terminal tractor

7.1.4.3 Visit at Göteborg RoRo

At the Göteborg RoRo terminal, a detailed interview was conducted with a terminal tractor operator to gain insights into workflow routines and interaction with the current vehicle interface. The interview followed the same structured questions used in previous sessions, focusing on interface usability, task execution, safety procedures, and overall operational efficiency.

The operator highlighted several recurring challenges in daily operations. Notable pain points included difficulties when reversing the vehicle, forgetting to raise the trailers support legs before movement, and uncertainty around where to place trailers when designated slots were already occupied. The feedback emphasized the need for improved task management and guidance while reversing to reduce cognitive strain as well as improving safety.

In addition to the interview, terminal tractor operations were observed during an active task. Due to safety and access constraints, direct observation from inside the vehicle cockpit was not possible. However, three GoPro cameras were installed within the vehicle to record the operators actions and machine control interactions for later analysis.

Review of the video material confirmed previously identified patterns and did not result in any significant new insights. The footage supported earlier findings from both field and digital observations, reinforcing the presence of consistent workflow challenges such as reversing maneuvers and missed safety steps.

The convergence of insights across interview data, direct observations, and recorded footage indicated that the research had reached a point of saturation. Further user studies were unlikely to uncover additional pain points. The findings provided a strong foundation for transitioning into the ideation phase, with clearly defined areas for design improvement.

7.2 Define

The Define phase involved gathering insights through affinity and fishbone analysis, followed by creating a list of requirements to guide the design process.

7.2.1 Affinity Analysis

As part of the design process, affinity analysis was employed to structure the data gathered from both the NTEX visit and digital observations, see Figure 7.6. The raw data consisted of notes and direct quotes from terminal tractor operators, which were initially unorganized and difficult to interpret. To make sense of this information and facilitate further analysis, the team used Figma to place individual post-it notes, each representing an important statement or observation made by the operators. These notes were then grouped into themes, creating a more organized structure that could be used to identify key issues and areas for improvement.

The purpose of the affinity analysis was to organize and categorize the data to make it more manageable for the next stages of the design process. By grouping the data into themes, we were able to focus on the most significant aspects of the operator's experience, ensuring that the design would address the key challenges faced in the workflow. This structured approach allowed us to gain a clearer understanding of the areas that needed attention.

The themes that emerged from the analysis were broad and covered various aspects of the operator's tasks and interactions with the terminal tractor. Some of the primary themes included navigation, fifth wheel control, physical vs. digital buttons, safety risks, digitalization, and outside vehicle interactions. For instance, under the fifth wheel control theme, we documented a quote from an operator: "When the kingpin is attached, I raise the fifth wheel and trailer so the support legs lift off the ground." Similarly, under cables/connectivity, an operator remarked, "Can't drive without connecting the cables, so you have to leave the hut in order to connect them."

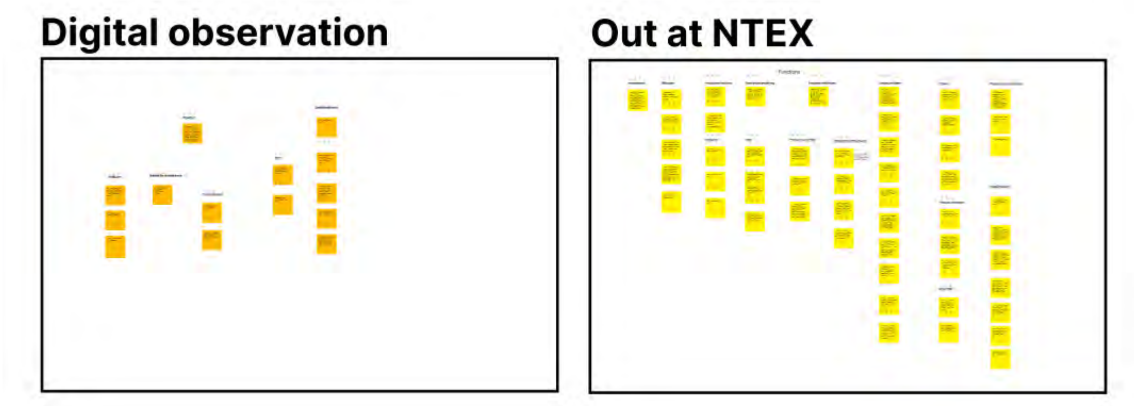

Figure 7.6: Image showing the affinity analysis, including post-it notes from both the NTEX visit and digital observations, categorized into key themes.

7.2.2 Fishbone Diagram

To further analyze the data collected from the affinity analysis, a fishbone diagram was used as a tool to identify root causes of problems within the terminal tractor's user workflow. The fishbone diagram helped to organize the insights from the affinity analysis into a structured, visual format. This tool allowed exploration of the underlying causes of the challenges faced by operators, identifying areas for improvement in the interface and overall user experience.

The fishbone diagram was structured around a central theme of "Usability in Terminal Tractor," with eight main branches extending from the central axis, see figure 7.7. Each branch represented a major aspect of the user experience, derived from the themes identified in the affinity analysis. For example, one branch focused on "Attaching Fifth Wheel to Kingpin," a critical task in terminal tractor operations. Two sub-branches were added under this category: "Aligning Vehicle" and "Securing Fifth Wheel," both identified as significant steps in the process.

The branch titled "Aligning Vehicle" was further expanded by breaking down the issues operators faced when aligning the vehicle with the kingpin. One sub-branch identified "Bad View" as a contributing factor to the difficulty in alignment. This was further subdivided into three branches, each representing different causes of poor visibility, such as camera placement issues, obstructed views, and insufficient display of critical information on the interface. By continuing to break down the problem into smaller components, the fishbone diagram facilitated the systematic tracing of root causes.

The use of this diagram was helpful in identifying specific pain points and bottlenecks in the terminal tractor workflow. It provided a clear visual representation of the interconnections between different challenges and their impact on the overall usability of the vehicle. As a result, the fishbone diagram became a vital tool for understanding the problems operators faced and guided the development of a comprehensive list of requirements for the interface design.

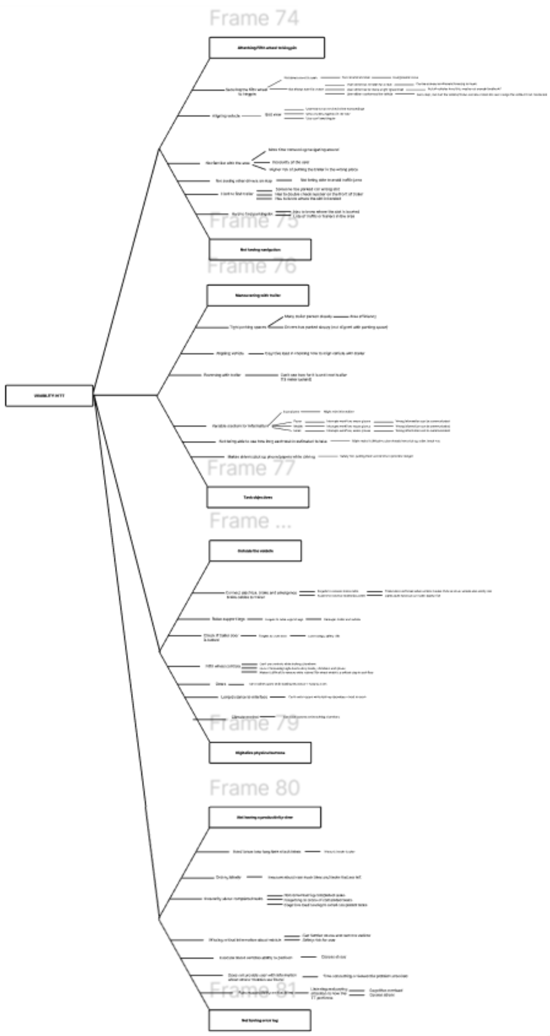

Figure 7.7: Fishbone diagram illustrating the breakdown of usability issues in terminal tractor operations, highlighting the root causes for key tasks such as attaching the fifth wheel to the kingpin and aligning the vehicle.

7.2.3 List of requirements

After completing the affinity analysis, a List of Requirements, see Appendix B, was created based on the insights gathered from both the affinity analysis and the fishbone diagram. The fishbone diagram had already broken down the core problems and identified key areas for improvement within the user workflow. The purpose of the List of Requirements was to organize these findings, prioritize them, and provide clear guidance for the interface design moving forward.

Examples of these requirements include:

1.1 The operator shall be able to see if the fifth wheel is open without turning their head.

3.1 The infotainment system shall assist the user in aligning the vehicle (lane assist).

4.1.1 The system shall display the distance to drop-off/pick-up locations for the trailer.

7.1 The infotainment system shall provide information about upcoming or pending tasks.

8.1 The infotainment system shall provide status information about the vehicle, including error notifications.

The List of Requirements was structured around the eight primary categories derived from the fishbone diagram. Each category addressed a specific aspect of terminal tractor operation, such as Attaching the Fifth Wheel, Aligning the Vehicle, Safety Risks, and Digitalization, among others. These categories represented critical challenges faced by operators during their daily tasks and provided the foundation for defining the interface requirements to address these issues.

For each category, the criteria were divided into two main groups: Requirements and Preferences. Requirements were considered essential for the interface's functionality, while Preferences were features that, although desirable, were not immediately necessary.

The criteria for each category were assessed and assigned a priority level:

Requirements were marked with the letter R. These were the most crucial elements, directly linked to improving safety, efficiency, and usability for the operator. A Requirement was determined based on whether the feature addressed a key issue identified during the affinity analysis that directly impacted the operator's ability to perform their tasks safely or effectively. If the absence of the feature would hinder the operator's workflow or safety, it was categorized as a Requirement.

Preferences were categorized based on their level of importance. The decision to categorize a feature as a Preference was based on whether it would enhance the overall user experience but was not critical to the systems basic functionality or safety. Preferences were further divided into Low, Medium, or High priority based on the potential impact they would have on the workflow.

- High Priority Preferences were features that, while not critical, would significantly improve the user experience or make the operators tasks considerably more efficient. These were prioritized when they aligned closely with operator needs or would substantially improve usability or safety without being immediately necessary.
- Medium Priority Preferences were features that were desirable and would enhance the workflow, but their impact was not as urgent as the high-priority preferences. These were often features that would improve convenience or ease of use but were not essential to the core functionality.
- Low Priority Preferences were features that, while beneficial, would have a minor impact on the overall workflow. These were features that could be implemented in the future if time and resources allowed but did not need to be prioritized during the initial design phase.

7.2.4 User Journey

To summarize the current workflow of a terminal tractor operator and pair pain points and specification of requirements to the different steps in the workflow, a user journey was created, see Appendix C. The user journey consisted of five rows and eight columns, the rows consisted of the following: user journey, line of action, measures, pain points and specifications of requirements. The columns represented the different sequences in the operators workflow which made it clear which steps of the workflow that most measures and issues are located. With this, the designers could ensure a consensus understanding of the workflow and its different aspects as well as that it served as a good communication tool to supervisors and other people outside the project.

7.3 Develop

The Develop phase involved turning insights into design concepts through ideation, sketching, wireframing, and creating a medium-fidelity prototype.

7.3.1 Ideation

Following the consolidation of user research and observation data, the project transitioned into identifying which areas of the operator workflow to focus on during ideation. Rather than immediately generating broad concepts, the team first reviewed the full list of user requirements and pain points, then mapped them against the typical sequence of terminal tractor operations:

- Drive to trailer
- Load trailer
- Drive to drop-off location
- Drop off trailer

This breakdown enabled a structured evaluation of where new design solutions could have the greatest impact. For each stage, critical functions and information needs were identified and categorized to determine where targeted ideation would be most valuable. The following elements were prioritized and mapped to the typical sequences mentioned above as key to improving the operator experience:

- Drive to trailer and to drop-off location
  - Task overview
  - Trailer number identification
  - Trailer weight
  - Pick-up and drop-off location details
  - Type of load
  - Information about available parking spaces
- Load Trailer and Drop off trailer
  - Fifth wheel status (including height recommendations and/or visual indicators)
  - Alignment support between fifth wheel and kingpin
  - Feedback about vehicle surroundings (e.g., cameras, sensors)
  - Feedback regarding trailer loading and off loading steps (e.g., support leg status, door lock confirmation, cable attachment)
  - Feedback about vehicle surroundings (e.g., cameras, sensors)
  - Feedback regarding trailer loading steps (e.g., support leg status, door lock confirmation, cable attachment)

7.3.2 Sketching

To begin the design process, Crazy 8 was used to quickly generate a broad range of interface ideas (see Figure 7.8, 7.9 and 7.10). This method was guided by the breakdown mentioned in subsection 4.2.3, which helped identify where design efforts could have the greatest impact.

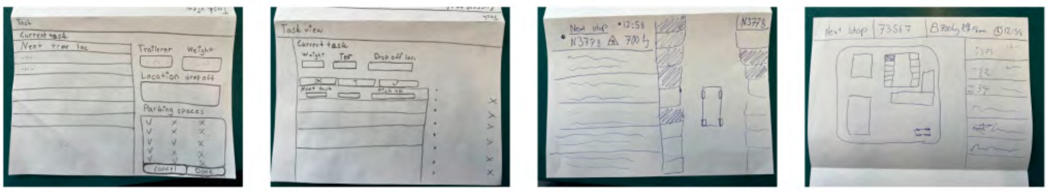

Figure 7.8: Sketches related to task view

Figure 7.9: Sketches related to reminders and pop-ups

Figure 7.10: Sketches related to the camera view.

7.3.3 Wireframing

Selected sketches were refined into three different wireframes in Figma; Task View, Camera View, and an example Pop-Up (See figure 7.11, 7.12 and 7.13). Chosen for their importance in shaping the core user experience. Prioritizing these elements helped establish a clear foundation for the interface, guiding future development.

Figure 7.11: Wireframe of task view, including productivity view and tasks.

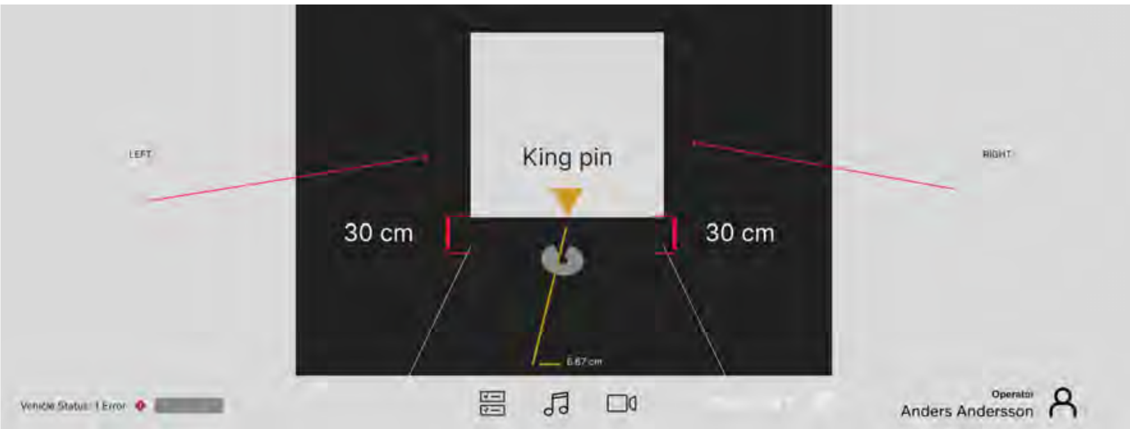

Figure 7.12: Wireframe related to the camera view.

Figure 7.13: Wireframe of an example pop-up that reminds user to do routine checks.

7.3.4 Medium fidelity prototype

The wireframes were further developed into a medium-fidelity prototype using Figma (see Figures 7.14, 7.15, 7.16, 7.17, 7.18, 7.19, 7.20, 7.21 and 7.22). Building on the initial sketches, this stage introduced Volvo design elements to enhance visual consistency and realism. Additional interface steps were incorporated based on the list of requirements, identified operator pain points, and key insights gathered during the define phase.

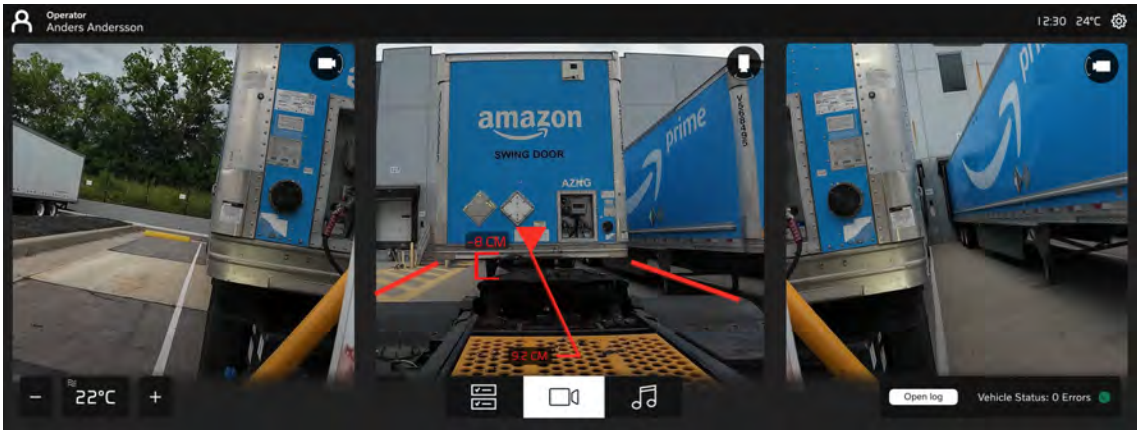

Figure 7.14: Camera View v.1, showing side views and back view.

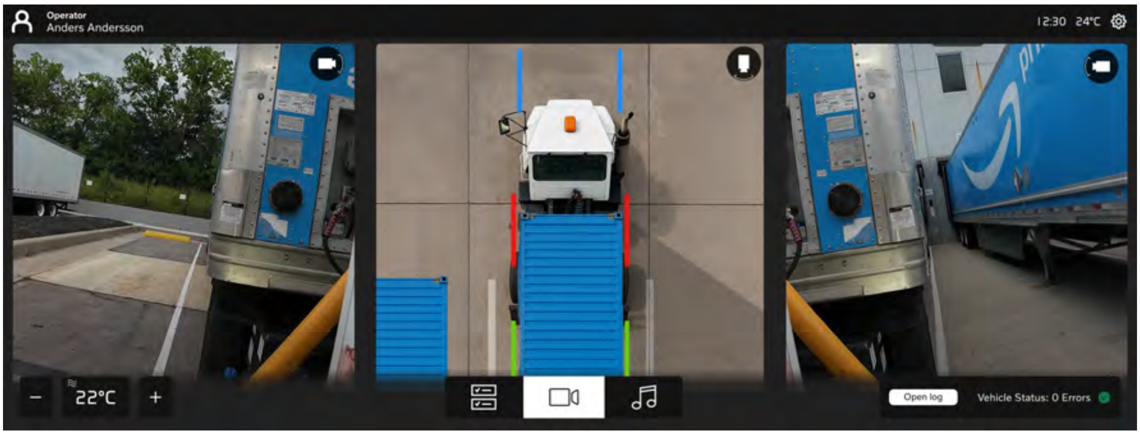

Figure 7.15: 360-view, same as Camera View v.1 but has a 360 view instead of back view.

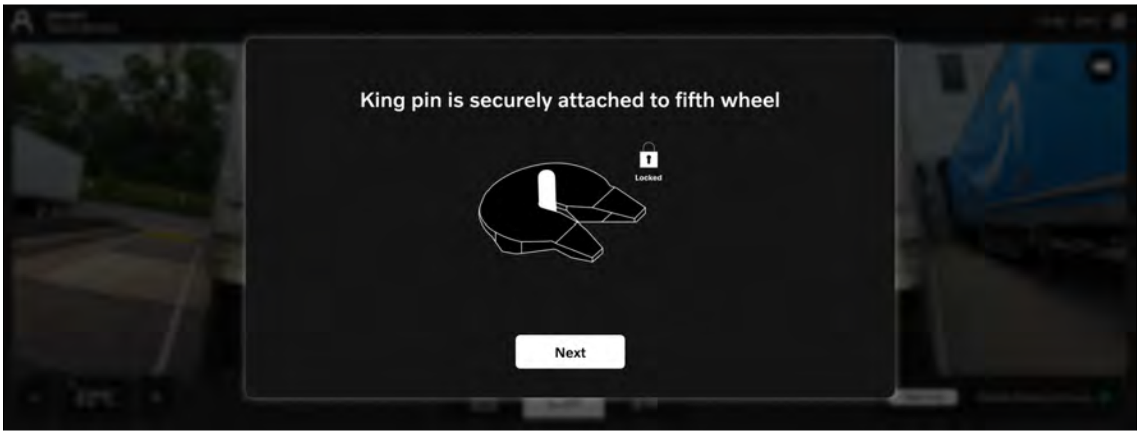

Figure 7.16: King pin pop-up, notifies user that king pin is attached.

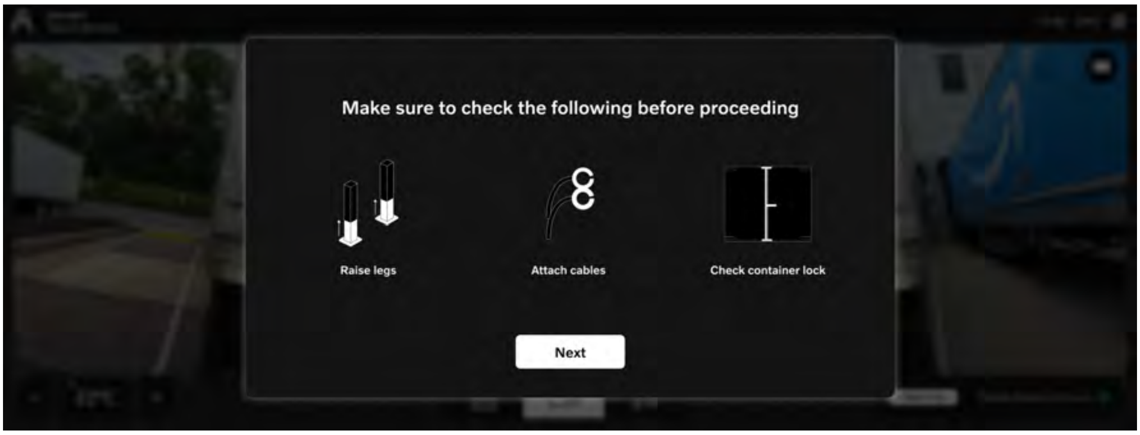

Figure 7.17: Check pop-up, reminds user to do routine checks.

Figure 7.18: Adjust pop-up, helps user to adjust height of fifth wheel.

Figure 7.19: Drop off pop-up, which reminds operator to lower legs and detach cables.

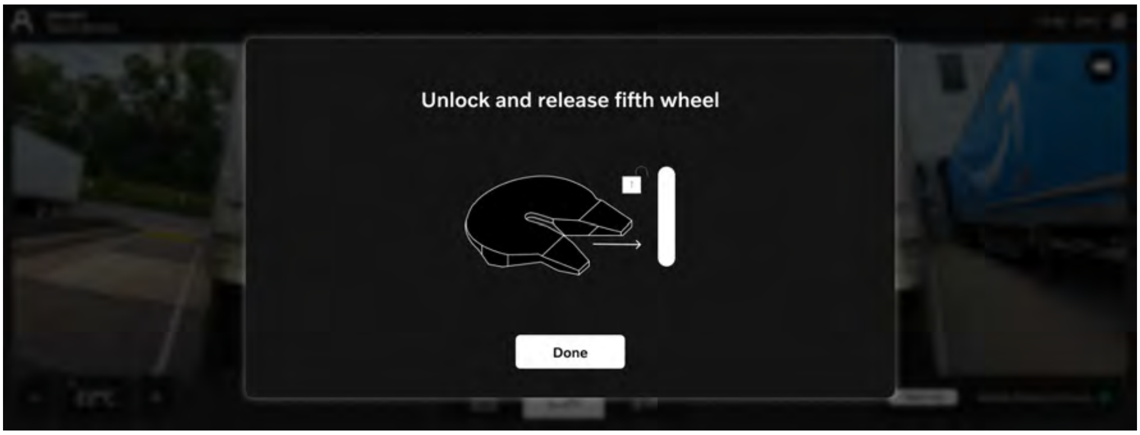

Figure 7.20: Release pop-up tells the user when it is safe to release fifth wheel.

Figure 7.21: Task View v.1, showing current, upcoming and previous tasks.

Figure 7.22: Task View v.2, presenting an alternative layout with bigger buttons.

7.4 Deliver

This section covers the evaluation of the interface through a heuristic evaluation, pilot test, focus group, and user testing; see table 7.1, as well as iterations made based on the collected feedback.

Type of study	**Source**	**Data gathered**
Heuristic evaluation	*Factors Affecting the Safety of In-Vehicle Information Systems and the Human Factors Design Guidance for Driver–Vehicle Interfaces*	Understanding of IVIS safety, usability principles
Pilot test	UX/UI expert, Volvo Penta	UI/UX oriented feedback, affordances, spacing etc.
User test	Terminal tractor operator, NTEX	System feedback, operational efficiency, functions etc.
Focus group	Interaction Design Master students	UI/UX principles and intuitiveness

Table 7.1: Summary of study types, sources, and gathered data

7.4.1 Evaluation

To evaluate the usability and relevance of the developed interface, a multi-phase process was conducted, starting with a heuristic evaluation, followed by a pilot study, user testing, and a focus group. The heuristic evaluation, conducted internally by the design team, was based on established guidelines for in-vehicle infotainment systems and helped build a foundational understanding of safety and usability considerations, the following sources were used: [62], [63]. Although it did not directly result in design changes, it provided a valuable reference point for interpreting later user feedback.

The next phase involved structured user testing in two steps: an initial pilot study with a UI expert, and a following study with a terminal tractor operator in a test rig. Both sessions used a predefined scenario and guiding questions to collect qualitative feedback on interaction, task flow, and interface clarity. The scenario simulated a full operational journey, with the participant acting as a terminal tractor operator responsible for picking up and dropping off a trailer. The interface was evaluated at each step of the process to assess how effectively it supported the workflow and how users responded to the design and flow of interactions.

Finally, a focus group session with six interaction design students was conducted to gather a broader range of perspectives. Although the participants lacked direct experience with terminal tractor operations, their strong background in UX/UI enabled them to provide valuable design-focused feedback. This session helped identify additional areas for refinement, particularly in interaction simplicity, visual clarity, and information hierarchy.

7.4.1.1 Heuristic Evaluation

Before conducting the pilot study, user testing, and focus group sessions, a heuristic evaluation was performed on Task View v.1 and v.2 to assess their alignment with established design principles for in-vehicle infotainment systems, better known as IVIS. This evaluation was conducted internally by the design team to build domain understanding and better prepare for incorporating expert and user feedback. The assessment was guided by two key references: [62] and [63]. These sources provided guidelines for interface safety and usability, with particular focus on reducing driver distraction, supporting glance behavior, and optimizing information hierarchy.

Both Task View v.1 and v.2 shared several key strengths aimed at supporting quick comprehension and safe interaction. Each version followed an "overview first, details on demand" approach and applied a clear visual hierarchy to emphasize the most relevant information. In both versions, high-contrast buttons helped important actions stand out, see figure 7.23, improving visibility and reducing the chance of missed inputs. Less important elements were visually less prominent in both versions, reflecting their lower priority. Finally, because neither version required user interaction while the vehicle was moving, both supported a display-only model that aligns with in-vehicle safety recommendations.

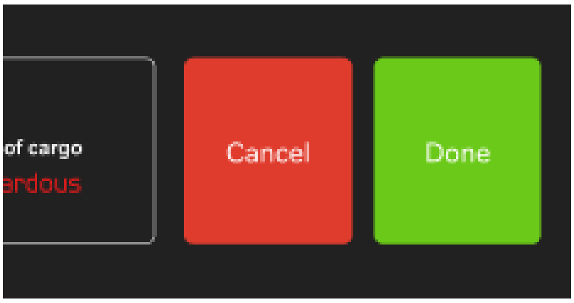

Figure 7.23: High contrast buttons to finish or cancel task.

Task View v.1 allowed more information to be visible at once, providing a quick overview of all tasks. However, this came with increased cognitive load, smaller buttons, and a higher risk of accidental interaction which could negatively affect glance time and user accuracy. In contrast, Task View v.2 featured larger buttons, clearer spacing, and reduced information density, resulting in quicker comprehension, lower cognitive strain, and improved touch accuracy which is particularly important given that buttons should be at least fingertip-sized as recommended in the literature. The main drawback of Task view v.2 was that users needed to scroll to view tasks further ahead, potentially increasing interaction time in certain contexts.

While the heuristic evaluation did not directly lead to changes in the interface, it provided a solid foundation for the teams understanding of IVIS safety, usability principles and helped shape a more informed approach to the later evaluation phases.

7.4.1.2 Pilot testing

An initial pilot study was conducted with a UI expert at Volvo to evaluate both the medium fidelity prototype and the structure of the user testing scenario. The session simulated a complete user journey, where the participant assumed the role of a terminal tractor operator responsible for picking up and dropping off a trailer. Throughout the scenario, the expert interacted with the interface at key stages and provided feedback on the usability of the design and the relevance and clarity of the testing script.

The entire session was recorded and later transcribed for detailed review. Key observations were extracted from the transcript and summarized to inform the next steps in development. The feedback primarily focused on affordances, interface clarity, and the effectiveness of the scenario. The expert emphasized the importance of displaying only the information necessary for the task.

The expert also highlighted the need for better visual affordances, particularly with respect to color use and button design. It was suggested that color should be used intentionally to guide user attention rather than for decoration. Button sizing and placement were identified as areas for improvement, with recommendations to optimize them for quick readability and accessibility during active vehicle operation.

In addition to feedback on the interface, the expert reviewed the structure and tone of the scenario and follow-up questions. The language used in the questions was noted to be overly academic, which could make interpretation challenging for non-specialist users. The expert recommended rephrasing the questions in a more casual, conversational tone to make the testing experience more intuitive and accessible for terminal tractor operators.

The design iterations informed by the pilot study are illustrated in Table 7.2, Figure 7.24, and Figure 7.25. Figure 7.24 presents Task View v.3, which includes significant changes such as enlarged buttons for improved usability, a revised color scheme to enhance visual affordances, and a relocated error log for better visibility. Figure 7.25 shows Camera View v.2, featuring expanded camera perspectives and enhanced user interaction capabilities. Table 7.2 outlines more refinements across the interface.

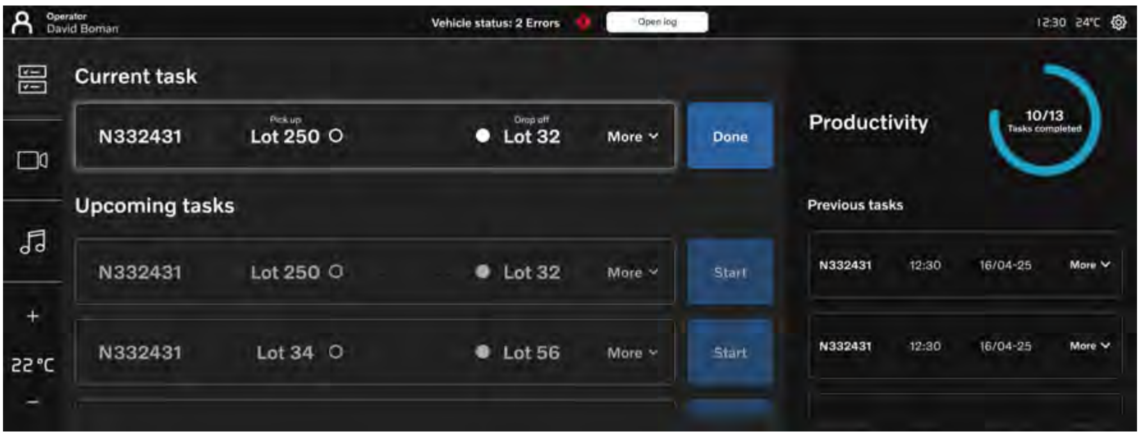

Figure 7.24: Task View v.3, big buttons, new color, new error log placement etc.

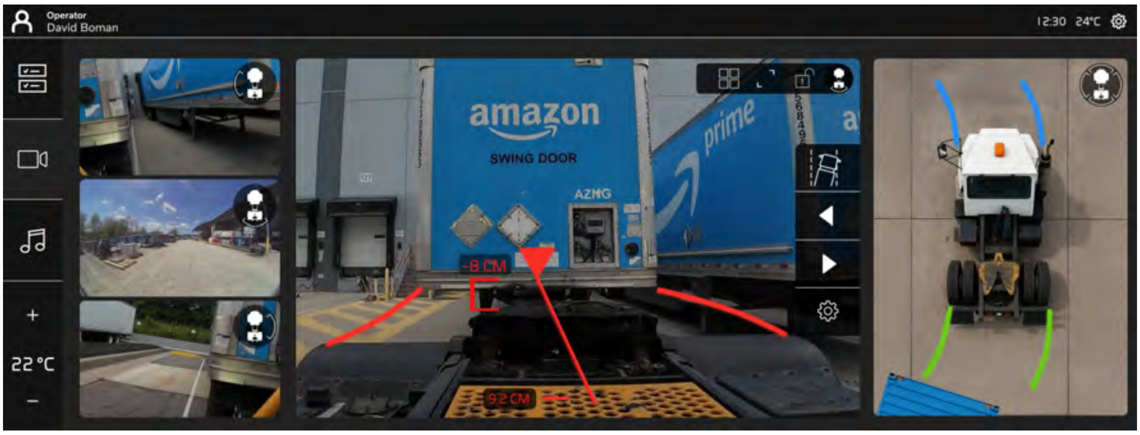

Figure 7.25: Camera View v.2, more views and user interactions.

View	Type of Change	Comment
Task view v.1 & v.2	Task view v.3 was created: bigger buttons, new color of buttons and clarified pick up and drop-of	The buttons to start a task were too small in v.1 and the colors took too much affordance
Kingpin Pop-up	Removed confirmation stage after pick-up	Exhausting having to confirm every time
Error log	Clickable by just clicking on text	Easier to open if whole text is clickable
Error log	Changed position from bottom right corner to middle of top bar	The last place a user looks is the bottom right corner
Productivity View	Added circular progress bar	Help differentiates from the tasks
Menu	Changed to a side menu from floating	Floating menu takes up a lot of vertical space from the other components.
Camera view v.1	Camera view v.2 was created with more views and functionalities	User might want 360-view both at pick up and drop off

Table 7.2: Showing changes made to the interface after pilot study.

7.4.1.3 User testing

Following the pilot study, a user testing session was conducted with a terminal tractor operator at NTEX. This participant had previously contributed to the initial user research, providing a valuable point of continuity between early insights and the evaluation phase. The purpose of this session was to validate the interface in a realistic setting and assess whether the design supported the users workflow effectively.

To simulate the intended context of use, a laptop with a touch display was mounted inside a terminal tractor, see figure 7.26, positioned where an in-vehicle screen might realistically be located. To enhance the realism of the setup and reduce distractions, the laptop keyboard was covered with cardboard. This allowed the operator to focus solely on the screen interaction as if engaging with an actual integrated interface.

Figure 7.26: Image of a laptop set up within the terminal tractor as a test rig, demonstrating the integration of the interface for testing and evaluation purposes.

The test followed the same scenario used during the pilot study, guiding the operator through a full task cycle: driving to the trailer, loading it, driving to the drop-off point, and completing the drop-off. The participant was asked to think aloud throughout the process, verbalizing thoughts, questions, and reactions. The session was recorded, transcribed, and summarized into a list of observations to identify potential areas of improvement.

During the session, the participant also reviewed multiple interface iterations, including Task View v.1, v.2, and v.3, as well as Camera View v.1 and v.2. This allowed for a comparative evaluation of the design progression. While minor suggestions were made, no major changes were deemed necessary following this session. The feedback reinforced that the interface was largely well designed from the start, with many core elements proving effective and intuitive in practice. These findings confirmed that earlier design decisions were aligned with user needs. The visual differences and refinements across the versions can be seen in Table 7.3.

View	Type of Change	Comment
Error log	Made option to have error log always visible	Satisfying to see if vehicle has 0 errors
Camera-view v.1	Decided to move forward with, Horizontal line removed	Camera view v.1 was simpler and user friendly
Camera-view v.2	Discarded	Too much information, high cognitive load
Task view v.3	Decided to move forward with task view v.3	Positive feedback from operator regarding task view v.3
Task view v.3	Added trailer number text above trailer number	Easier to locate trailer number at first glance
Menu v.1	Discarded	Too impractical
Menu v.2	Decided to move forward with	Creates more vertical space

Table 7.3: Showing changes made to the interface after User testing.

7.4.1.4 Focus Group

The purpose of the focus group was to evaluate the interface further and gather more comprehensive feedback, as previous evaluations had been limited to one UX expert and one operator. To broaden the perspective, the focus group consisted of six interaction design students. These participants were chosen primarily because they had no prior experience with terminal tractors, ensuring a fresh perspective on the interface. Despite their lack of direct experience with the vehicle, all participants possessed a strong understanding of UX/UI principles, making them suited to provide valuable insights.

The focus group session was conducted in person. The session began with a presentation outlining the work that had been done up to that point, including background information about the project, the context of terminal tractor operations, pain points and the goals of the interface design. Following the presentation, the participants were guided through the interface, where each key feature was explained and demonstrated. This walkthrough provided the participants with a clear understanding of how the interface was intended to function.

After the walkthrough, an open discussion was held, allowing participants to provide feedback on various aspects of the interface, including the design of pop-ups, button layouts, navigation, and overall usability. The feedback was broad but mainly covered details in different parts of the interface.

The focus group session was recorded, transcribed, and analyzed. The transcription was broken down into bullet points to identify specific areas for improvement. Key themes emerged from the discussion, including the need to simplify certain interactions, enhance visual clarity, and ensure essential information was more prominently displayed. While the feedback led to several refinements, most of the resulting changes were minor adjustments rather than major changes, which indicated that the interface was already in a strong state. A summary of these refinements is presented in Table 7.4.

View	**Type of Change**	**Comment**
Kingpin Pop-up	Feedback that kingpin is locked is time limited but also possible to just click through	User should not have to click but if they want to skip it is possible
Camera-view v.1	Swapped camera side views	Less confusing if the left side of trailer is on left side on screen etc.
Kingpin Pop-up	Bigger lock symbol in attached king pin	Hard to see that it was a lock symbol
Adjust Pop-up	Change measurement in height-adjustment of fifth wheel	Easier to tell distance in height in centimeter rather than percentage
Error log	Able to report and see if error has been reported	Not all errors are solvable instantly
Error log	Change done button in error log to close	Confusing to have done button when closing window, could suggest that you fixed the errors
Error log	Decided that error log is always visible	Satisfying to see if vehicle has 0 errors
Check Pop-up	Decided that user must click done after routine checks	Annoying for users but might reduce risk of damaging support legs

Table 7.4: Interface changes made following the focus group.

8
Results

This chapter presents the final iteration of the digital interface following the evaluation phase. The outcome is a conceptual, user-centered interface designed to enhance operational efficiency and safety while reducing cognitive and ergonomic workload, directly addressing the research question. In addition to the prototype, this chapter also outlines a set of key design considerations for digital interfaces in off-highway vehicles, gathered throughout the project. These findings aim to guide future development toward more intuitive and effective interface solutions in similar contexts.

8.1 Final design solution

This section presents the final design solution for the digital interface. A 12,8-inch screen display located to the right of the operator seat, see figure 8.1. The main views involving; *Task view, Camera view, Carplay view, Error log* and *Menu* are described and analyzed individually under their respective rubrics.

Figure 8.1: Placement of the interface inside the cockpit of a Terminal tractor.

8.1.1 Task view

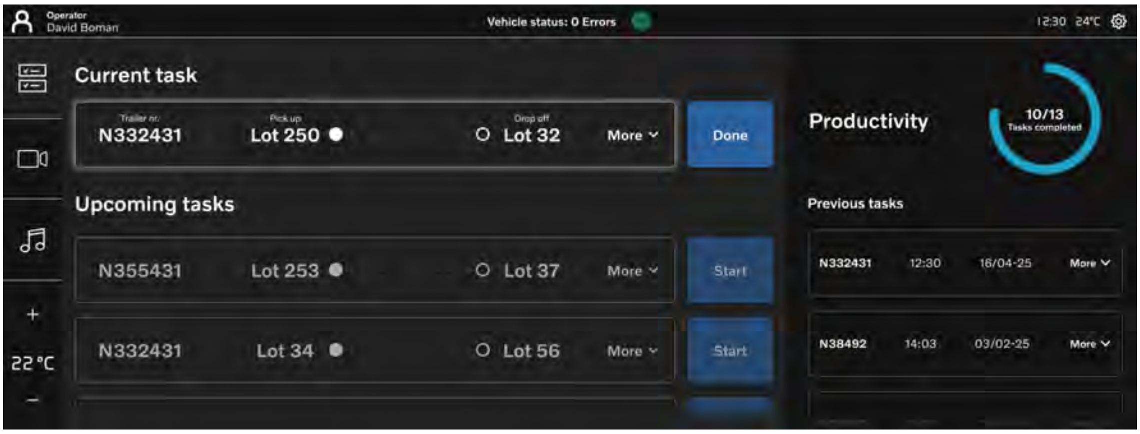

Figure 8.2: Task view with an active task.

The task view serves as the main view that is shown to the operator during the majority of their workflow. The view is divided into two main columns where the left includes a list view of upcoming tasks as well as the current active task. The right column includes a productivity view of completed tasks as well as a list view of previous tasks.

The arrangement and sizing of the elements within these columns are based on their respective purpose and frequency of use. Items that are more critical or frequently used/viewed are given greater prominence through specific design choices, including strategic placement, typography, size, color, and shadow effects.

The most frequently used items in this view are the current and upcoming tasks. As a result, they are positioned in the left column, which is wider than the right. This left side placement aligns with the natural reading flow of most users, left to right, top to bottom [64]. The increased width further encourages the users gaze to focus on this section.

8.1.1.1 Current task & Upcoming tasks

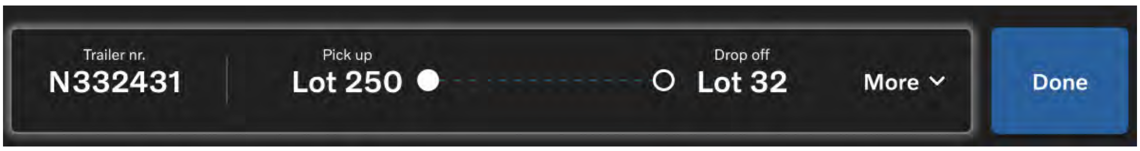

Figure 8.3: Current active task item.

Figure 8.4: Upcoming task item when a task item is active.

The task items are placed in a list view where the task with highest priority is placed at the top. Inside the task items the information is displayed with overview first and details on demand [65], with the most important information for the driver being the trailer number and where the trailer will be picked up and dropped off. As a result, this information is always visible and presented left to right in the order they are used. The information is presented with a bold and large font size with limited amount of text to minimize the amount of time the driver must take their eyes off the road to perceive the desired information.

The two interactive elements; More and Done/Start are placed at the far right of the task item. When clicking More, a drop-down bar with more information about the task appears if the driver needs additional information about the transport. The button has a lower visual hierarchy because of its non-essential functionality in the interface. Done/Start is more frequently used and is interacted with every time the driver wants to end or start a new task, as a result, this button uses a contrasting hue and a large separate bounding box to make it visually stand out and make it easy to press with any finger.

Furthermore, to guide the drivers gaze towards the active task, a pulsating light around the item bar is placed to further give the active task higher visual hierarchy, see figure 8.3. When a task is active the upcoming tasks also gets dimmed down to further drive the drivers gaze towards the active task and minimize the risk of the driver looking at the wrong task item when looking for specific information, see figure 8.4.

Figure 8.5: Current active task expanded.

To view more information about a currently active task the user can click the More button to reveal a drop-down menu with information about the client, weight of the trailer and what type of cargo the trailer has, see figure 8.5. When the task item is expanded the user also gets the option to edit the task information if something is wrongly documented or if issues happen along the way. They also get the option to cancel the task if that is needed. These functionalities have a great importance but quite low frequency of use, hence why they are hidden in the drop-down.

8.1.1.2 Productivity

At the top in the right column a circle diagram is placed showing how many tasks that have been completed and how many there are left, see figure 8.2. By having this be displayed, the operator can quickly view and get a grasp of how far they have progressed in their tasks. This type of information is not vital, but it helps the operator to more easily see how much they have left to do so they can plan their shift. This could also be achieved by scrolling through the task list but that would be more demanding and imply a safety risk if the operator was to be driving at the same time.

8.1.1.3 Previous tasks

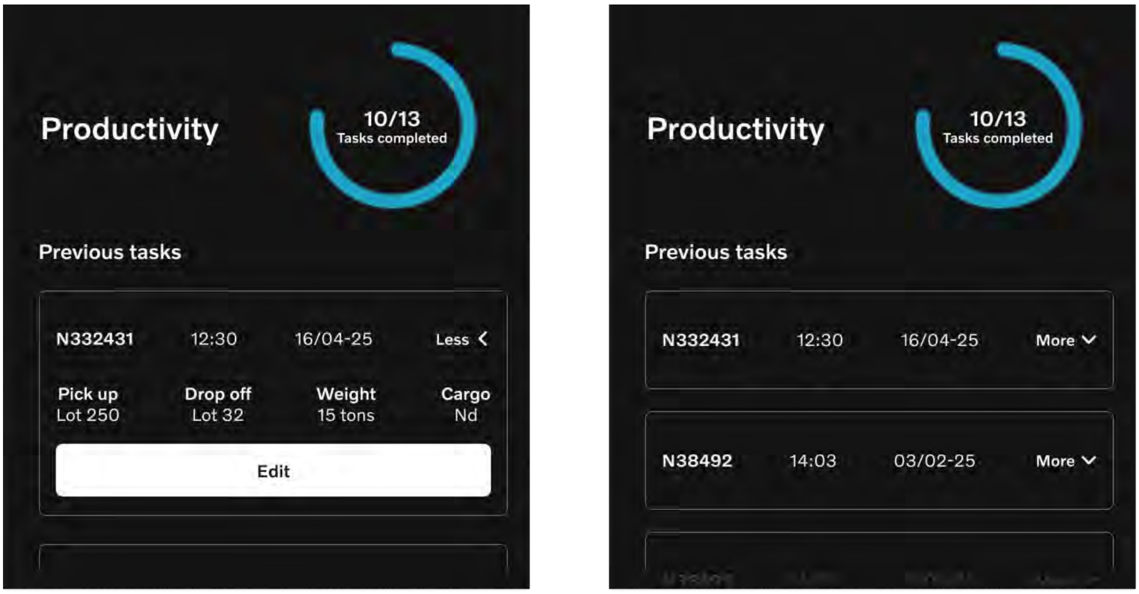

Figure 8.6: List of previous tasks. Expanded list item to the left, compact list item to the right.

Under the productivity view, a list of previous tasks is displayed, see figure 8.6. These previous task items hold information about completed tasks with time stamps and the option to Edit. If an operator is unsure about a task, they can view this section to double-check that it has been completed and also edit information about the drop-off location of the trailer if that was wrongly documented.

Since this section has a lower frequency of use than the upcoming task it has a lower visual hierarchy achieved with smaller font sizes and no contrasting colors that makes it stand out.

8.1.2 Camera view

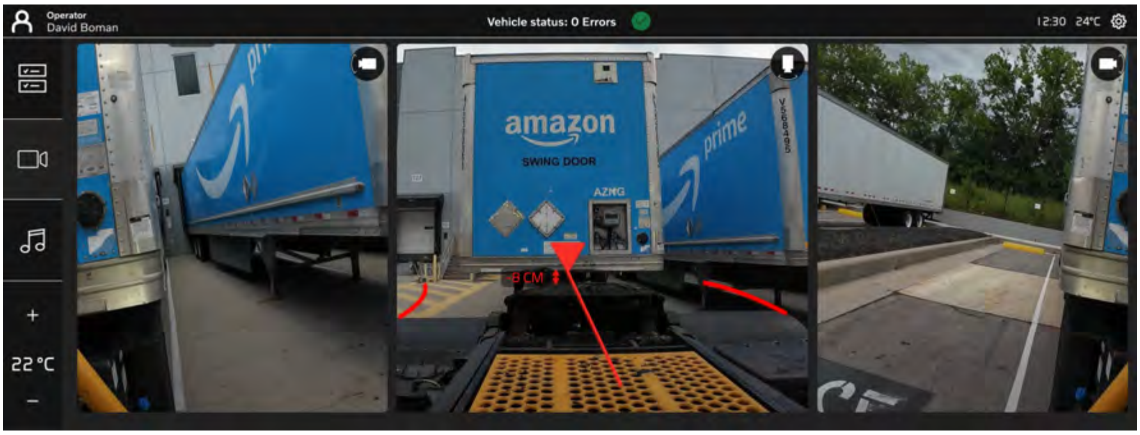

Figure 8.7: Camera view with no trailer attached and not aligned.

The camera view can be navigated to by clicking the button in the menu or by engaging reverse, then it shows up automatically. The interface offers two different camera views and the one being shown to the operator depends on if the terminal tractor has a trailer attached to it or not. When there is no trailer attached and the operator is reversing the screen displays a camera view of each side and one directly rear, aimed at the fifth wheel, see figure 8.7. By resorting to these three views, the operator sees just what is needed to align and attach the trailer to the Terminal tractor in an effective and safe manner. Not having a top- and/or front view increases the space that the left, right and rear camera shows which results in a camera view that makes it easier for the operator to perceive smaller details and/or obstacles.

Furthermore, in the rear camera view, colored lines are shown to aid the driver in aligning the fifth wheel in both horizontal and vertical direction. The lines behind each wheelhouse depict which way the Terminal tractor is heading based on the current rotation of the steering wheel. These lines are red up until the terminal tractor is aligned to the trailer in which the lines turn into a green hue giving a clear indication of correct alignment. On the rear face of the trailer, a red triangle is also shown to indicate the middle of the trailer which is where the kingpin is located. To the left of the triangle, a measurement of the height difference between the fifth wheel and the underside of the trailer is shown to the operator. This measurement communicates how much the fifth wheel should be raised or lowered to accurately slide it underneath since the fifth wheel should have contact with the underside of the trailer. If the fifth wheel is too low, it will either miss the kingpin or not correctly attach, if the fifth wheel is too high it can slam into the trailer which could hurt the vehicle and the trailer.

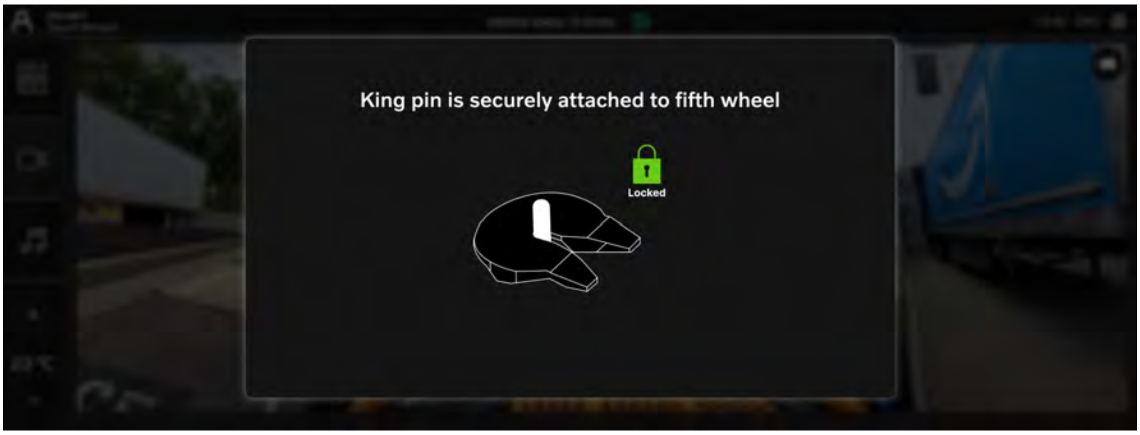

Figure 8.8: Final version of pop-up showcasing successful kingpin attachment.

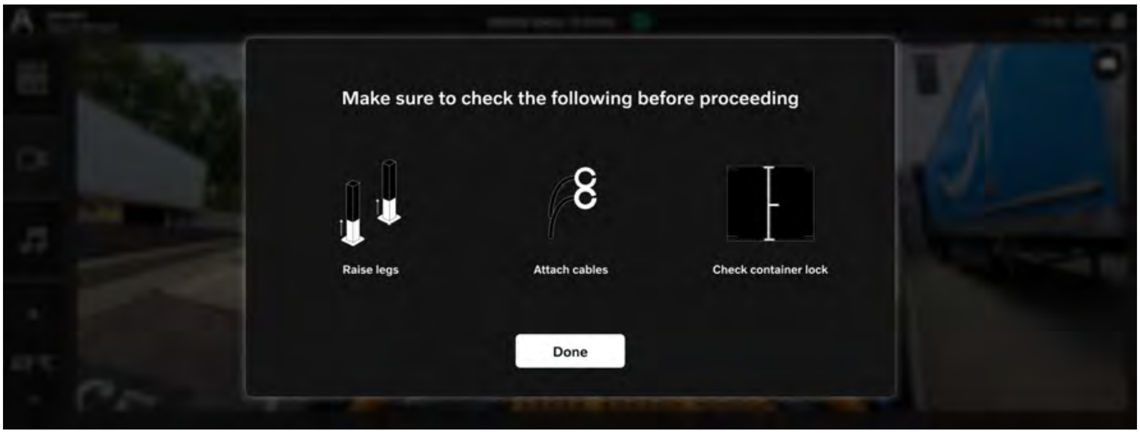

Figure 8.9: Final version of pop-up showcasing necessary steps for complete trailer attachment.

Figure 8.10: Final version of pop-up showcasing recommendations for fifth-wheel height adjustments.

When the driver has connected the fifth wheel to the kingpin a popup window is shown giving feedback that the connection has been made, and the mechanism is locked, see figure 8.8. This popup disappears after 5 seconds or if the driver clicks on the screen, after that, a new popup window is shown showcasing the necessary steps to complete the trailer attachment, see figure 8.9. These are; wind up support legs, attach cables and check trailer door. The user must click Done to proceed to the next window in which a new recommendation popup is shown that gives recommendations regarding if the operator should lower or raise the fifth wheel to achieve a balanced load in the trailer and to not scrape the trailer, see figure 8.10.

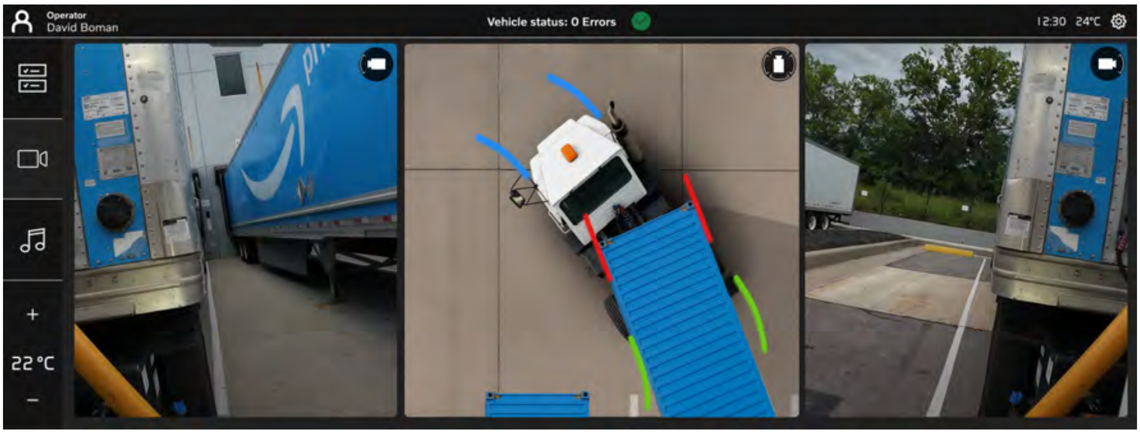

Figure 8.11: Camera view with trailer attached and not aligned.

When the Terminal tractor is attached to a trailer the rear-view camera serves no purpose due to it being aimed at the trailers front face. Because of this, a 360-camera view is presented giving a clear view of the vehicles alignment and surrounding environment, see figure 8.11. Having this situational awareness of the surrounding environment all in one screen decreases the cognitive load and increases safety since it does not require the driver to constantly turn their head in different directions to see what is around them. They only have to look at the screen and maneuver the vehicle. To aid the driver in maneuvering the vehicle, green and blue lines are shown depicting where the terminal tractor is heading based on the steering wheels rotation, along with this, two red lines are shown to clearly indicate the trailers alignment to the vehicle.

Since it would not be possible to put cameras on the trailers, the birds eye view might not be able to capture the entire cargo. To aid the driver in seeing the far back of the trailer the side facing cameras are shown.

After the driver has aligned the trailer to the parking lot and engaged the parking brake, a pop-up window appears again showcasing necessary steps for a complete and safe detachment, see figure 8.12 and figure 8.13.

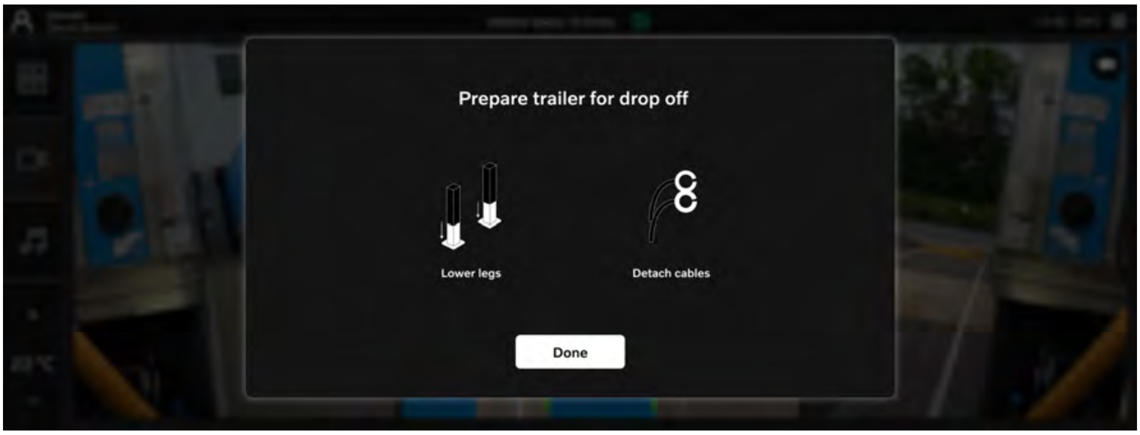

Figure 8.12: Pop-up showcasing necessary steps for complete trailer detachment.

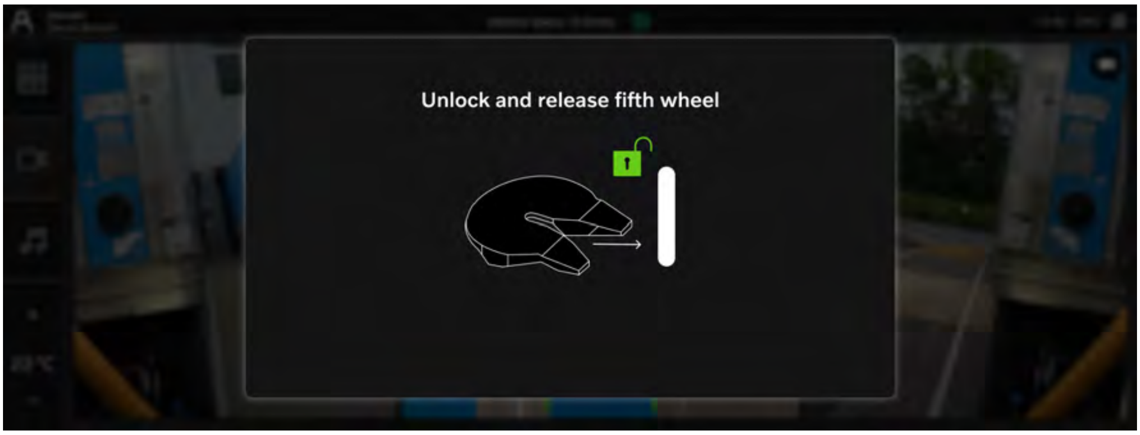

Figure 8.13: Pop-up showcasing that the fifth wheel can be released safely.

8.1.3 Carplay/Media view

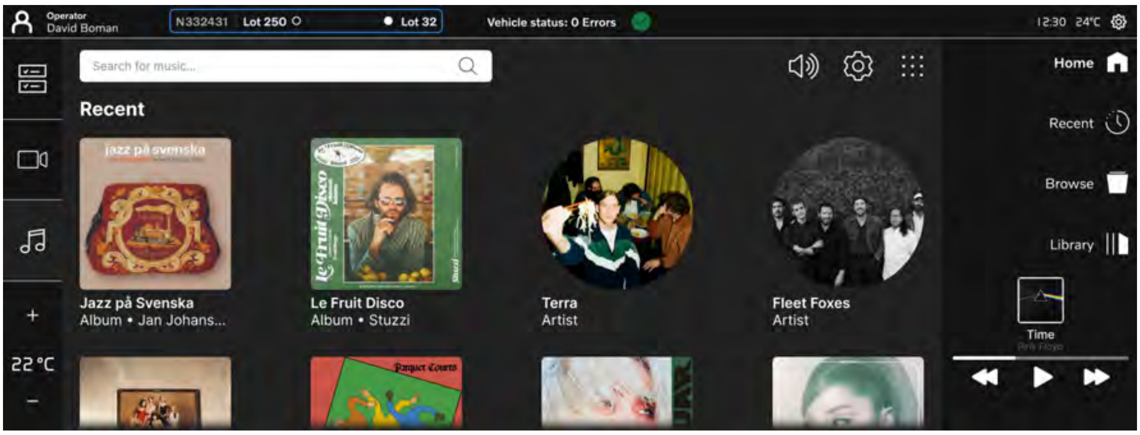

Figure 8.14: Carplay view during an active task.

The carplay view for the interface has not undergone an extensive design process since this view depends on the connected services design language and principles.

However, a proposed design solution has been made which gives the operator the opportunity to listen to music while driving. If this view is navigated to when an active task is being performed a small blue bar is shown in the top bar, showing the most necessary information, similarly to how it is depicted in the task view, see figure 8.14.

8.1.4 Menu

The menu for this digital interface is placed on the left side of the screen and includes buttons for accessing the task view, camera view, carplay view and climate controls. The placing of the menu is carefully chosen to be on the side of the screen; this placement makes use of the wide aspect ratio of the interface to not take up too much vertical space from the different list items in the task views.

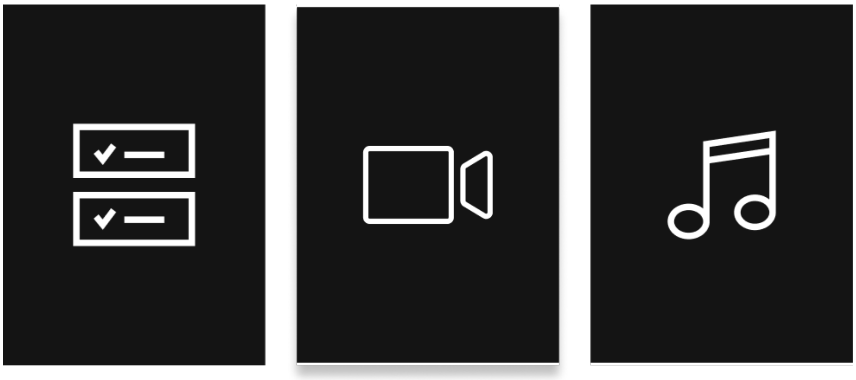

Figure 8.15: Icons for the menu buttons.

The icons used in the menu are selected from Volvo Pentas own icon library, each chosen to represent the function of the corresponding view. For the list view, a list icon with checkmarks is used, symbolizing the items in the task view. The camera view is represented by a camera icon, clearly indicating the visual monitoring function. For the CarPlay view, a note icon is used, reflecting the integration of a media player.

To enhance clarity, the active view is visually distinguished with a background thats slightly lighter than the others. This subtle design choice mirrors the background color of the active view, ensuring clarity in which button corresponds to which view, as shown in Figure 8.15.

Furthermore, along with the side menu, a thin bar at the top of the screen is displayed, providing general information about time, weather and profile icon as well as an overview of errors.

8.1.5 Error log

If an error occurs during vehicle operation, a red status symbol and the message Vehicle status: X Errors appear prominently at the center of the top menu bar, see figure 8.16. Placing the error status in this central position minimizes the risk of the operator overlooking the issue when looking at the screen. This error log should not replace the tell tales for urgent errors in current dashboard/interface solutions behind the steering wheel in terminal tractors but instead serve as a complement for more detailed information and minor errors. Given the limited vertical space, the operator can access detailed information by clicking the Open log button or anywhere within the vehicle status box to open the error log window.

Figure 8.16: Error overview, located at the center of the top bar.

When opening the error log, a window with information about each error is shown. The errors are presented in a list view with information about what type of error it is, where it is, the date it happened as well as a button to register the error as reported. When unfolding the list item, the operator can get more detailed information about the error as well as recommended measures to take to fix the problem, see figure 8.17. If the operator is not able to resolve the error and must report the error to a workshop or relevant administration, they can register this information by clicking the report button, see figure 8.18.

Figure 8.17: Error log with two errors, compact list items to the left, expanded items to the right.

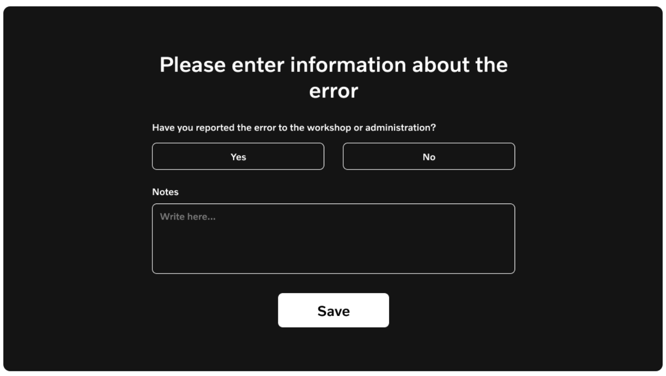

Figure 8.18: Window for register information about error report.

8.2 Design considerations and insights for off-highway vehicle interfaces

The insights in this section are drawn from the full scope of the project, including input from terminal tractor operators, UX/UI designers, field visits, digital observations, and literature studies. These diverse sources contributed to a deeper understanding of what supports effective interface design for off-highway vehicles. Each insight highlights a key design consideration aimed at improving operational efficiency and safety, while also reducing cognitive and ergonomic workload for operators. Together, they offer practical guidance for creating more intuitive and user-centered digital interfaces in demanding work environments.

8.2.1 Avoid redundant labeling

One key insight from this project is that traditional notions of intuitiveness are less critical in interfaces designed for expert users, such as terminal tractor operators. While ease of use remains important, these users are highly familiar with their operational context and require interfaces that are streamlined rather than overly explanatory. For example, elements like the trailer number do not need excessive visual hierarchy or redundant labeling (e.g., Trailer number N30430), a simple identifier such as N30430 is sufficient. Reducing unnecessary text and icons not only respects the users expertise but also helps declutter the interface, making it more focused and efficient for task execution.

8.2.2 Match Information Density to Operational Context

Another critical insight is the need to consider the operators context and activities performed simultaneously when designing how information is presented. Terminal tractor drivers often interact with the interface while driving, limiting their cognitive capacity and visual attention. Functionalities accessed during driving must therefore be especially clear, concise, and prominently positioned to support quick recognition with minimal distraction. Contrarily, when the vehicle is stationary, the interface can present more detailed or layered information, as the operator has greater capacity to process and interact with the content.

8.2.3 Prioritize Physical Buttons for Machine Controls

Findings from this project further support the argument that certain machine controls, particularly those linked to core operational tasks, should remain physical rather than fully digital. Physical controls allow operators to act without demanding visual attention to the interface, enabling them to focus on the effect of the action rather than locating and confirming it on a screen. For instance, raising or lowering the fifth wheel is a task where tactile feedback and muscle memory are important, especially in demanding or low-visibility conditions. Retaining such functions as physical buttons enhances safety, efficiency, and operator confidence.

8.2.4 Treat Digital Interfaces as Complementary, Not Replacements

This thesis reinforces the view that digital interfaces should initially be introduced as complements rather than outright replacements for existing systems in off-highway vehicles. In contexts like terminal tractor operations, users rely on established workflows and physical controls that have been refined through experience. A digital interface can enhance functionality by offering additional feedback, configurability, or data visibility but it should not disrupt core operations or require users to relearn essential tasks. Positioning the digital system as a supportive layer allows smoother adoption and preserves trust in critical interactions.

8.2.5 Avoid Overfitting the Interface to a Single Operational Context

One important consideration is to avoid making the interface too contextually specific. While the terminal tractor itself may be consistent it can across deployments, the work processes, cargo types, and operational priorities vary significantly from one terminal to another. Designing an interface that is too narrowly tailored to a single workflow risk limiting its broader applicability. Unlike regular passenger vehicles, which serve relatively homogeneous use cases, terminal tractors operate in diverse environments with varying demands. Therefore, the interface should maintain a level of flexibility and abstraction to accommodate different tasks without requiring major reconfiguration.

8.2.6 Digital Data Cannot Fully Reflect Operational Realities

Digital observations can provide valuable insights into user behavior and general patterns, offering a basic understanding of how operators interact with the system. However, they cannot fully replace interactions with users. Observing users in actual working conditions creates deeper, more accurate insights into usability challenges. In this project, while digital observations supported early design decisions, direct user engagement was essential for refining the interface and ensuring it met operational needs effectively.

9

Discussion

This section provides a comprehensive reflection on the entire design process, detailing the critical moments and key decisions from early concepts to the final evaluations. It spans the development stages from hypothesis-driven design to the results and outcomes of our final interface. In addition to evaluating how the final concept addresses the main research question and its sub-questions, this section also engages with relevant related work to contextualize our findings within existing research. Furthermore, we acknowledge the limitations that influenced the final product and propose directions for future work to enhance the design and support its integration into workflows and operational environments.

9.1 Final Concept Addressing the Research Questions

This section presents the final concept of the digital interface, the primary deliverable of this masters thesis. The design has been well received by stakeholders and evaluators, who highlighted its intuitiveness, clarity, and navigational simplicity, as exemplified by one operators feedback:

Easy and simple design that is easily graspable, no clutter.

The concept was developed to meet the specification of requirements and user preferences (see Appendix B). While certain limitations exist mainly due to the constraints of the prototyping tool, the final design meets most expectations and offers clear potential for further development. Below, the findings are discussed in direct relation to the research questions.

9.1.1 Main RQ: How can an intuitive digital interface be designed for terminal tractors to enhance operational efficiency and ensure safety, while reducing the cognitive and ergonomic workload?

A key tension in the design process was the balance between intuitiveness and efficiency. While an intuitive interface should, in theory, promote faster interaction, there is a risk that oversimplification undermines depth or that experienced users feel limited by the system's guidance. Efficiency, particularly in industrial contexts like terminal tractor operations, often depends on shortcuts, learned behaviors, and system flexibility. Intuitiveness, by contrast, leans toward universal accessibility, sometimes at the cost of that flexibility. This raises a central question: is the goal to optimize for first-time users, or to streamline tasks for experienced operators? The interface cannot fully satisfy both without compromise which became apparent when labeling certain information items. An example of this derived from evaluation with an operator was the labeling of Trailer number, at first, he did not understand what the number displayed was communicating but under the second interaction it was clear for him. So, for a first-time user to optimize their understanding, a label for the trailer number is preferable. However, by just displaying the trailer number or shortening the label it might not be obvious for the user the first time interacting with it, but it results in a less cluttered display where only the most necessary information is displayed.

Another contradiction emerges between safety and efficiency. Features like pop-ups regarding support legs or forced workflows undeniably enhance safety. However, they also introduce friction. For some users, especially those under pressure, such enforced steps can feel obstructive. But leaving all the responsibility to the operator brings back the very safety risks the system is meant to reduce. This creates a difficult trade-off. An interface that feels efficient now by, for example, allowing users to skip safety checks can lead to serious problems later. As one operator, who also works in a workshop, pointed out, I have to fix broken support legs because people forget to raise them Safety failures like these often result in the most costly and time-consuming setbacks. The real challenge is designing an interface that feels smooth and efficient while still enforcing critical safety steps. Achieving that balance may not just be a matter of design but could also require changes in work habits and how safety is understood in daily routines.

The ergonomic dimension adds another layer of complexity. At first glance, the interface may not offer a traditionally ergonomic solution since it does not redesign the operators seat, controls, or cabin layout. However, it addresses ergonomic strain in more subtle ways. For example, adding clear camera views means operators do not have to twist or move around as much, especially when docking or reversing. Even if it is not a physical ergonomic solution, it still helps in practice showing that good interface design can make up for some physical limitations. Still, this raises a critical point, to what extent should digital interfaces be responsible for solving physical design problems?

These contradictions highlight a broader issue: that intuitive, efficient, safe, and ergonomic are not always aligned and sometimes pull in opposite directions. The design process becomes less about checking boxes and more about navigating trade-offs. Rather than aiming for a perfect balance, it may be more realistic and honest to acknowledge where compromises are made, and for whose benefit.

9.1.2 Sub-question 1: What methods can be used to identify and evaluate operational needs for heavy off-highway vehicles?

The combination of heuristic evaluation, video analysis, operator interviews, and a focus group proved to be an effective strategy for uncovering operational needs, especially given the limited direct access to terminal tractor operators. Drawing inspiration from methods outlined by Sitompul and Wallmyr [22] and Andréasson and Boman [24], analyzing publicly available online videos became an especially valuable workaround. This approach provided a rich understanding of both broad workflows and detailed pain points, and it showed how alternative user research methods can compensate, at least partially, when access is constrained.

Working without direct and repeated access to users brought clear challenges, but it also highlighted the value of being prepared. By analyzing videos and reviewing earlier research, we were able to approach the field studies with a solid understanding of the operational context. This preparation allowed us to ask more relevant and targeted questions, focusing on deeper insights rather than spending valuable time grasping the basics. For instance, watching yard jockey videos from Amazon workers helped us understand the full user journey before even meeting the operators in person. This meant we could ask more meaningful questions such as "Whats the most challenging part of aligning the kingpin?" instead of the more basic "Why do you align the kingpin?"

However this preparation came with a risk, our early assumptions sometimes narrowed our thinking. Predefined hypotheses helped us identify likely problem areas, but they also introduced bias. For instance, we were convinced a GPS view would be valuable, and even when user feedback showed the opposite it was difficult to let go of that idea. This shows a common challenge, when access to users is limited, it is important to be prepared but it is just as important to stay flexible and question your own assumptions.

To make the most of the limited time we did have with users, we chose to evaluate multiple design concepts and simulate different scenarios during each session. This approach was highly productive, allowing us to gather a wide range of feedback efficiently. However, the breadth of input may have come at the cost of depth, exploring fewer concepts in more detail might have yielded richer insights into specific details.

9.1.3 Sub-question 2: How can the most critical operational tasks be identified and prioritized?

Identifying and prioritizing critical operational tasks was not just a matter of listing functions, it required interpreting what "critical" really means in a complex, multi-stakeholder environment. Our approach combined video observations, interviews, and affinity mapping, which helped surface common themes. Task management, trailer alignment, and vehicle status monitoring emerged as the most pressing needs, based on both frequency of use and associated safety risks.

However, this process also revealed a key challenge, what is considered "critical" can vary depending on perspective. For example, the logistics department tended to emphasize task coordination and workflow efficiency, while workshop personnel were more concerned with maintaining vehicle integrity and avoiding damage, especially during trailer docking. These priorities do not necessarily conflict, but they do highlight different kinds of risk.

In the end, our design choices reflect a careful balance between different views of what is most important. The task view was prioritized because it is used throughout almost the entire user journey, with operators frequently referring to it, making it central to their workflow. In contrast, the camera view is used mainly during trailer drop-off and pick-up, but despite being less frequent, it plays a crucial role in improving safety and reducing cognitive strain. These choices emphasize the need to continuously reassess what counts as critical not just at the beginning of the project, but throughout the entire design cycle and raises important questions about whose priorities shape these decisions and whether certain user perspectives may be underrepresented in the final outcome.

9.1.4 Sub-question 3: What category of controls should remain physical and what works better in digital form?

Early feedback from operators strongly favored keeping frequently used or safety-critical functions such as emergency stop, gear shifting, and controlling the fifth wheel as physical controls. The reasoning was that physical buttons offer tactile feedback, are easy to locate without looking, and allow users to keep their attention on the task at hand rather than the interface. This preference aligns with established safety and usability principles, and it understandably shaped our early design thinking.

However, this early input may also have unintentionally limited our exploration of alternative solutions. In retrospect to our project, we can see how it may have narrowed the scope of ideation particularly in the case of the fifth wheel height control. Because we assumed the user would be physically looking over their shoulder to judge the wheel height, it seemed inappropriate to move that control into the digital interface. But in the final design, where the operator is already visually engaged with the display, the context has shifted. A digital control for the fifth wheel may not have caused the distraction we initially feared.

This points to a larger issue: early user feedback, while valuable, can also reinforce existing habits and mental models, potentially at the cost of innovation. By treating physical controls as a fixed requirement, we may have missed opportunities to explore how digital interaction could streamline operations without compromising safety or usability. It raises the question of whether we should challenge user assumptions more actively during the design process, especially when introducing new workflows or technologies. Not all digitalization is inherently better, but assuming digital controls are always less safe may prevent meaningful improvements where digital interaction is already the focus.

9.2 Reflection on Process and Execution

Throughout the project, several decisions shaped both the direction and outcome of the design process. This section reflects on key moments and turning points, from early design assumptions to changes in scope, user research and discusses how each phase contributed to the outcome. This reflection highlights the lessons learned, challenges encountered, and how each decision strengthened our understanding of user needs and interface design in the context of terminal tractor operations.

9.2.1 Hypothesis-Driven Interface as a Starting Point

At the start of the project, we created a relatively high-fidelity interface prototype in Figma, see section 7.1.2.5, before conducting any user studies. This early design was based primarily on a set of functional requirements and features suggested by Volvo, and was intended to help us familiarize ourselves with the operational context of terminal tractors. While not grounded in user input at this stage, the goal was to form an initial hypothesis around the interface structure and functionality.

This approach offered several benefits. Most notably, it enabled us to explore how the suggested features could be visually and functionally represented and allowed us to reflect on their relevance and implementation early in the process. It also gave us something tangible to present in early discussions, which helped us communicate ideas more effectively and prepare for later stages of the project.

However, the limitations of designing without user insights became apparent as we moved forward. During user evaluations and field studies, we identified several mismatches between the initial design and the actual needs and behaviors of operators. As a result, the original interface was ultimately discarded. Nevertheless, the comparison between this business-driven interface and the later user-oriented design provided valuable insight into the importance of grounding design decisions in user research.

Rather than viewing this discarded prototype as a misstep, it served an important role in our process since it clarified our understanding, helped surface early assumptions, and highlighted the gap between stakeholder requirements and user needs. This experience reaffirmed the importance of integrating user studies early and consistently throughout the design process.

9.2.2 Change of Scope

A change in scope occurred early in the project, which initially aimed to explore the possibility of designing a general interface solution for both forest harvesters and terminal tractors. However, after conducting preliminary research, including walkthrough videos of machine interfaces and general investigations into each vehicle type, it became clear that the differences between the two were substantial. Forest harvesters and terminal tractors operate in fundamentally different environments, have distinct mechanical setups, and serve very different tasks.

These findings led us to conclude that a shared interface would not be feasible or meaningful. The guiding idea became that when you design for everyone, you design for no one. As a result, we made the decision to focus exclusively on terminal tractors before the scheduled field visit to a forest harvester even took place. This change of direction allowed us to deepen our understanding of the terminal tractor's specific context, users, and interface requirements.

Narrowing the scope significantly strengthened the project. It gave us more time to conduct targeted research, gather specific data, and better understand the operational environment and user needs unique to terminal tractors. In support of this shift, we also revised our research question to reflect the refined scope.

The change was well received by both our academic supervisor at Chalmers and our industry contact at Volvo Penta. Since we had invested only a small amount of initial effort into researching forest harvesters, the impact on the project timeline was minimal. While little from the forest harvester research could be directly applied, the early comparative insights helped confirm that a one-size-fits-all interface would have been an unrealistic design goal.

9.2.3 User Research

To gain a deeper understanding of terminal tractor operators and their workflows, we conducted user research at *NTEX* and *Göteborg RoRo*, where we were able to engage directly with a total of three operators. Our research approach combined on-site observations, in-vehicle contextual observations, user testing, and interviews. This approach allowed us to capture both the broader operational context and more specific user needs and preferences.

In addition to field research, we also carried out digital observations by analyzing YouTube vlogs created by *yard jockies* which are operators of terminal tractors in similar environments. These informal vlogs turned out to be surprisingly valuable, as they offered a detailed view of the full user journey across a typical workday, from trailer pickups to drop-offs and task coordination. When we later conducted fieldwork in the harbor environment, we were able to verify many of the behaviors and patterns that we had seen in the videos.

The focus of our research was primarily on task management, specifically the processes of picking up and dropping off trailers. These insights became instrumental in refining our design approach. Several features that were part of our early, business-driven interface turned out to be unnecessary or irrelevant when viewed through the lens of actual operator workflows. The research allowed us to distinguish between assumptions and real user needs and helped us shift towards a more user-centered design.

However, access to participants proved to be a challenge. Terminal tractors are highly specialized vehicles, and their use is largely confined to secure harbor environments, making them difficult to observe and test freely. While the number of participants was limited, the quality and depth of the insights we gathered were valuable and had a significant impact on the final design.

9.2.4 Define

The *Define* phase was a critical turning point in our design process, as it allowed us to compile the insights from our user research and establish a focused direction for the design of the digital interface. Without the presence of any existing interface to inform the design, we had to rely entirely on user-centered research to drive our decisions, ensuring that the solution would truly meet the needs of terminal tractor operators.

The first step in this phase was to concretizes the data collected during field research. Using an affinity diagram, we grouped related observations and feedback into categories, revealing recurring challenges such as the lack of task management support and the heavy reliance on handwritten notes for container tracking. This manual referencing process increased cognitive load, as operators frequently had to shift attention between paperwork and vehicle operation. To further investigate these issues, we employed a Fishbone diagram to explore their root causes, which helped identify underlying contributors to both cognitive and ergonomic strain. Although no interface was directly evaluated at this stage, these methods provided a crucial foundation for understanding user tasks, pain points, and the design opportunities they presented.

From these analyses, we developed a list of requirements that laid the groundwork for our design decisions. These requirements were driven primarily by the need to enhance operational efficiency, improve safety, and reduce cognitive and ergonomic workload. Since there were no existing interfaces to guide us, this list of requirements became the key reference point for ensuring that our design would be functional, intuitive, and responsive to the operators needs.

A notable point during this phase was the decision to focus heavily on simplification. Given that operators perform repetitive tasks in a physically demanding environment, reducing cognitive load and physical strain became a central priority. This meant prioritizing clarity and ease of use in the interface. We knew that simplifying the task flow and eliminating unnecessary complexity would improve operational efficiency, ensuring that operators could focus on performing their tasks effectively rather than wrestling with a complex system. The design process was guided by these fundamental goals: efficiency, safety, and usability.

In some ways, the absence of an existing interface worked to our advantage. Without the constraints or assumptions that might come with an existing system, we had the freedom to approach the design from a clean slate, allowing the needs and pain points identified during user research to fully shape our decisions. This was particularly important because the context of terminal tractor operations was unique, and the design needed to reflect the specific environment and tasks, rather than simply adapting an existing solution.

Ultimately, the Define phase solidified the direction of our design by providing a structured, user-centered framework based on operator needs. The use of tools like the Affinity diagram, Fishbone diagram, and the creation of a list of requirements ensured that our design would be focused, practical, and responsive to the challenges terminal tractor operators face in their daily work. By prioritizing these user insights, we could ensure that our design would truly enhance the efficiency and safety of the operators, while minimizing cognitive and ergonomic strain.

9.2.5 Evaluation

The evaluation phase benefited from being carried out in a relatively realistic context, with the prototype placed inside an actual terminal tractor. This helped ground the feedback in a more accurate physical setting, particularly in assessing screen size, button placement, and ergonomics. However, certain limitations were present that affect how the results should be interpreted.

One key constraint was the use of static camera views. Although these gave a sense of the intended interface layout, they relied on fake data and did not have input from actual cameras. As a result, the evaluation could not fully capture how operators would respond to live surroundings or how effectively the camera system supports maneuvering. A more comprehensive evaluation with live camera feeds and active scenarios such as trailer pick-up and drop-off would likely produce richer data and more nuanced insights, particularly around attention management and interface responsiveness.

Another important factor was the limited number of test participants. The user testing was conducted with a single operator who had also taken part in the initial research phase. While his input was valuable and aligned with much of the knowledge gathered throughout the project, his feedback inevitably carried significant weight in shaping the final design. This introduces a degree of bias, as his specific workflow may not fully represent variations that exist among terminal tractor operators in other regions or organizational contexts. Additional interviews with NTEX operators were not expected to yield radically new insights, but visiting other companies or operational environments could have added broader perspective and validated the design across different user routines.

9.3 Limitations and Future Work

While this study provided valuable insights into the design of a digital interface for terminal tractor operators, several limitations affected the depth and generalizability of the findings and point toward opportunities for further development.

A key constraint was the conceptual nature of the prototype. Built in Figma, it allowed for focused evaluation of usability and task flow, but lacked integration with live vehicle systems, sensor data, or operational tools such as booking and task allocation platforms. This limited the realism of the experience and prevented full assessment of how the interface would support decisions during operations like trailer alignment or reversing. Future work should explore deeper system integration to test the interface under operational conditions with live data and dynamic feedback, such as lighting changes and physical motion.

Similarly, the evaluation context was limited. Although testing was conducted inside a terminal tractor, the prototype could not be evaluated during actual driving or live task execution. This restricted the ability to assess how users interact with the interface while managing situational demands, environmental distractions, or time pressure. Incorporating more accurate testing during actual driving or using simulators could result in better insights into interface performance and safety under real conditions.

User testing was also constrained. Since only one operator participated in the final evaluation, the results may not fully reflect the diversity of user needs and experiences. While his feedback aligned with earlier insights, relying on a single voice increases the risk of bias. Future studies should include a wider range of operators across terminals, regions, and levels of experience to better account for variations in workflow, interface preferences, and operational contexts.

10 Conclusion

Digital interfaces are increasingly integrated into off-highway vehicles such as terminal tractors, where they have the potential to enhance safety, usability, and operational efficiency. This master's thesis aimed to explore how a user-centered digital interface can support terminal tractor operations through interaction design with the following research question:

How can an intuitive digital interface be designed for terminal tractors to enhance operational efficiency and ensure safety, while reducing the cognitive and ergonomic workload?

This project showed that interaction design is an effective way to address the complexities and safety concerns of terminal tractor operations. By focusing on the user and using an iterative design approach, the study identified key challenges like cognitive load, visibility, task management, and error handling that a digital interface could improve. These insights helped shape the final design, which includes three main interface views: Task view, Camera view and CarPlay.

The design process focused on understanding the work environment, aligning with stakeholders, and getting continuous feedback. Field studies, interviews, and evaluations showed how operators use a mix of physical controls, visual cues, and informal methods to manage their tasks. Instead of replacing current systems, the new interface is designed to work alongside them, providing better feedback, a clearer overview, and improved task management, all without adding complexity or compromising safety.

The result includes not only the three interface views but also a set of design principles that guided their development:

1. Avoid redundant labeling
2. Match Information Density to Operational Context
3. Prioritize Physical Buttons for Machine Controls
4. Treat Digital Interfaces as Complementary, Not Replacements
5. Avoid Overfitting the Interface to a Single Operational Context
6. Digital Data Cannot Fully Reflect Operational Realities

This master's thesis demonstrates that interaction design is a powerful tool in the development of digital systems for industrial vehicles. It shows how design methods can help create solutions that are both functional and contextually appropriate. While the design concept provides a working foundation, the broader contribution lies in the design process and principles that can guide future development of similar interfaces.

To conclude, this project contributes to the field by showing a clear and structured way to design digital systems that support the real needs of terminal tractor operators in complex work environments. It emphasizes the importance of creating technology that enhances existing workflows instead of replacing them, while also ensuring that new solutions align with the daily practices of their users.

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A

Appendix - Interview transcribed

Vilka funktioner använder du mest på instrumentpanelen när du anländer till förarhytten och ska börja köra? Så tänk att du sätter dig i hytten. Vad gör du?

Jag sätter på ACn. Ja men ACn.

Alltså det är inte så jättemycket funktioner egentligen. Det beror på, vi har ju en gammal tugg och en lite nyare. Som har en display och är lite mer avancerad och så.

Sen har vi en gammal som inte har någonting alls. Den startar bara och så ser du varvtalen typ. Men jag kollar väl om jag har bränsle.

I den vita som han kör kollar jag om jag har AdBlue och bränsle. Men det är väl det egentligen.

Och vilka funktioner använder du mest på instrumentpanelen när du kör? Vad är rullning?

Blinkers, antar jag är det en funktion? **Ja absolut.**

Vindrutetorkare, det är väl också. Men. Hastighet.

Varvtal. Växel. Det är väl det egentligen.

Det är inte några riktiga funktioner som jag kollar på när jag kör riktigt.

Och när du väl har kört fram till en trailer. Och ska lasta av eller på den. Hur ser processen ut då om du bara kollar på instrumentpanelen?

Om jag bara kollar på instrumentpanelen? **Ja hela processen egentligen. Ja alla funktioner som är där**. Jag kör fram, ställer mig så bra så att jag kan backa.

Lägger i backen, kollar så att den lägger i backen också. Om det är en nyare trailer så ser du om det står D, R eller P. Eller neutral. Lägger i backen och kollar speglarna så att du hamnar rakt.

Sen ofta kan du kolla bak med huvudet också. Så att du vet ungefär att vänd-speglarna och kingpin sitter. Men det är inte riktigt.

Det är inga riktiga funktioner att kolla på där heller. Nej. Speglar och hålla koll.

Och precis innan du ska stänga av fordonet. Är det något speciellt du behöver kolla på då? Eller logga? Räkna trailers sen?

Nej, inte så som jag har arbetat. Men en sak man kollar på som är viktig när du backar till trailern.

Det är att du har en grön symbol för vändskivan. Den blir grön när du har kopplat rätt. **Okej, är det här på det nyare fordonet?** Ja, så då ser du om du är verkligen rätt kopplad.

Eller om den lyser rött så betyder det att du inte riktigt hamnat perfekt. Den ligger inte helt rätt. Och då är den inte helt låst heller.

Så den är viktig att kolla efter när du backar till trailern. Om du inte hade haft den funktionen. Hur hade du gjort då? Hade du lyssnat? Ja, först och främst lyssnat så att det klickar.

Men sen hade jag höjt upp trailern så att inte stödbenen var i marken. Sen hade jag lagt i driven utan att koppla på någon luft. Så att trailern fortfarande är bromsad.

Och försökt köra därifrån. Då märker du om du sitter fast eller inte. För att trailern är bromsad.

Så då hade jag lagt i driven och testat att bara se så att du sitter fast. Men det behöver du inte göra med hjälp av den här grejen? Nej, i princip inte. Om man litar på den så behöver man inte göra det.

Sen kan man ju testa ändå. Men jag brukar bara koppla och se att det blir grönt så kör jag.

Om du tänker på den här nya instrumentpanelen och allting. Och displayen. Finns det funktioner som du anser är ganska onödiga eller aldrig använder?

Alltså nej. Temperaturmätaren kanske jag inte sa förut.

Det är också en sak som är bra med att veta vad du har för temperatur i fordonet. Så att inte den överhettar eller något sånt händer. Sen får du även upp i den displayen felkoder.

Som vårt förare sa partikelfilteret satt sen flera gånger. Då har den sagt att ni behöver fixa detta och service behövs. Och det är ju jättebra.

I den så känner jag inte att det finns några onödiga funktioner riktigt. Allting är väl användbart. Och det mesta du ser är ju hastighet, växel, temperatur, AdBlue, bränsle, felkoder och det här att koppla trailen.

Alltså alla de är ju nödvändiga. Om du tänker att allting skulle lägga ner i den här instrumentpanelen. Och vilka knappar och funktioner är mest vitala att den fortfarande funkar? Så du kan göra ditt jobb.

Lägga i växel såklart. Sen är väl det att den kopplar rätt. Det här med grön och röd.

Utan displayen så hade jag testat det. **Men det underlättar?** Det underlättar absolut. I hela den här processen från att du plockar upp en trailer och ska flytta den till ett annat ställe.

I hela den resan, finns det något ställe där du känner att du blir frustrerad eller tycker det är svårt att gå vidare? Är det någonstans där du bara, det här hade man kunnat köra bättre?

Det är när du backar till parkerar. Och du står väldigt tajt som här ute på våran gård. Så finns det ibland att man föreställer sig väldigt dumt och det ställer sig folk i vägen.

Och så måste du hålla på och köra fram och backa. Och du vet inte riktigt hur långt du har till trailern bakom dig. Du kan ju inte se det på något sätt.

Du ser det i speglarna absolut. Men du är 13 meter bakom dig ungefär. Så du vet ju inte om det är två meter du har eller en meter eller en halv meter.

Du tänker när du har en trailer på dig. Så att backa när du har trailern och parkera den. Kan jag tycka är lite frustrerande när det är trångt.

För att det är svårt att se. Men annars tycker jag inte det är några konstigheter. Det är ingenting jag brukar bli frustrerad på.

Och det var lite samma fråga där. Om du skulle förbättra det. Om du tänker på den här scenarion när du backar in. Hur hade du förbättrat det? Tänka helt fritt liksom.

Det är väl typ att ha en avståndsmätare av något slag. En kamera av något slag.

Men det är väl det egentligen. Bara veta avståndet hur långt du har bakom. Hur långt du kan backa innan du behöver köra fram och ta nya tag.

Kopplat till fysiska kontroller och att ha display. Är det några kontroller som du föredrar som fysiska knappar? Och tycker att det är bra att de inte är displayknappar?

AC-vridet. Det gillar jag inte när det är display.

Utan det gillar jag att man kan vrida AC-en. I och med att du kan göra det samtidigt som du kör och inte behöver kolla. Så trycker du rätt så vet du vart den sitter.

Samma med vindrutetorkare. Det gillar jag att det är en knapp. Höja och sänka vändskivan.

Det är också skönt att ha på knapp. I och med att du kan köra och göra det samtidigt. Vändskivan är femte hjulet.

Det är det egentligen. Det är skönt att ha fysiskt.

Vilka funktioner tycker du fungerar bra som är digitalt? Som kan vara fysiska eller är det bara digitala som är bra?

Jag klickar ju aldrig på displayen.

Den visar ju bara saker. Den ger mig bara information. Men jag klickar ju aldrig på displayen.

Jag vet inte om det går. Jag har inga funktioner att trycka på displayen. Det jag använder är fysiskt.

Vilken information är viktigast för dig när du startar fordonet? Från displayen?

Bränsle, AdBlue, temperatur. Se att den kommer upp lite grann i temperatur. Så att den inte är iskall så fort jag börjar köra.

När jag startar fordonet är det temperatur och bränsle. Det är det viktigaste att veta.

Vilken typ av information behöver du under körning?

Bränsle, AdBlue.

Det är bra att veta så att du inte kör dieselstopp. Hastighet. Växel är bra att ha kan jag tycka.

Den funktionen med att se så att vändpivan är rätt kopplad. Så att du inte tar en sväng från ingenstans och kopplar den loss. Då vet du om det är något som glappar här.

Temperatur. Det är det jag tycker är viktigt medan man kör. Sen är det här med felkoderna också att du kan få upp det i displayen om det händer något med fordonet.

Du får upp de felkoderna. Det får man ju inte på den gamla maskinen. Du har ju ingen aning vad som händer om det är något som händer.

Men på den nya så får du upp direkt om det. Om fordonet känner av att det är något fel. Om du får dåligt med luft i något av däcken så kommer det också upp.

Det är väl också en bra funktion.

Finns det information som visas idag men som du sällan eller aldrig använder?

Nej. Jag tycker det är en bra display ändå.

Jag visar det jag behöver veta. Jag känner inte till något jag saknar.

Det är inga situationer där du känner att du saknar viktig information?

Det är med att backa i så fall.

En avståndsmätare av något slag hade kunnat vara häftigt. Om du skulle förbättra något i dagens instrumentpanel och på displayen. Utöver det här med kameran och det.

Är det något du kan tänka att det här hade jag velat förbättra?

Nej. Inte på raka eller så. Det är ingenting jag tänker på riktigt.

Jag tycker det är rätt bra som det.

Hur viktigt för dig är det att ha navigation och GPS i ditt arbete? Alltså att se vart du ska köra någonstans?

För mig så är det väldigt enkelt. Hela detta området kan jag.

Vi kör ju inte utanför detta området. På andra sidan motorvägen kör vi lite också. Men om man kan alla ställen så vet jag vart jag ska.

Så för mig är navigation ingenting jag behöver. Det är direktiven egentligen. Jag får ett direktiv att köra denna bit.

Hur får du dem direktiven? Telefon. **Måste du ringa?** Ja ofta får man samtal eller sms. Eller så har du en lista att de här ska flyttas från detta stället till detta stället.

Och då följer du listan. Bockar du av efter vad det är du har kört. **Är det på papper då?** Du kan ha papper eller telefon.

Så som du vill. Men det hade varit en cool grej att ha i displayen. Typ kunna koppla din telefon till displayen.

Eller kunna få information skickad till displayen. Där du bara har härifrån dit. När den är klar så försvinner den.

Det hade också kunnat vara. Det hade underlättat att du inte behövde ta upp telefonen. Eller kolla på papper medan du kör.

Det är ju ett störmoment som man måste göra. Ta upp en telefon. Ja visst.

Hur tydlig tycker du att informationen om dina arbetsuppgifter är idag? Är till exempel trailernummer och parkeringsplats. Funkar det eller brukar det vara att man gör fel?

Nej det brukar fungera klart rent. Men det finns absolut situationer där trailern saknas.

Den står inte på det stället där de säger att den står. Och då åker jag dit och letar. Men det finns inget.

Ibland så. Som människor gör fel. Folk skriver fel nummer.

Det är helt vanligt och helt okej att någon skriver ett fel nummer ibland. Då är det bara att ringa och hämta en fråga. Så brukar det inte vara några konstigheter.

Men absolut. Det finns sådana problem. Men det är inga stora konstigheter.

Då kollar vi mer på produktivitets-vy. Hur skulle du känna om du hade en vy som visade hur många trailers och uppgifter du har utfört under dagen? Skulle det vara användbart på något sätt?

Ja absolut. Och veta vad du har kört.

Säg att du har 30 trailers du ska köra den här dagen. Och veta att du har kört 20 och har 10 kvar. Det är alltid kul att veta hur mycket du har kört och hur mycket du har kvar.

Annars så kör du i blindo. Det är lite jobbigare än att veta att du har 2-3 timmar kvar. Så absolut.

På en arbetsdag, om vi säger att ni ska köra 30 trailers. Är du klar för dagen när du har kört de 30?

Det finns alltid något att göra. Jag blir aldrig klar.

Ta en typisk dag när man bara kör trailers i terminaltraktorn. Vilka fysiska rörelser gör man oftast i hytten?

Det kan vara att man vänder på sig. Det är mycket att vända nacken.

Kolla dit, kolla dit. Kolla bakom. Hela tiden.

Jag känner att det är väldigt viktigt att ha uppsikt när man kör. Röra sig hela tiden med blick och nacke. Kolla döda vinklar och sådana grejer.

Det är där olyckorna händer. När man inte är extra uppmärksam. Det är då olyckorna händer.

När man tar för givet att det är ingen där. Det är då det händer. Det är mycket fysisk huvudrövning.

Lite med kroppen också. Kolla extra noga. Lite med fingrarna. Pilla på lite knappar. **Brukar du använda den här funktionen ofta? Att kunna rotera stolen?** Ingen av våra maskiner har det. Så det använder inte jag.

Tror du att du hade använt det? När du ska backa in till bryggan. Så du ska parkera trailern vid bryggan. Då är det skönt att kunna vända stolen.

Då kan du kolla ut genom rutan. Om du har på höger sida 10 cm från kanten. Då vet du att du har 30 cm på andra sidan.

Det hade jag nog använt om jag kunde vända stolen. När du använder den här maskinen.

Är det någon knapp som du känner är svårt att nå? Eller vissa kontroller som är otillgängliga? Nej.

Behöver du ofta använda maskinen när du har på dig handskar? Eller smutsiga händer? Hur påverkar det din förmåga att interagera med kontrollerna? Vi kör aldrig med handskar. Vi använder handskarna utanför. När vi vävar stödbenen.

Eller när vi kopplar luften. Eller om vi ska öppna bakdörrarna. Kolla om den är tom.

Allt som handlar utanför tuggen är med handskar. Men allt inuti tuggen är utan handskar. **Jag kom på en fråga. Kopplar du luften?** Du har två kablar. En röd och en gul. Den gula är för att trailerns bromsar.

Den röda släpper nödbromsen. Och pumpar in luft i trailern. Den gula är när du trycker på fotbromsen.

Så bromsar trailern bakom dig. Du kan koppla den röda och köra utan det. Men då bromsar inte trailern när du bromsar.

Då kommer all vikt mot dig. Och sen har du elkabeln till ljuset.

Funkar det att köra om du skulle glömma att koppla alla kablar? Går det att köra då? Nej.

För nödbromsen är... Du kommer ingenstans. I så fall så... Nej, du kommer ingenstans. **Men det är inget man brukar glömma, eller?** Nej, glömmer du så märker du det.

Vad brukar du kolla för att kontrollera maskinens status? Eller för operativ feedback? Är det mest på instrumentpanelen eller är det mer på den här displayen? Alltså typ operativ feedback. Men det menar jag med feedback på hur fordonet presterar. Eller om det är något som är nere.

Då kollar jag i displayen. Inte så mycket bakom ratten? Det är ju bakom ratten, displayen. Det är instrumentpanel och display i ett.

Så den är ju helt... Vad fan heter det? Analog. Om vi tar på just den här skärmen och dens placering där bakom ratten. **Tycker du det finns något annat ställe där den hade gjort sig bättre i hytten? Typ vid sidan, lite högre upp, eller?** Nej, jag tycker den sitter väldigt bra.

Sen hade man haft lite fler funktioner. Säg om man hade utvecklat till backkamera. Då hade jag velat ha den kanske antingen lite vid sidan.

Eller en större skärm. För annars kan jag känna att det hade blivit trångt att ha allt på ett. För den är kanske bara en sådan typ.

Så i så fall hade man fått bredare, eller så hade man fått placera den... Kanske lite längre fram, lite till vänster. Vänster brukar vara väldigt bra, kan jag tycka. När man har kameror och så vidare.

Antingen höger eller vänster. Längst vid rutan nästan. Okej, ja.

B

Appendix - Specification of Requirements

Criterias	Requirements or Preferences	Grading (High, medium, low)
1. Fifth wheel & Kingpin		
1.1 Operator shall be able to see if fifth wheel is open without turning head	R	R
1.2 Clear feedback that fifth wheel is locked without doing extra checks	R	R
1.2.1 Clear visual feedback	R	R
1.2.2 Clear haptic feedback	P	Low
1.2.3 Clear auditory feedback	P	Low
1.3 The infotainment system shall give feedback to the user about its surroundings while aligning vehicle to trailer	R	R
1.3.1 Clear visual feedback	R	R
1.3.2 Clear haptic feedback	P	Low
1.3.3 Clear auditory feedback	R	R
1.4 The infotainment system shall notify the user when obstacles are in the way	R	R
1.5 The infotainment system shall indicate if the fifth wheel is approaching the kingpin correctly or incorrectly	R	R
2. Navigation		
2.1 The infotainment system shall provide the user with a clear navigational view of the working area	R	R
2.2 The infotainment system shall provide the user with information about other driver's whereabouts	P	Medium
2.3 The infotainment system shall provide the user with clear directions to assigned trailer	R	R
2.4 The infotainment system shall provide the user with clear directions to assigned parking slot	R	R
3. Maneuvering with trailer		
3.1 The infotainment system shall assist the user in aligning the vehicle (lane assist)	R	R
3.2 The infotainment system shall provide the user with information about the space behind trailer when reversing	R	R
3.2.1 Visual information	R	R
4. Task management		
4.1 The infotainment system shall provide the user with information about their transport without interrupting their workflow	R	R
4.1.1 Distance to drop off/pick up of trailer	R	R
4.1.2 Time to drop off/pick up of trailer	R	R
4.1.3 Drop off/Pick up location	R	R
4.1.4 Trailer number	R	R
4.1.5 Weight of trailer	?	R
4.1.6 An estimation of task completion time	P	Medium
5. Outside the vehicle		
5.1 The infotainment system should provide visual feedback if the user has forgotten to attach brake, electric or emergency cables	P	Medium
5.2 The infotainment system should provide visual feedback about raising the trailer's support legs	P	High
5.3 The infotainment system should provide visual feedback if the rear trailer door is locked	P	High
6. Physical buttons		
6.1 The vehicle system shall provide physical buttons within an arms length for all machine controls	R	R
6.4 The infotainment system should provide digital buttons within an arms length	P	High
7. Productivity view		
7.1 The infotainment system shall provide information about tasks	R	R
7.1.1 Task completed	R	R
7.1.2 Upcoming tasks	R	R
7.1.3 Progression status	R	R
8. Error log		
8.1 The infotainment system shall provide status of the vehicle and errors	R	R
8.2 The infotainment system shall provide recommendations of how to proceed with errors	R	R
8.3 The infotainment system should provide the user with reminders to perform routine checks	P	Low

Figure B.1: Specification of requirements

C

Appendix - User Journey with pain points

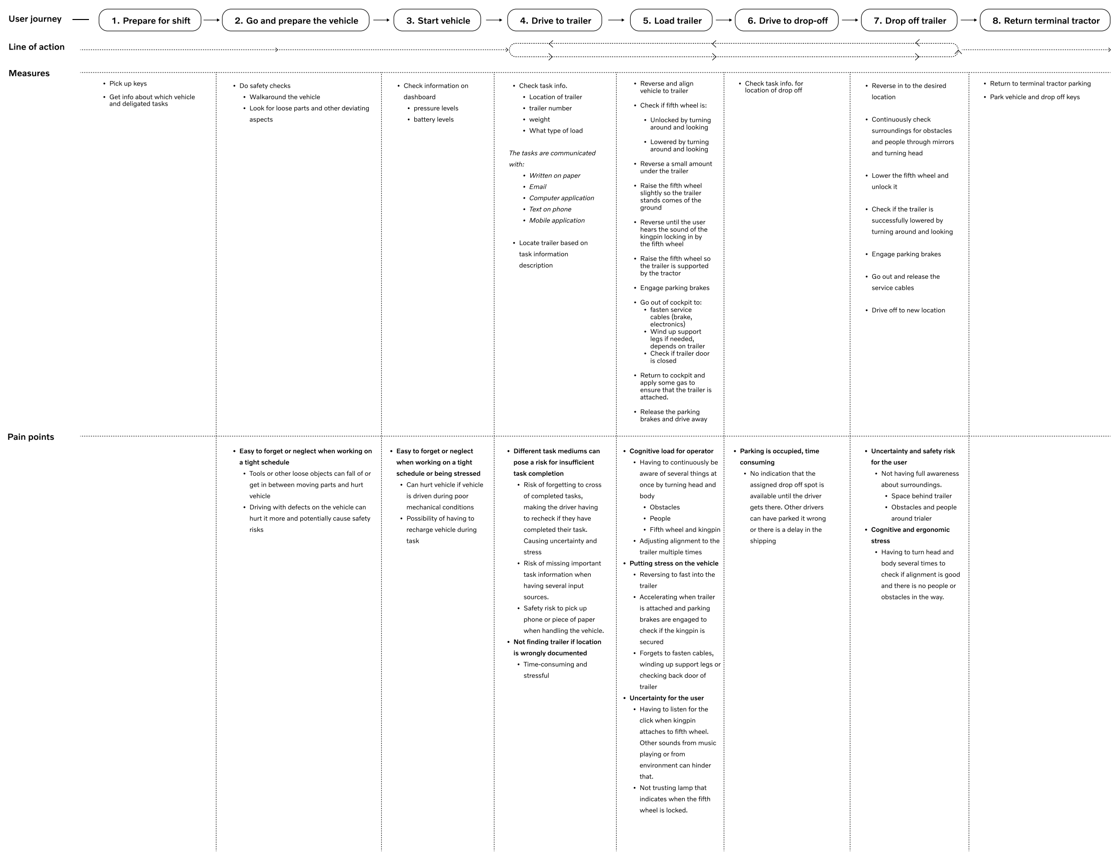

Figure C.1: User Journey with mapped pain points.