A Comfortable Transition to Electric

Investigating the Design Process of Developing a Dashboard Interface for an Electric Terminal Tractor

Master's thesis in Interaction Design and Technologies

FILIP ANDRÉASSON CHRISTOFFER BOMAN

Department of Computer Science and Engineering
CHALMERS UNIVERSITY OF TECHNOLOGY
UNIVERSITY OF GOTHENBURG
Gothenburg, Sweden 2019

Master's thesis 2022

A Comfortable Transition to Electric

Investigating the Design Process of Developing a Dashboard Interface for an Electric Terminal Tractor

FILIP ANDRÉASSON
CHRISTOFFER BOMAN

UNIVERSITY OF GOTHENBURG

CHALMERS
UNIVERSITY OF TECHNOLOGY

Department of Computer Science and Engineering
Division of Interaction Design
Chalmers University of Technology
University of Gothenburg
Gothenburg, Sweden 2022

A Comfortable Transition to the Electric Terminal Tractor
Investigating the Design Process of Developing a Dashboard Interface for an Electric Terminal Tractor
FILIP ANDRÉASSON
CHRISTOFFER BOMAN

Supervisor: Paweł W. Woźniak, Department of Computer Science and Engineering
Examiner: Palle Dahlstedt, Department of Computer Science and Engineering

Master's Thesis 2022
Department of Computer Science and Engineering
Division of Interaction Design Chalmers University of Technology and University of Gothenburg
SE-412 96 Gothenburg
Telephone +46 31 772 1000

Cover: Illustration of a terminal tractor [Authors contribution]

Typeset in LaTeX
Printed by Chalmers Reproservice
Gothenburg, Sweden 2019

A Comfortable Transition to the Electric Terminal Tractor
Investigating the Design Process of Developing a Dashboard Interface for an Electric Terminal Tractor
FILIP ANDRÉASSON
CHRISTOFFER BOMAN
Department of Computer Science and Engineering
Chalmers University of Technology

Abstract

With the world gradually shifting toward renewable energy sources, many fossil-driven industrial vehicles must transition to electric counterparts. Such transitions can be imposing on the comfort of users and poses an interesting design challenge. In this thesis, we perform a user-centred design process to create a digital dashboard interface for a new electric terminal tractor. We investigate how this process affects the user experience of the final interface concept, and what to consider when designing for a comfortable transition from traditional to novel interfaces. The process was challenged by a low availability of users, resorting to alternative methods to accomplish user-centred design. The final concept was developed through three design iterations, using legacy bias as a tool for creating comfortable transitions. Each iteration resulted in a set of concepts which were subsequently evaluated. The final concept was well-received by all stakeholders, and it managed to improve the user experience for terminal tractor operators, while still remaining a comfortable transition from traditional interfaces.

Keywords: electric terminal tractor, dashboard interface design, research through design, user-centred design, legacy bias, user experience.

Acknowledgements

Thank you Paweł W. Woźniak, for your indispensable expertise and knowledge. Your guidance and council made this thesis possible.

Thank you Johan Almroth, for your confidence in our process and constant support. Your everlasting effort has been invaluable for the success of our project.

Thank you CPAC, for the opportunity to conduct our thesis with your trust and encouragement. A special thanks to all of our colleagues in this project and those others who have helped us, always eager to share your expertise.

Filip Andréasson, Gothenburg, June, 2022
Christoffer Boman, Gothenburg, June, 2022

Contents

List of Figures

List of Tables

1

Introduction

Developing more modern vehicles that run on renewable energy sources is a prevalent topic. In the container port industry, terminal tractors are one of the main contributors to greenhouse gas emissions (Martínez-Moya et al., 2019, Starcrest, 2021, Yu et al., 2017), which creates a need for electric terminal tractors, as they can drastically reduce the carbon footprint of cargo handling in container ports (Chang et al., 2019). The dashboard interface of traditional, fossil-driven, terminal tractors most commonly utilises analogue gauges that display information from the powertrain to the driver. In the development of an electric terminal tractor, the dashboard interface needs to be revamped to accommodate an electric powertrain. Since these new interfaces display information in an unfamiliar way, as well as introduce several novel components, the transition from traditional to electric dashboards can be difficult and frustrating for terminal tractor operators.

In this thesis, we perform a user-centred design process to create a digital dashboard interface for a new electric terminal tractor, a vehicle used to shuttle and arrange semi-trailers in container ports. We investigate how this process affects the user experience of the final interface concept, and how it could contribute to a comfortable transition from traditional to novel interfaces. This thesis is done in collaboration with CPAC, in a project commissioned by a terminal tractor manufacturer in the USA to develop a new electric terminal tractor.

Container ports are often located in connection to residential areas, causing an environmental impact on both air and water quality, as well as noise. Additionally, the industrial vehicles used in container port operations are major contributors to climate change (Di Ilio et al., 2021). Therefore, the shift towards other powertrain alternatives for industrial vehicles, such as electricity or fuel cells, affects societies both locally and globally. This transition into electric vehicles poses an interesting challenge for human-machine interface development and designing user experiences, due to the novelty of using electric vehicles in container port operations.

However, technological growth remains a constant threat to the displacement and alteration of many professions, which practitioners may suffer unemployment. The users that are caught in the transition of a technologically evolving environment are expected to adapt their behaviour and accommodate any innovation, regardless if it radically changes the execution and satisfaction of their assignments. By shifting the focus towards a more user-centred design of these transitions, perhaps the practitioners will be more accepting of, and open to adapting to, the rapid evolution of technology.

The transition to an electric powertrain can be an alarming thought to some of the primary users of terminal tractors since it implies many changes to both their profession as well as the tractor itself. The dashboard alone will introduce several novel systems to the users, like the tell-tale icons that warn them about new malfunctions, and information systems that are unique to EVs. Creating a comfortable transition would alleviate the stress and anxiety of adapting to the new system, placing the experience of the transitioning user in the spotlight.

In collaboration with CPAC, a Gothenburg-based Volvo subsidiary, we are developing the dashboard interface in a project commissioned by a terminal tractor manufacturer in the USA. CPAC and the client company are developing a new model of a terminal tractor with an electric powertrain, that is, delivering power through electric motors rather than an internal combustion engine. Since the new powertrain will replace many systems of their old tractors, the dashboard must transition from a mostly analogue interface to a digital one. The scope of responsibility for the thesis in this project is the design and user experience of the new digital dashboard interface. CPAC has recently grown rapidly as a company, and from their side, this thesis is an experiment to challenge their processes to consider the user experience in a project.

1.1 Research Contribution

The electrification of the automotive industry has led to an interesting subject for research in terms of design. Various research projects have been conducted concerning the design of vehicle dashboard interfaces (Francois et al., 2017, Lundström and Hellström, 2015, Lundström, 2014, Fank et al., 2021. Terminal tractors, on the other hand, are quite niche as subjects of research and have not been studied as extensively as cars and trucks. Most studies on vehicle dashboard design, however, concern information visualisation, and few touches on the topic of design considerations when transitioning a vehicle to electric (Strömberg et al., 2011). To our knowledge, there is no academic research regarding the challenges and considerations of designing an electric vehicle dashboard interface with the intent to create a comfortable transition for the user, which will be the greatest contribution to academia in this project.

Additionally, the design of digital interfaces in terminal tractors seems to be an often-overlooked aspect. Many of the terminal tractor displays that were investigated in this project had much room for improvement, sometimes lacking features that were critical information for the driver. Utilising digital displays in terminal tractor dashboards, and industrial vehicles in general, is a relatively recent development, so, design research in this field may, therefore, be of great value for the industry of industrial vehicles as a whole.

1.2 Research Aim

By conducting a design research project, in which we develop a concept for the dashboard interface of an electric terminal tractor, we hope to gain an understanding of the important aspects of designing an interface for professional vehicles in regards to what contributes to a good interface which allows a comfortable transition for users. Therefore, we aim to answer the following research question:

> *What are the considerations when designing a digital dashboard in a user-centred approach, to achieve a comfortable transition from a traditional to an electric terminal tractor?*

To answer this, a generative design process is conducted, where a range of designs will be developed and tested to learn what considerations are important, and what key design choices we can identify.

We consider a comfortable transition to be two-fold. First, the transition from a traditional tractor to an electric should feel natural, intuitive and be as stress-free as possible. Secondly, switching back and forth between traditional and electric tractors should not impose any additional stress. It is unlikely for terminals and ports to replace all their traditional tractors with electric, which would force drivers to repeatedly switch between a traditional and electric tractor.

One part of making the transition comfortable and understanding the full impact of the dashboard interface is to investigate the user experience. Terminal tractors are vehicles operated in hazardous environments, and it is important to consider the full experience and effectiveness of using the new interface to make sure it can be used as effectively as a traditional dashboard.

The project deliverable will be a complete design for the interface. It should cover all necessary functions and the different states which the interface can enter, depending on if the propulsion system is on or off. The design concept will be delivered to CPAC at the end of the project, who will implement the functionality before delivering it to the client company.

1.3 Delimitations

Even though the user experience for the dashboard involves far more than the digital screen, the work in this thesis is limited to the design of the display interface. We also limit ourselves to focus on the primary users of the screen, the terminal tractor drivers. Secondary users, such as mechanics, engineers, or anyone else encountering the interface, will not have their user experience considered because of time limitations. And finally, we will only consider touch interaction as input for the display, a limitation which was placed on the project before we got involved.

1.4 Report Structure

To give the reader a greater understanding of the chapters in this report, they will be described here, and hopefully guides in navigating the report. It is important to note that while we strive to explain the process in a logical and chronological order, the reality of the project was sometimes different. As design projects often tend to be, our process has been far from linear, but for the sake of readability, the report structure has been organised in the most coherent order.

The process has been divided into three phases: *Understand*, *Create* and *Evaluate*. By splitting the process into these three distinctly different parts, we hope to make the process easier to navigate. Furthermore, the resulting final concept is described independently in Chapter 9 - *Final Concept* to present it more prominently. So, if the reader wishes to be spoiled with the final result before reading the process, this would be the place to look.

Below, the chapters are listed with a short description, ordered as they appear in the report:

1. Introduction

   The initial introduction chapter explains the project, the aim, and the delimitations, and provides an introduction to the thesis and its structure.

2. Background

   The background chapter explains some knowledge that may be required to completely understand the project, as well as the circumstances which shaped the process and outcome. It gives a thorough explanation of how terminal tractors operate, as well as stakeholders, and the state of the project as it was when the thesis became involved.

3. Theory

   The theory chapter describes our findings from research in related domains. It also brings up relevant frameworks and aims to provide an understanding of what we as designers related to when conducting this project.

4. Method

   Here, the methods and tools that were used during the execution of the project are presented. The methods are structured into data collection, data analysis, ideation, prototyping, and tools.

5. Planning

   In the planning chapter we present how the project is structured and a time plan for the process. The process will be divided into three phases, namely understand, create and evaluate, which will each be described in their corresponding chapters.

6. Understand

   The understand-phase is the first phase of the process, where the main goal was to gain knowledge about the users, terminal tractors and vehicle dashboard design in general, to be able to start generating valuable ideas.

7. Create

   The create-phase is the second phase of the three process phases and is the biggest part of the project. The focus in this phase was to develop interface concepts, slowly converging towards producing a final concept through three iterations.

8. Evaluate

   The third and final phase of the three process phases is a shorter chapter in which we validate our final concept created in the previous phase. This was done with evaluations with an operator and various stakeholders of the project.

9. Final Concept

   The chapter explains the final concept and all of its features. This result is presented independently, to separate it from all the other concepts and results derived from the project.

10. Results

    Additional results from the process are presented and described in this chapter. It summarises all the earlier concepts that were developed in the iterations, as well as describes our learnings and insights from developing an interface for the transitioning user.

11. Discussion

    During the project, we encountered several problems that were challenging to solve. This chapter will justify and discuss the approach that was used to solve said challenges, as well as discuss the final concept, some results, parts of the process, and ethics in general.

12. Conclusion

    The final chapter of this report will provide conclusions we were able to draw from conducting this project, as well as give some final remarks.

2

Background

To completely grasp the content of this report, some of the used concepts and contexts need to be further explained. Parts of this chapter contain information that was critical to being able to fulfil the project. Other parts describe background information that is important to disclose to understand the circumstances which shaped the project. But first, the terminal tractor is described, as the entire project revolves around it and its operators.

2.1 Understanding a Terminal Tractor

Understanding the terminal tractor is important to understand, and empathise with the drivers. This section will explain the terminal tractor both in detail and in general, based on the insights we have gained from this project.

The terminal tractor, often referred to as ’jockey truck’, ’shunt truck’, or ’yard truck’, is an industrial vehicle primarily used to shuttle and arrange semi-trailers in container ports and terminals. The terminal tractor utilises a fifth-wheel coupling to lift and move trailers without having to raise the trailers’ landing gear. Combined with their small size and impressive agility, terminal tractors excel at handling trailers for short distances. They are traditionally powered by smaller internal combustion engines and operate at slow speeds, up to 40km/h. Driving with a lifted trailer makes the arrangement unstable, and drivers need to be careful making turns and driving at higher speeds.

Different brands and models of terminal tractors will vary in function and features. However, the attributes described in this section have been observed in all the tractors that were investigated during the project. As there are few electrical terminal tractors in operation, however, this section mainly describes traditional terminal tractors.

2.1.1 Elements of the Dashboard

Driving a terminal tractor is mostly similar to other cars or trucks, and this section will focus on the features that are either specific to terminal tractors or differ from other vehicles. To begin, maybe the most essential part of a terminal tractor is the

Figure 2.1: Terberg terminal tractor, Stockholm Nord Container Terminal, Sweden. [Beng Oberger, CC BY-SA 4.0, via Wikipedia Commons]

fifth wheel coupling, which is controlled with a panel inside the cockpit. The panel consist of a lever to move the boom up and down, and a button to release the fifth wheel.

Figure 2.2: A photo of the dashboard of a traditional terminal tractor. [Johan Almroth]

The operator also has buttons to control the air-pressure brakes on the tractor and trailer. These are two buttons controlled by either pushing or pulling, one red and one yellow. The yellow button is the tractor parking brake, and the red button is to supply air pressure to the trailer. We have observed that this button is commonly referred to as the 'trailer parking brake', even though "not for parking" is explicitly written on the button. Lastly, in addition to these two buttons, there is also a third button to immediately activate the emergency brakes.

Terminal tractors differ in the information they display to the driver. From what we have observed, most tractors today use a variety of analogue gauges, while more recent models may use a digital display, that is often quite small. The icons and symbols for various features also differ but the information that is generally present in the dashboard includes air-pressure meters, speedometer, odometer, total engine hours, fuel gauge, effect meter, motor temperature, and battery level.

The terminal tractors we observed do not use a gear stick, instead, it is geared using a small panel on the dashboard with a button for each gear. The 'parked'-state is not accessed with the gear selection panel, but by activating the parking brake. This state is thus neutral gear with the parking brake activated. The terminal tractors from the client company also had a small display for a fleet management system, through which operators would receive their orders, however, many other terminals use radio, or equivalent, to hand out orders to operators.

2.1.2 Tractor Trailer Connections

Understanding the role of the two air-pressure tanks, and the connections between the tractor and trailer will explain some of the design decisions that were made in the project. There are three connections to be made in a tractor-trailer configuration other than the fifth wheel coupling. The first connection is a cable for providing electricity to the trailer, to enable its lights and sensors. The other two connections supply the trailer with air pressure by so-called 'gladhand' connectors. These connections are critical, as the trailer requires air pressure to activate its brakes. One of these lines is red and used for emergency brakes. This line need to be pressurised at all time for the brakes on the trailer to release. The other line, which is blue, is service brakes. This line makes it possible to use the trailer brakes when the tractor is braking, and in contrast to the emergency connection, it does not need to be pressurised for the trailer brakes to be released.

Terminal tractors have two air tanks in case one of them would break. Each tank applies braking force on one tractor axle, either the front or rear and is hence often referred to as either the front or rear tank. In the situation that one of the tanks would brake, the driver would only be able to use one axle on the tractor to brake with, but the trailer brakes would work as normal, as pressure to the trailer is provided by both tanks. If pressure were to be lost in both tanks, however, the brakes of the tractor and trailer would engage, and bring them to an urgent halt, as the emergency brake line would no longer be pressurised.

Consequently, it becomes critical for operators to keep an eye on the pressure level of the tanks when driving. When connecting to a new trailer, all three connections should be made to safely move the trailer, but in practice, it can be moved by only connecting the emergency line. This way, however, the trailer would not be able to brake, and its lights and anti-lock braking system (ABS) would not work.

2.1.3 Electric Power Train

The transition into an electric power train introduces several changes to the terminal tractor. Some can be translated from the traditional tractor, like how the battery state of charge is perceived similarly to the fuel level in a tractor with an internal combustion engine, or how regenerative braking acts like the motor brake. There is an important distinction to be made between engines and motors; 'engines' refers to internal combustion engines, whereas 'motors' refers to electric motors.

One of the features that we discuss in this report is the retarder. A retarder is a device used to replace some of the primary friction-based braking systems on some vehicles. Retarders work as a secondary brake to slow down vehicles, or maintain a steady speed while travelling down a hill, as friction-based brakes would become ineffective.

The retarder on electric vehicles works differently but achieves a similar effect. By varying the intensity of how much the motor regenerates power, the motor braking force that engages when the pedal is released can be controlled. Electric vehicles can hence be driven in a 'one-pedal' mode with a high retarder level. Electric cars often have easy access to changing the level of the retarder, as it provides great utility to the driver.

Another concept that is worth noting is the high- and low-voltage system of the electric terminal tractor. The tractor will have one high-voltage system which is used to drive the vehicle. The batteries for this high-voltage system are big and need to be cooled, and the temperature monitored. There is also a low-voltage system, used to power the various applications such as the dashboard, and turn on the high voltage system.

2.2 The Future of Terminal Tractors

It is only possible to speculate about what the future holds, and how terminal tractors will operate in it. However, it can be said, that there is a transition towards autonomous vehicles happening in all of society, and some of the work performed by terminal tractors could probably be automated. Several companies are presenting concepts for a fully autonomous vehicles for port operations (Terberg, 2022, Kalmar, 2022, Konecranes, 2022). Therefore, it seems like a possibility that terminal tractors will operate autonomously in the future.

The automation of manual labour is a controversial topic. While some papers argue that automation will not cause the elimination of certain jobs (Gittleman and Monaco, 2020), even though they are considered at high risk of automation (Georgieff and Milanez, 2021). However, what is not commonly discussed is the change that these professions will inevitably go through.

Even though these jobs may not disappear, any current practitioners will have to either accept a new role and fit its needs, or they will indirectly lose their job. Orii et al. (2021) used scripts to analyse a trucker community on the internet forum reddit.com, which provided a lot of insights regarding how stakeholders of trucking perceive the notion of automation. An overarching theme in many discussions on the forum was the lack of trust stakeholders had in automation, both in how it should be implemented as well as the consequences it may have. It is therefore not strange to assume that a new electric terminal tractor can be seen as a step towards automation, since the same companies that develop electric vehicles also publicly propose an autonomous future.

2.3 Standardisation Organisations

The report discusses icons that are derived from standardisation organisations, regarding when and how certain icons should be used. Two organisations will be referred to, ISO and SAE International. The first one, the International Organisation of Standardisation, is an independent and non-governmental organisation that are developing standards for product and services. The standards are created to ensure consistency, and ISO certificates are evidence of products being up to standard and ensure their quality and safety. They currently have developed over 24 000 International Standards, for example, standards for the use of tell-tales in vehicles (ISO, 2022), which are the icons that inform the driver of malfunctions or general vehicle status. Likewise, SAE International is another association that develops standards for various engineering industries. SAE are globally active but are based in the USA (SAE, 2022).

The standards developed by the two organisations are often very similar, in fact, most ISO-grades also have an equivalent SAE grade. For example, the ISO standard *ISO 2575:2021, Road vehicles - Symbols for controls, indicators and tell-tales* also has an SAE equivalent, *SAE J2402_201001, Road Vehicles - Symbols for Controls, Indicators, and Tell-tales* that only a have a few alterations compared to ISO (SAE, 2010; ISO, 2021). All the icons, symbols and tell-tales that are brought up in this report have the same icon in ISO and SAE, therefore, all SAE standards are inherently ISO standards as well.

For an icon to conform to an ISO standard, it does not need to match its proposed icons perfectly. The ISO standard *ISO 2575:2021* does state that some deviations are accepted, and for some icons, they propose to change parts to match the context, for example updating the part of a logo that contains a vehicle into something that represents the actual vehicle.

2.4 Stakeholders

In this thesis, there are several stakeholders involved, both from Chalmers University of Technology, where the thesis is conducted and from CPAC, where the project is executed. This section will describe some of the stakeholders, and how they are relevant to the project.

2.4.1 Chalmers University of Technology

The first stakeholder for this master thesis is Chalmers University of Technology. Performing the thesis is required to complete a master's degree in Interaction Design and Technologies. Chalmers provides the requirements for what counts as a valid project and will have an examiner grade the project in the end. For a project to be approved, it must contain a certain level of academic value within the subject of interaction design. A supervisor from Chalmers has also been selected to assist and aid in the process.

Supervisor: Paweł W. Woźniak
pawel.wozniak@chalmers.se

Examiner: Palle Dahlstedt
palle.dahlstedt@cse.gu.se

2.4.2 CPAC

CPAC Systems AB is a Volvo Penta subsidiary and part of the AB Volvo Group. They have provided us with the opportunity to conduct our master thesis within their project to develop parts of an electric terminal tractor with a client. A supervisor from CPAC was assigned to us, and supported our thesis project, making sure we were able to perform our academic studies while helping us to provide value to CPAC.

Supervisor: Johan Almroth
johan.almroth@cpacsystems.se

2.4.3 Client Company

The project is commissioned by a terminal tractor manufacturing company based in the USA. In this report, they will henceforth be referred to simply as the 'client company'. They are developing the new electric terminal tractor, and have commissioned CPAC for integrating the electric powertrain in the tractor and various other tasks. Since the powertrain replaces several of the old systems in the dashboard interface, CPAC is responsible for the development of the new dashboard interface. The client company is therefore our main stakeholder in the design of the dashboard interface.

2.4.4 Filip Andréasson

Filip has a bachelor's degree in Software Engineering from Chalmers University of Technology. Particularly enjoying courses at Chalmers like Designing User Experience, and Information Visualisation, Filip enjoys creating digital experiences for people. Motivated to involve users in the design process, he strives to create inclusive and empathetic solutions in his projects, and empower the world through user-centred design and creative problem-solving.

https://filipandreasson.com
filandr@student.chalmers.se

2.4.5 Christoffer Boman

Christoffer has a bachelor's degree in Industrial Design Engineering from Chalmers University of Technology. Being a creative spirit and maker to the bone, Christoffer has an everlasting passion for building and creating all sorts of things, both digital and physical artefacts. The most exciting part when working with user experiences is creating meaningful interaction.

https://christofferboman.com
cboman@student.chalmers.se

2.5 Project State

This section describes the state of the project when we got involved at the start of our thesis. At this point, CPAC and the client company had been developing the powertrain for a while. They had a newly finished first functioning prototype, that had just been tested and shipped to the client in the USA. Many requirements for the tractor were still to be determined, and nothing was yet specified about the interface itself. The interface of the prototype was just a debug screen, consisting of boxes with various information and buttons. The placement of the screen was not decided at the start of our project, and to delimit our project further, it was decided to begin with the assumption that the screen was to be placed somewhere behind the steering wheel.

Figure 2.3: The screen that will be used in the final product for the interface, which is 11". The placement in the dashboard is not decided by the project stakeholder but is assumed to be somewhere behind the steering wheel. [Authors contribution]

The screen itself for the interface can be seen in Figure 2.3. It is an 11" wide touchscreen with a resolution of 1024x768 pixels. The full size of the screen with borders included is 26x21cm. It is used to run android applications and exists in several other of CPAC's industrial applications.

3

Theory

This chapter presents the theoretical frameworks relevant to the project. First, Research through Design will be described, which has been used to produce the design knowledge for this thesis. Two sections follow that discuss the theoretical finding we made regarding designing dashboard interfaces, and how to regard legacy bias in design. After which, we describe some useful frameworks we have used to support and illustrate the process. Finally, we introduce the standardisation organisations ISO and SAE.

3.1 Research through Design

A design problem can generally be regarded as a *wicked problem*. A wicked problem has, by definition, no definitive formulation, nor set amount of solutions. Therefore, an attempt to solve a wicked problem can only be 'good' or 'bad' (Rittel and Webber, 1973). A useful strategy to generate design knowledge is to use what is called *Research through Design*.

Originally coined by Frayling (1994), Research through Design is a research practice in which the main focus is to improve the world by making new things that directly influence it (Zimmerman and Forlizzi, 2014). Zimmerman and Forlizzi (2014) argue that, while Research through Design is similar to design practice, the focus of producing new knowledge makes Research through Design in essence different from the practice of creating a commercially successful project. Approaching a problem with Research through Design, the intent of the researcher is to investigate how their design actions produce new knowledge.

Wicked problems can not be answered speculative or by trial and error, some sort of generative design practice must be made to gain knowledge. That often means that a design concept must first be created to gain knowledge of it. Wensveen and Matthews (2015) writes

> "We are quick to note, however, that the relationship between design research and design practice is often blurry. Design research, by which we refer to the discipline that aims to produce knowledge concerning design, often addresses research questions that cannot be answered without

> doing some kind of design activity."

Furthermore, Gaver (2012) argues in their essay that design, and Research through Design, is in essence generative. Gaver summarises the proceedings of Carroll and Kellogg (1989), noting that to conclude whether a certain design is 'good' or 'bad', it must first be created. Or as they cleverly put it:

> "Carroll and Kellogg (1989) noted that the mouse needed to be invented before studies could be done that showed this was a good design".

Research through design is suitable for this project due to the generative nature of iteratively designing an interface. As we seek to understand how design choices in the development of an interface will affect the user experience, we opted to perform some design activities that we can evaluate and draw insights from. Any new knowledge gained from evaluations can be embedded in the next iteration of the interface to gain an outlook for the future of dashboard design, by combining our vision with the insights of researchers, end-users and industry specialists.

3.2 Design Process Models

Numerous models are used to illustrate or explain the general design process. No model can perfectly describe all design processes, and in this section, two popular models are brought up that will both be used in the project.

3.2.1 Design Thinking

Design thinking is a way to explain the general design process, and has been helpful to strategise the design process for the project. Design thinking is said to be an iterative process that aids the designers to set aside their biases and previous experiences to a greater extent, to ultimately produce a solution for the user and their needs. Dam and Siang (2018) notes that the strength of Design Thinking is helping the designer to think 'Outside the Box'. Instead of relying on the designer's previous experiences, Design Thinking reiterates the value of holistically understanding the subjective problem of each user in their specific context.

There are different takes on Design Thinking, and multiple various models that illustrate the process differently, even though they stick to the same basis. This project follows the model of Design Thinking that the Hasso Plattner Institute of Design at Stanford, or 'd.school', proposes. It utilises a 5-step process as the main components of the process (d.school, 2018), namely: Empathise, Define, Ideate, Prototype and Test.

The first step, *Empathise*, revolves around immersing yourself and gaining a deep understanding of the target user group. The second step, *Define*, aims to frame the problem and generate possible solutions based on your own experience mixed with the insights from the first step. The third step, *Ideate*, is a diverging step in the Design Thinking process, to generate diverse ideas in large quantities. The fourth step, *Prototype*, projects the ideas produced in the previous steps into the physical world, with the aim to both test functionality and understand the implications of the idea. Finally, *Test*, the final step in the process, gives the designer a possibility to assess the integrity of the idea, to further refine the design or gain new insights for the drawing board.

3.2.2 Double Diamond

The Double Diamond is a widely known representation of the design process, proposed by the design council (Hambeukers, 2019). It provides a simple description of the steps in a design process that works regardless of which methods and tools are used (Ball, 2019). The name derives from how the model is visualised by two diamonds, where the periodic widening and narrowing of the diamond reflect the diverging and converging phases of the design process.

The model suggests four distinct phases in the design thinking process: Discover, Define, Develop, and Deliver (Ball, 2019). The first diamond consists of Discover and Define, where the designer will first understand the user (diverging) and then define the problem (converging). The second diamond consists of Develop and Deliver, where the designer will construct solutions (diverging) and test them to discard those that are less optimal (converging). The strength of the double diamond is that it is a simple and effective illustration of the design process. However, it is criticised for appearing to be linear, which the design process arguably is not. In some depictions of the Double Diamond, circling arrows are added to the model, to indicate that it is an iterative process (Hambeukers, 2019).

No model can perfectly describe a general design process, (Hambeukers, 2019), and by utilising two intersecting models, the Double Diamond and d.school's model, a design process more specific to a project can sometimes be created. Combining these into more specific models is not unusual and can be seen in other projects (e.g., Ordóñez et al., 2017, Sihombing, 2021).

3.3 User-Centred Design

User-centred design is an approach that involves users throughout the design process. User-centred design is described by the Interaction Design Foundation (n.d.-b) as

> "an iterative design process in which designers focus on the users and their needs in each phase of the design process."

The goal of performing user-centred design is to create products that are more fit for the user. User-centred design focuses on user experience as a whole and is strengthened by a multidisciplinary team (Interaction Design Foundation, n.d.-b). Incorporating the ideas and opinions of users into every stage of the design process is an investment toward continuous validation of the developed product.

3.4 Designing a Dashboard Interface

In this section, we present some of our findings from investigating the research domain of dashboard interface design. Vehicles are becoming increasingly digital and no longer pose the same technical limitation to dashboard interface design as they used to. According to Coppola and Morisio (2016), a modern car uses ten times as many lines of code as a Boeing aeroplane. This shift creates a surge in research on the performance of different ways to convey information in vehicles, for instance when using gauges (e.g. Francois et al., 2017, François et al., 2019).

There is a considerable amount of research on the different aspects of dashboard interface design, specifically in cars and trucks (e.g. Lundström and Hellström, 2015, Lundström, 2014, Fank et al., 2021). While research on car dashboards focuses more on understanding electric cars, eco-driving, or battery and range perception, research on truck interface focus more on clusters of information and how to display novel features. As truck and terminal tractor drivers both use their vehicles in their respective professions, usually for an extended duration of time, other aspects are often more important to consider, with respect to cars. But in designing a dashboard interface for any vehicle, the psychology of the driver needs to be considered. There are many difficulties while operating a vehicle that could be alleviated by good interface design.

3.4.1 Range Anxiety

Lundström and Hellström (2015) discusses how interfaces that make users unsure how their actions affect their battery leads to dissatisfaction and underutilised batteries. This is supported by Rahmati and Zhong (2009), who found that inadequate interface design and manuals impose a cognitive load on the user, leading to underutilised batteries, and in turn, dissatisfied users.

Even though an EV has sufficient battery capacity for a wide range of use-cases, users tend to not fully utilise the capacity of the car, due to the phenomena called "range anxiety" (Lundström and Bogdan, 2014, Lundström, 2014). By providing a better interface for battery consumption, users become more confident in utilising the full battery potential, which increases their satisfaction and efficiency in travelling.

The Guess-o-Meter

In several studies, the range estimator of EVs has proven to be unsatisfactory and is sometimes referred to as the "guess-o-meter" (Lundström, 2014, Lundström and Hellström, 2015). Some papers propose ways to better present information for the range estimator.

Lundström and Bogdan (2014) explored the design of a display that presented a graph of the estimated energy consumption against the real consumption for users to get the tools to compare and learn about their consumption, therefore being able to maximise the range of the EV. Lundström (2014) argues that users have a hard time understanding state-of-the-art range-estimators, especially the underlying causes of events such as when the estimated range suddenly drops drastically. In their study, they explore what they call a "differentiated driving range" display, which displays the estimated range for different speeds and climate control options. They observed a big difference in range with different climate settings, especially at low speeds, that users would be unaware of in the most state-of-the-art interfaces.

Shifting to a Percentage Based Display

In their paper, Lundström and Hellström (2015) presents a study on how they could change the user perception of electric cars by simulating the performance of an EV compared to the users' fossil-driven cars in everyday use. Among other things, they proposed a shift from a *kWh and bar perspective*, to a *percentage perspective.* From their findings, displaying the battery percentage is often underrepresented in EV interfaces, but is the easiest for users to understand and use in their day-to-day life. In addition, they propose the idea to research a *percentage per kilometre* display, for users to calculate trips easier.

3.4.2 Gauge Design

Gauge design is directly linked to road safety. An indicator that is performing well will let the driver be less distracted from looking at the road. Trucks, compared to electric cars, often use a more extensive array of gauges since they need to observe additional vital aspects, such as air pressure. There is a substantial amount of research on the topic, what follows are two particularly relevant papers.

Speedometer Designs

Francois et al. (2017) performed a study to examine the different impacts that analogue, digital and redundant (a combination of both analogue and digital) speedometers have on the driver's capability. They concluded from a review of existing literature that there seems to be a difference in the optimal design depending on what the task is, i.e. if the driver needs an absolute or relative reading of the speed or needs to detect a dynamic change.

In the study, they conclude that a digital meter is more efficient and less distracting for absolute and relative reading tasks, whereas the analogue speedometer is more effective for detecting a dynamic speed change, which complied with earlier literature. However, the study also found that the redundant speedometer had the best performance for each of the three reading tasks. The redundant speedometer was also the best scoring in terms of user preference.

Gauge Design Guidelines

In another study, François et al. (2019) examined the difference in how generic gauge designs affected the efficiency, visual capture, and satisfaction of truck drivers. They conducted a study in which they developed and compared the difference if a gauge used a bar or pointer, if it was circular or linear, for both horizontal and vertical. They found that circular gauges were preferred by users, and pointer gauges should be favoured over bars in terms of performance. Linear horizontal gauges with pointers are good for absolute readings, and vertical linear gauges should be avoided in general. The best performing design for all types of readings was a linear horizontal pointer gauge.

Both papers discuss that their results may be inaccurate if put into a complex context, such as a cluster of gauges, or if the designs use colours and other shapes to convey their information. The modern speedometer is often paired with symbols for speed controls and setting. But the findings from the papers could still be useful as general guidelines to consider when making a more complicated design.

3.5 Design With Regard to Legacy Bias

Legacy bias is a phenomenon that refers to the bias users show toward previous knowledge and experience (Morris et al., 2014). This section describes how Legacy Bias could be utilised as a tool when developing a new interface. Two papers are brought up that discuss the consequences and benefits of Legacy bias in gesture elicitation studies. These studies are often used on emerging technology, but we argue that the methodology of these studies should also be applicable for innovative practices on present technology.

Using the legacy bias smoothens rather than hinders the transition toward new forms of interaction Köpsel and Bubalo (2015).

Interactions for gesture-based systems are becoming ubiquitous. Interactions range from mouse and keyboard to multi-touch screens and gesture or voice controls. To design for these interactions a popular methodology is using a method called gesture elicitation (Morris et al., 2014, Köpsel and Bubalo, 2015). It is a method that emerged from participatory design and lets end-users propose gestures to use for various actions in the design. The claim is that the result from an elicitation study is solutions that are less complex than those produced by only designers.

Morris et al. (2014) argues how legacy bias can be the pitfall of gesture elicitation studies and proposes three techniques to reduce legacy bias: production, primer and partners. *Production* refers to that by requiring participants to produce multiple proposals, they will move beyond the first legacy-inspired action, and will in most cases find a better solution they prefer better. *Priming* is done to make participants think outside their legacy and standard notion, by letting them do something that opens up their imagination. This could, for example, be to let them watch demonstrations of how the interface could be used, so they can relate to more than what they are used to. *Partners* is the idea that multiple persons can come up with less biased ideas if they collaborate.

In contrast, Köpsel and Bubalo (2015) argue based on the findings from Morris et al. (2014), that legacy bias is not something to be rejected, instead one should take what is good and only invent new solutions for what is problematic or disadvantageous to design a more comfortable and familiar environment, even in new systems. They also argue how designing with the help of legacy bias is not only relevant for new interactions, but for developing new surfaces or websites. They argue that slight performance improvements are potentially undesirable if they come with large reductions in comfort, so as to not repel the user from the design.

To summarise, when making an innovative design, an important aspect for the designer is to consider the legacy bias of users. This phenomenon is a helpful tool to find the most favourable solution, however, it could also hinder the ideation process of achieving better solutions. In both cases, it is therefore important to identify how legacy bias will affect the users' interaction with the product. The techniques proposed by Morris et al. (2014) could be a great strategy to identify legacy bias and study users in its presence.

3.6 Usability, Usefulness and Utility

User Experience (UX) is a term originally coined by Don Norman in 1993 and refers to the entire experience of a product (Interaction Design Foundation, n.d.-a). Norman explains UX as the following:

> "*User experience* encompasses all aspects of the end-user's interaction with the company, its services, and its products." (Don Norman, n.d.)

Consequently, a good user experience can be hard to define, but common to all good user experiences is a solution produced to meet the particular user's needs in their specific context (Interaction Design Foundation, n.d.-a). Being specific to the user and their context implies that user experience, in essence, is subjective to each project. The designer is then challenged to not only provide a good user experience but also define what user experience is in the scope of the project.

Since user experience is a broad term, it can be helpful to isolate and analyse certain aspects of the concept. The terms usability, usefulness and utility are one suitable approach for that purpose. By the definition of Nielsen (2012b), usefulness is a subpart of UX and is an attribute to describe how useful a product is to a user. Many attributes contribute to how useful a product is, but its usefulness can be defined as the sum of Utility and Usability (Nielsen, 2012b).

$$\text{Usability} + \text{Utility} = \text{Usefulness}$$

Usability is an attribute that refers to how easy and pleasant an interface is to use. It is an important consideration as users will dislike products with poor usability. Nielsen (2012b) argues that five quality components define the usability of a product, namely:

- Learnability: The ease of use the first time users use the design.

- Efficiency: How quickly the users can perform tasks.
- Memorability: How easily users can reestablish proficiency when they return to the design after a period of not using it.
- Errors: How many errors users make, how severe they are, and how easy it is to recover from them.
- Satisfaction: How pleasant the design is to use.

Utility, instead, is the attribute that describes the functionality of the design and whether it provides the features the user needs or not. Both utility and usability are equally important in a design (Nielsen, 2012b). It will not matter if the usability of a product is great if it lacks anticipated features. Conversely, if the system has every required feature but the users find it complicated to use, the outcome would be equally poor.

4

Method

This chapter presents the methods and tools used in the execution of the project. While their descriptions may not perfectly align with how they ultimately were used in the project, the inherent benefits, challenges and consequences remain more or less the same. The methods described in this chapter are grouped into methods for data collection and data analysis, ideation, and prototyping. Finally, the most essential tools used in this project are also presented.

4.1 Collecting Data

Collecting data is a crucial part of most projects related to UX, and acquiring information from users is a core activity in all of them. There are two different types of data collected from UX-Research: *Quantitative*, e.g. quantifiable measurements taken during user tests such as task-completion times or amount of errors, and *Qualitative*, e.g. direct comments from the user or insights from witnessing a user operating the system. Budiu (2017) argues that the main difference between the two is that quantitative data is hard to interpret without a reference point, whereas qualitative data offers insights that stand on its own. "Knowing that only 40% of the participants can complete a task doesn't say why users had trouble with that task or how to make it easier.", says Budiu. A reference point for quantitative data could be data collected in previous relevant observations or qualitative findings.

Freitag (2019) argues that quantitative research methods should be used on several occasions, among them to "Identify the existence of problems in a product." or to "Verify or ask a specific question about qualitative findings.". Qualitative research should then support quantitative data with probing insights to gain a deeper understanding of the problem. Conversely, quantitative data should support qualitative research by providing statistical significance (Budiu, 2017). Either way, both Freitag and Budiu agree that both types of data serve different purposes, yet are both valuable to the ultimate goal of user-centred design.

Interviews, observations and questionnaires are examples of methods that can be used to collect both quantitative and qualitative data through the use of different strategies. For instance, a questionnaire could use a combination of quantifiable measurements such as semantic differential scales or Likert scales, as well as more open questions that allow the participants to express their nuanced perspectives.

A useful technique to use together in interviews is the Think-Aloud method, in which participants are asked to spontaneously report what they are thinking as they perform a task. Nielsen (2012a) argues that the Think-Aloud method "[...] serves as a *window on the soul*, letting you discover what users really think about your design.". Albeit, Nielsen also expresses a note of caution regarding several aspects of using Think-Aloud, such as causing behavioural bias in the participant from being observed.

4.1.1 Conducting an Interview

Interviews are an important method in most researchers' toolbox, however, conducting good interviews requires some level of skill, and there are several techniques that can be helpful for performing a good interview. Depending on the situation, different techniques and interview styles would be best suited.

For example, interviews can be structured or non-structured, and which to choose depends entirely on the situation and goal. By preparing a script beforehand, yet still allowing the interviewers to deviate from the script as they seem fit to gain the most knowledge, the interview can be categorised as a semi-structured interview. Furthermore, one of the most important techniques used in interviews is *laddering*, which is a method for asking probing questions to gain a deeper understanding of the users' reasoning, which is very useful at the early stages of user research.

Laddering

Revealing the true reasoning behind users' behaviours and intentions is important to form an accurate picture of the person behind them. The *Laddering* technique is developed to aid this purpose of understanding the core values of people. To describe what makes laddering so effective, the *Means End Chain theory* provides an explanation of the hierarchy of user perception (Hawley, 2009). The hierarchy consists of *attributes*, *consequences* and *core values*. Laddering is the method used to steer the interview deeper in the hierarchy to access the core values of the user.

Attributes are the top layer of responses given in an interview. People are very good at recognising attributes in a design, e.g.:

> "I like this speedometer because it is big and sporty."

By asking variations of the question *"Why?"*, the interviewer can access deeper layers in the response, for instance:

> "Why do you prefer the speedometer to be big and sporty?."

The consequences of the attributes describe the impact which the design has on the users. Therefore, by understanding *why* the user values a certain attribute, the designer can start to uncover the core values of the person. To continue the previous example, a response that reveals a consequence of said attribute could be

> "When the speedometer is big and sporty it makes me feel like I'm driving a sports car."

The consequences of attributes project the core values of a person that are revealed in the design. So, by laddering further, any consequences that surface during the interview can be explored to pinpoint the underlying core value. According to Hawley (2009), these core values are the fundamental beliefs and perspectives of a person and have a strong emotional impact. Hawley further gives some examples of what these personal beliefs could be: "[...] security, belonging, happiness, fun, and enjoyment.". A continuation of the example with laddering towards the core values of the user, and a possible response could be:

> "Why do you want to feel like you're driving a sports car?"
>
> "It makes me feel powerful and in control."

Understanding that the reason a user wants a big and sporty speedometer is that it makes them feel like they are powerful and in control as if they were driving a sports car, is more valuable than simply understanding that they like big speedometers. In this hypothetical situation, this knowledge could be used to turn a design question from "How do we make a sporty dashboard?" to "How can we make the driver feel powerful and in control with a dashboard?"

Conducting a laddering approach in an interview comes with some challenges. Hawley (2009) describes from personal experience that it sometimes was hard for people to describe the connection between their own attributes, consequences and core values. This is amplified by the inexperience most people have with the method. Also, asking someone *"why?"* repeatedly is very tedious, and using laddering during an interview needs to be approached with caution.

4.1.2 Questionnaire

Using questionnaires is an effective tool for collecting data from a larger group of users. There are several digital free applications to help with creating, distributing and reviewing digital questionnaires, such as Google Forms. This makes the questionnaires easy to spread and very flexible, allowing respondents to answer anytime and at their own pace. In some situations, questionnaires can be used as a more time-efficient complement to interviews, where researchers can send a questionnaire after an interview to gain further knowledge that they did not have time for in the interview.

4.1.3 Semantic Differential Scale

A method that pairs well with a questionnaire is a semantic differential scale. The method is designed by psychologist Charles E. Osgood in the 1950s and can be used to measure an individual's unique, perceived feelings toward a product. It is a measurement scale designed to measure a person's subjective perception of a product by using a set of bipolar scales Using a 7-point bipolar rating scale, respondents are expected to give a rating for an object where the middle point is neutral, and the endpoints are two opposing words (Lavrakas, 2008). The method can be used to find the traits that users desire, but find difficult to explain with only words.

4.1.4 Likert Scale

Much like the semantic differential scale, a Likert scale measures the subjective perception of a person through the use of a bipolar rating scale. However, the Likert scale is labelled with, most commonly, five categories (often in the form of *Strongly Agree*, *Agree*, *Neither Agree Nor Disagree*, *Disagree*, and *Strongly Disagree*) that are used to rate each item in the survey. According to Lavrakas (2008), the Likert scale is probably the most commonly used attitude measurement method in survey research. It was originally developed by Rensis Likert in 1932.

4.1.5 Social Media Ethnography

One of the strongest methods for collecting Data and conducting user research is Ethnographic studies. Collecting data from ethnographic studies allows designers to empathise with their target group of users. Generally, it is done by visiting end-users in their natural context. Brewer (2000) defines ethnography as the following:

> "The study of people in naturally occurring settings or 'fields' by means of methods which capture their social meanings and ordinary activities, involving the researcher participating directly in the setting, if not also the activities, to collect data in a systematic manner but without meaning being imposed on them externally"

The goal of an ethnographic study is to understand the socio-aspect of users, but in some circumstances, contact with users can not be established. There are some methods that propose alternative ways to perform ethnographic studies in these cases. One example would be with the help of social media. Wang and Liu (2021) provide their account of performing qualitative research in online groups and forums, finding that performing ethnography online comes with the benefit of instant access to social networks, albeit, information in these networks is often scattered or incomplete.

4.2 Analysing Data

After collecting data for a project, analysing the data can make it into something useful and interpretable. How one decides to structure the data will have a large impact on how the results are interpreted and is, therefore, an important consideration. There are many methods and ways to structure data, and in this chapter, the two formal methods that we have used in the project for data analysis will be presented, namely affinity diagram and thematic analysis.

4.2.1 Affinity Diagram

Constructing an affinity diagram is an effective and versatile method to cluster a large amount of data into themes or groups, and is useful in many phases of design thinking (Interaction Design Foundation, 2021). Originally, it was intended to be performed as a physical activity with post-it notes that are placed on a table, wall, or whiteboard. In this case, Miro acts as a virtual whiteboard with unlimited space, where you are able to place virtual post-it notes and text, and even draw or add other elements such as pictures and videos. In our opinion, it is more effective, convenient and available than traditional physical post-it notes.

In short, the method is conducted as follows (Interaction Design Foundation, 2021):

- Put ideas or data pieces on post-it notes
- Place the post-its on a surface and let them group into clusters
- When the notes are placed, discuss the clusters, change them if needed and create names for the clusters.
- Select the most important clusters and describe what you have gained for insights into a relevant and usable form.

4.2.2 Thematic Analysis

Another method to synthesise insights is thematic analysis. It is more suitable for analysing data more intensely than using an affinity diagram and is a good research approach to gaining knowledge about qualitative data from interview transcripts. One of the considerations when performing a thematic analysis is if to use a semantic or latent approach, that is, whether the findings should be data-derived and be more true to the user and realistic, or if researchers are allowed to interpret implicit meanings within the data (Clarke and Braun, 2013).

Briefly explained, the thematic analysis is conducted in 5 stages (Clarke and Braun, 2013):

- **Familiarisation of data**. Which could for example be transcribing interviews.
- **Coding**. Which refers to identifying relevant pieces of data, by colour coding them.
- **Identifying patterns**. Once the data set is coded, you look for patterns that appear and start creating themes from the codes.
- **Review and finalise themes**. Next, identify broader patterns that can support the research goal. Review the themes and make sure the names are appropriate and precise.

- **Develop the analysis**. The final step is to present the data. Each theme can hopefully tell a story about the data that help answer the goal of the research.

4.3 Participatory Design

Involving stakeholders in the design process allows them to assist the designers in producing solutions for themselves. A strategy to accomplish this is Participatory Design (Muller, 2007). Elizarova and Dowd (2017) proposes a wide range of methods that can be utilised in a participatory design approach to create a better understanding of the users and learn of their needs and desires. Although, involving more stakeholders can also come with challenges, such as increasing the social biases of the participants in the meeting.

4.4 Ideation

A big part of solving a wicked design problem is to create ideas, and there are several methods that are designed to assist in that process. Ideation refers to the creative process of generating and developing new ideas. By utilising different ideation methods, designers can boost their creative process to better envision new ideas.

4.4.1 Brainstorming

Probably the most widespread method for ideation is brainstorming. Brainstorming is often used as a synonym for ideation, or as a loose umbrella term for several other ideation methods. However, brainstorming in a more strict sense is a specific method with its own set of guidelines. A brainstorm is a session with a group of people, where the goal is to find solutions to problems or to develop new ideas. Ideas that emerge from brainstorming sessions are helpful to write down on a whiteboard or similar, in order for everyone to see it. It can be done by a facilitator or collaboratively.

Following the recommendations of the methods' inventor, the *rules* to follow while brainstorming is presented below (Osborn, 1963). The purpose of these rules is to encourage wild ideas, in greater quantity:

1. *Criticism is ruled out.* This rule implies that no participant should ever criticise an idea. In doing so, participants will get discouraged from being active during the brainstorming session. Criticism should instead be saved for a future evaluation of the ideas.

2. *"Free-wheeling" is welcomed.* Contributing to the session with crazy, unconventional ideas is encouraged since they are likely to lead to creative solutions.

3. *Quantity is wanted.* The more ideas that are produced the more options will be available later for evaluation. A larger quantity of ideas also increases the odds of contributing with a more creative solution.

4. *Combination and improvements are sought.* This rule relates to the act of using other ideas as a springboard for combinations and improvements of the original idea.

4.4.2 Braindrawing

Braindrawing is a similar method to brainstorming, where participants sketch out their ideas, in order to create and ideate around more visual mediums. In order to create quick sketches, the method is best used with pen and paper, or a whiteboard, that can either be used by a facilitator or collaboratively. In the case of only a few people conducting the method, the need for a facilitator is often eliminated.

4.4.3 Crazy-8

Crazy-8 is a divergent method used to generate 8 unique ideas or sketches for a specific challenge in 8 minutes (Google Design Sprints, n.d.). This emphasises quantity over quality, incentivising participants to sketch down the first thing that comes to mind. Crazy-8 is a suitable method for diverging one's thinking about how to solve a problem.

4.4.4 Inspiration Board

An inspiration board is a collection of visual materials used to get a better understanding of a certain style or concept (Guerra, 2020). They are intended to inspire the designer in their own ventures and could be used as a visual reference for new ideas. Typically, inspiration boards can include a wide range of content, anything can be used as long as it helps the designer to be inspired.

4.5 Prototyping

Another essential part of design thinking processes is prototyping, which refers to the creation of prototypes. These can vary greatly in their purpose and creation, being everything from a quick sketch to a working application. These prototypes can then be used to test, illustrate or explore. This section will discuss the role of prototypes in a project, how the distinction of fidelity is useful to make, and various prototyping concepts, methods and tools that are relevant for this project.

The reasons and benefits of a prototype may vary greatly. In their paper, Wensveen and Matthews (2015) identified four different purposes that prototypes may be used for, namely: Experimental Component, Means of Inquiry, Research Archetype, and Vehicle for inquiry. We would argue that we create prototypes for all of these purposes in different stages of the project, although the main use for prototypes has been as a Vehicle for inquiry. The project's research question is answered through the design process itself, and creating prototypes is not only a way to test, validate, and illustrate, but the process of prototyping is also a way to gain insights and understand the problem. Prototypes are an extremely powerful and versatile method in design thinking, that can be used in several phases.

4.5.1 Fidelity of Prototypes

Prototypes can generally be divided into high- or low-fidelity, depending on their level of complexity and detail. This is a useful distinction, as they generally have opposing purposes. Lo-fi prototypes are often created in the earlier design stages, and in high quantities, to test a wide range of ideas. Instead, hi-fi prototypes are generally used in the later stages and have more detail and complexity to test a concept in more depth. Furthermore, fidelity could be regarded as a spectrum where a prototype can be of higher or lower fidelity, to avoid that a prototype must be defined as either hi- or lo-fi.

4.5.2 Playful Hacking

Playful hacking is a semi-structured method or technique within Research through Design that aims to motivate the designer and gain insights. Sometimes it can be valuable to play without a need to produce any results, as it could give unexpected yet valuable results. By allowing designers to deviate from the challenge at hand and instead work on something similar to the project that does not necessarily have any direct contributions, they could gain knowledge or insights that help the project indirectly.

Goddard and Cercos (2015) explains in their paper how they found hacking to enrich their research practice and to help balance linear, outcome-oriented, research activities. The usefulness of the method comes from learning by doing, and they propose playful hacking as a useful part of research culture and claim it has supported them with increased creativity, collaboration, and above all, motivation in research, even though it may appear inefficient when evaluated in isolation.

4.5.3 Quick and Dirty

The phrase quick and dirty prototyping refers to creating prototypes in a quick and simple manner without thinking too much about quality (Brown, n.d.). The reason for this mindset is that any prototype is often better than none, and it is most often easier to understand a prototype rather than an explanation of a concept. Therefore, it makes good practice to make crude prototypes when new ideas emerge, as it is an efficient way to try the feasibility of an idea or concept. The strength of the technique also comes from being creative: drawing on the screen, or placing a post-it note on top of a sketch can be enough to make a prototype, that is just as effective as something more detailed.

4.6 Tools

The tool that is used to support a method is directly linked to the execution and outcome of said method. Understanding the possibilities and limitations of certain tools is necessary to understand the process in general. Therefore, the last section will describe the most essential tools used in the project, that have shaped the project into what it is. These are mainly the digital software that were used to support the methods. Different stages in the process require different types of results or levels of fidelity, and using a variety of tools is essential for a successful project.

4.6.1 Miro

Miro is a multi-purpose online platform that allows for collaboration and creation on a virtual whiteboard (Miro, 2022). Miro is, among other purposes, a great tool for organising pictures, text and figures on a canvas. It can hence be helpful for different types of ideation, creating picture boards and affinity diagrams, or just to structure *things*. Miro has been used as the gathering spot for everything visual we have obtained during the process.

4.6.2 Low Fidelity Tools

In this project we consider a prototype to be anything that is produced to show a design's intent. There are various media that can be used for low-fidelity prototypes. The common ground is that they should be quick and easy, as the goal of creating lo-fi prototypes is quantity over quality (Shuhalii, 2020). For this reason, the best lo-fi practices often include paper sketches or whiteboard drawings. Printing out digital sketches can also be an effective technique.

4.6.3 Adobe Suite

The Adobe Suite includes a lot of programs and services developed by Adobe, each with a different and specific purpose (Adobe, 2022). Three of the available tools are relevant for the project, namely Illustrator, XD, and Photoshop. Using these three tools, designers are able to create different types of high-fidelity prototypes, which can focus either on aesthetics, interactivity or both.

To briefly separate the use cases for the three programs, Illustrator is vector based and better for symbols and shapes, while Photoshop is better for raster images and photos. XD, on the other hand, has the purpose of creating interactive prototypes and is very limited in creating complex designs. Most times, a combination of the tools is needed, for example, photos may be edited in Photoshop, and symbols created in Illustrator before both being used in an XD prototype.

4.6.4 Android Studio

Android Studio is the official integrated development environment (IDE) for Google's Android operating system (Android Studio, 2022). It is used for developing apps for, e.g., mobiles and car entertainment systems. The program can be used both for full-stack applications, or rapid prototyping to create simple interactive applications quite easily.

5

Planning

This chapter describes how the project was structured, and the original time plan for the process.

5.1 Process Phases

In order to structure the process and make planning easier, the process was divided into three separate phases: *Understand*, *Create* and *Evaluate*. See Figure 5.1.

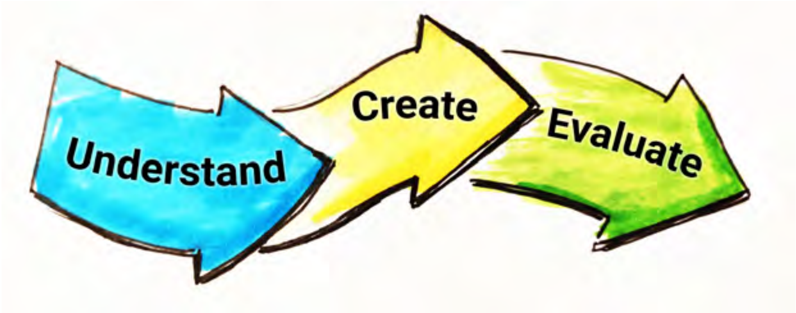


Figure 5.1: An illustration of the process phases for the project, namely *Understand*, *Create* and *Evaluate*. [Authors contribution]

In the understand-phase, the aim was to both deepen our understanding of terminal tractors and to understand and create empathy for operators. This was to be done using extensive interviews, observations and an ethnographic study. The actual development of a concept was done in the create-phase, which consisted of three design iterations. In each iteration, a set of concepts were developed and evaluated, which the next iteration could build upon. In the final phase, the final design result was validated. For this, we would evaluate the concept together with a number of users, using interviews and observations. The plan was, if it proved possible, to use an interactable prototype to conduct user tests.

These phases are indented to be executed semi-linear, meaning that each phase should be more or less finished before moving on to the next one. Although, due to the iterative nature of the project, the line between one phase and the next could be blurry.

5.2 Process Model

No process model can perfectly describe the structure of a project. We took inspiration from two models when we described our process: the double diamond, and d.school's design thinking model. The double diamond was useful when considering the linear and creative aspects of the process, but we found the design thinking model more useful when planning activities.

We have considered the process as partly linear. Each phase had an intent and a specific milestone where that intent should be completed. The milestone also marked the start of the next phase, which built upon the insight from the last phase. These milestones were reached by convergence and divergence, which the double diamond model perfectly captured.

The two diamonds in the original model are used as a general description for design processes. In our project, we found it easier to describe our process in three phases and extended the double diamond model to include all phases linearly. This extended model included one diamond for each of the three process phases, and in the create-phase, the diamond was iterated over three times.

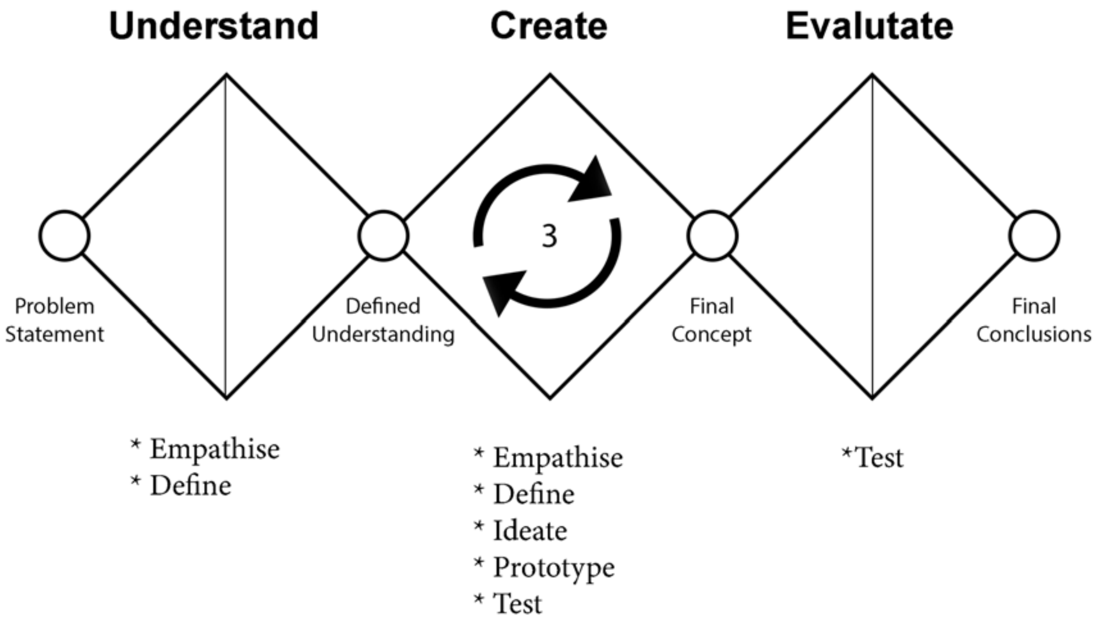


Figure 5.2: A process model of the project, inspired by the converging and diverging phases of the double diamond, and steps in the design thinking model. Each phase is represented by a diamond, which starts and ends in specific milestones. The design thinking steps in each phase are presented below the diamond. [Authors contribution]

While the double diamond was suitable for describing the linear and creative structure of our design process, we did not find its' original description of each stage in the process suitable for our project. Instead, we used the stages of the design thinking model to structure the activities of the project. In Figure 5.2, we have used the design thinking model in each phase, which is characterised by a diamond of the extended double diamond model.

To summarise, the extended double diamond describes the linear thinking of our process by divergence and convergence, to reach the milestones we set out. However, the design thinking model was used to describe each phase as non-linear and their associated activities, to plan a design project with a continuous user focus.

5.3 Time Plan

A simple time plan was constructed and visualised in a Gantt chart, see Figure 5.3 below. The planning could not be too detailed, as it was not known when users were available, and the process had to be flexible to match up with milestones from the company. The process was therefore planned in more detail as the project progressed.

In the Gantt chart, each project phase is split into a few subcategories and visualised using different colours. The understand phase has three subcategories: stakeholder retrospect, user studies, and define. The first one includes all methods that are used to collect data or gain information that does not actively involve users, and user studies are those activities that do. Define is the activity of analysing the data and presenting suitable results that can be used in the next phase.

The planned time for each phase can also be observed in the chart and was as follows:

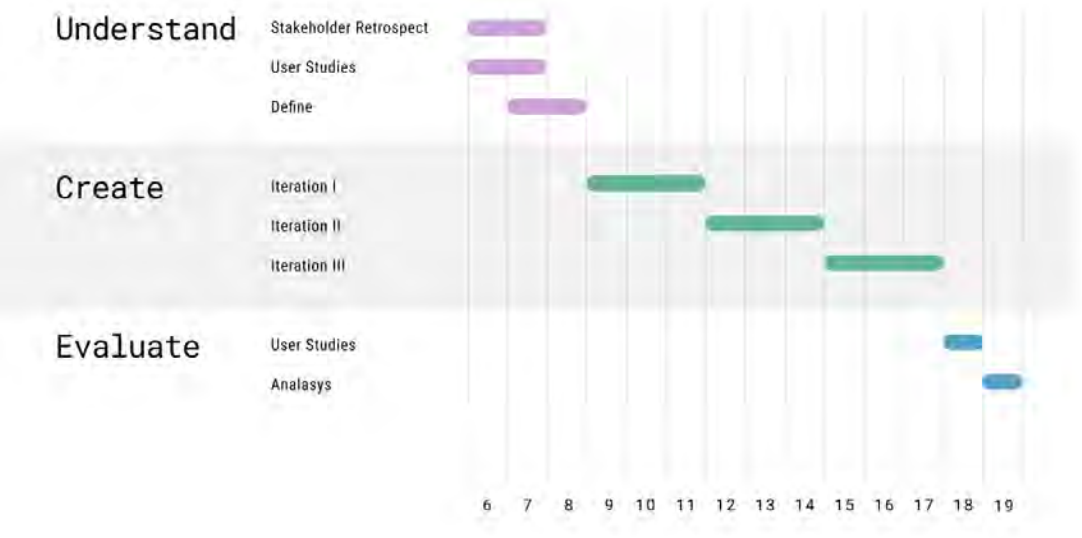


Figure 5.3: A Gantt chart of our time-plan. The number on the horizontal axle is the number of the week, from February to June. [Authors contribution]

three weeks for the first phase, nine weeks for the second phase, of which the three iterations would take three weeks each, and two weeks for the final phase. In the actual execution of the project, the planning of the process often had to be changed due to complications.

In the following chapters, each process phase will be presented in its own corresponding chapter.

6

Understand Phase

The process is divided into three phases, *Understand*, *Create* and *Evaluate*, which are all presented in their own corresponding chapters. Their distinctions are based on the intent of the phases' activities, and the chronological order they were conducted. The process started with activities based on gaining knowledge and empathy about the user, which is described in the *Understand*-phase. After which, activities for developing designs and progressively converging to a final design concept, are presented in the *Create*-phase. Finally, the last phase, *Evaluate*, consisted of activities that attempt to validate the final design concept with evaluative methods.

This chapter describes the first phase of the process, *Understand*. In this phase, the main goal was to understand the user, their needs, and the bigger context. There was very little knowledge concerning terminal tractors and their operators when the project began, therefore, the original plan for the phase was to conduct several interviews and ethnographic studies to build a solid foundation of understanding and empathy. However, due to our limited ability to contact terminal tractor operators directly, we were led to conduct ethnographic studies in an alternative manner. It also made us focus more on general terminal tractor knowledge, in order to understand the user and research other vehicle dashboards.

Figure 6.1: The project process is divided in three phases. This chapter describes the first phase, *Understand*. [Authors contribution]

6.1 Anatomy of a Dashboard

At the beginning of the project, we investigated dashboards of electric vehicles both by browsing images on the internet as well as documenting electric vehicles in the wild. We made a digital collage of images using the program Miro, which consisted of dashboards from terminal tractors and other electric vehicles and it served as an inspiration board for our design endeavours. The dashboard consisted of trucks, cars, and tractors, both real pictures and speculative designs. While these dashboards often do not portray the information a terminal tractor operator would need, they highlighted what industry specialists or designers have identified as important information in electric vehicles in general.

Furthermore, we tried to understand what traditional terminal tractor dashboards display to their operators, to understand what would be the most important features for us to consider. This was done by analysing photos from inside of the client's terminal tractor and browsing the internet for images and brochures that described the dashboard. We also attended a seminar for the presentation of one of the client's competitor's new electric terminal tractor. The inspiration board was continuously filled with more pictures as the research and understanding progressed. With this, we could discern what the most typical dashboard interface elements are, for both traditional tractors and electric vehicles overall.

One thing to be noted from researching different brands of terminal tractors is how terminal tractors with digital dashboard displays often seem to overlook their interface design. We would for example often see icons that did not match, parts that were hard to read or see, elements not lining up with each other, and interfaces being generally unaesthetic.

6.2 Requirement Gathering

During the Understand phase, we also tried to find requirements for the interface, regarding both its design and function. We conducted non-formal interviews with members of CPAC and read various technical specification documents to find information of value. We did for example analyse documentation of all the possible signals the screen can receive from the system data bus, and got an understanding of the icons that should exist. The client company had also sent a simple sketch of their vision for the interface and named a competitor who, according to the client company, had a state-of-the-art interface.

Generally, it was a very low amount of information that could be found regarding the design of the interface and the user interaction. Additionally, many things were not yet determined, as CPAC and the client company were still in discussions regarding which features the system should support. Despite this, we could find some relevant requirements that we could compile into a requirement specification document. We could also assume some other requirements and let them be evaluated later on in the process. For example, we knew that the air pressure value should be in an acceptable range and that the design should inform the driver if they fall to critical values, but we did not know the exact values of this range yet. Additionally, this document also describes what we found during our own investigation of dashboard interfaces, as described in Section 6.1. This document was used continuously during the project and updated along the way as new requirements emerged, and specifics were answered. The requirements that were identified at this stage of the project, as well as how important we speculated each feature would be, are presented in Table 6.1.

Requirement	**Unit**	**Importance**
Speedometer	Miles per hour	Important
Odometer	Miles	Not important
Runtime	Time	Not important
System voltage	12v/400v	Not important
Air Pressure 1	PSI	Very important
Air Pressure 2	PSI	Very important
Battery	%	Very important
Battery used during session	%	Slightly important
Effect	kWh	Slightly important
Average effect	kWh	Slightly important
Battery temperature	F°	Not important
Motor temperature	F°	Not important
Tell-tales	off/blue/amber/red	Very important
Turn signals	off/blinking green	Very important
Gear status	P/N/D/R	Not important
Dialogue box	-	Slightly important
Menu button	-	Not important
Client company logo	-	Important
Clock	HH:MM	Important

Table 6.1: The requirements that were identified during the *Understand*-phase. Each requirement is presented with its respective unit and how important we speculated that it would be. [Authors contribution]

6.3 Social Media Ethnography

We wanted to investigate user behaviour and their general attitude towards the electrification and automation of their profession. We found that by going on social media, there was a lot of content posted by operators who shared their opinions and experiences candidly. We found that on YouTube there were videos in first-person view that documented what the working situation looks like for a terminal tractor operator. Furthermore, these videos often had an active comment section of, seemingly, operators that discussed driving terminal tractors.

During this activity, we did not reach out to operators, since we saw the probability of establishing contact with any of these users as very low. In hindsight, we probably should have made the time investment to reach out to some of the people we encountered. While the probability would be low, the possibility of establishing contact with operators would be worth it.

Social Networks

By visiting user-created forums, or "communities", related to terminal tractors on the social news and discussion website reddit.com, we could collect more information about user behaviour. Users on Reddit share their posts and comments under a pseudonym, allowing them to remain anonymous. Therefore, the discussion in these communities tended to be very sincere. We learned that the drivers often complained about their salary, comparing it to each other. Additionally, they could openly complain about their colleagues, the profession in general, and certain models of tractors.

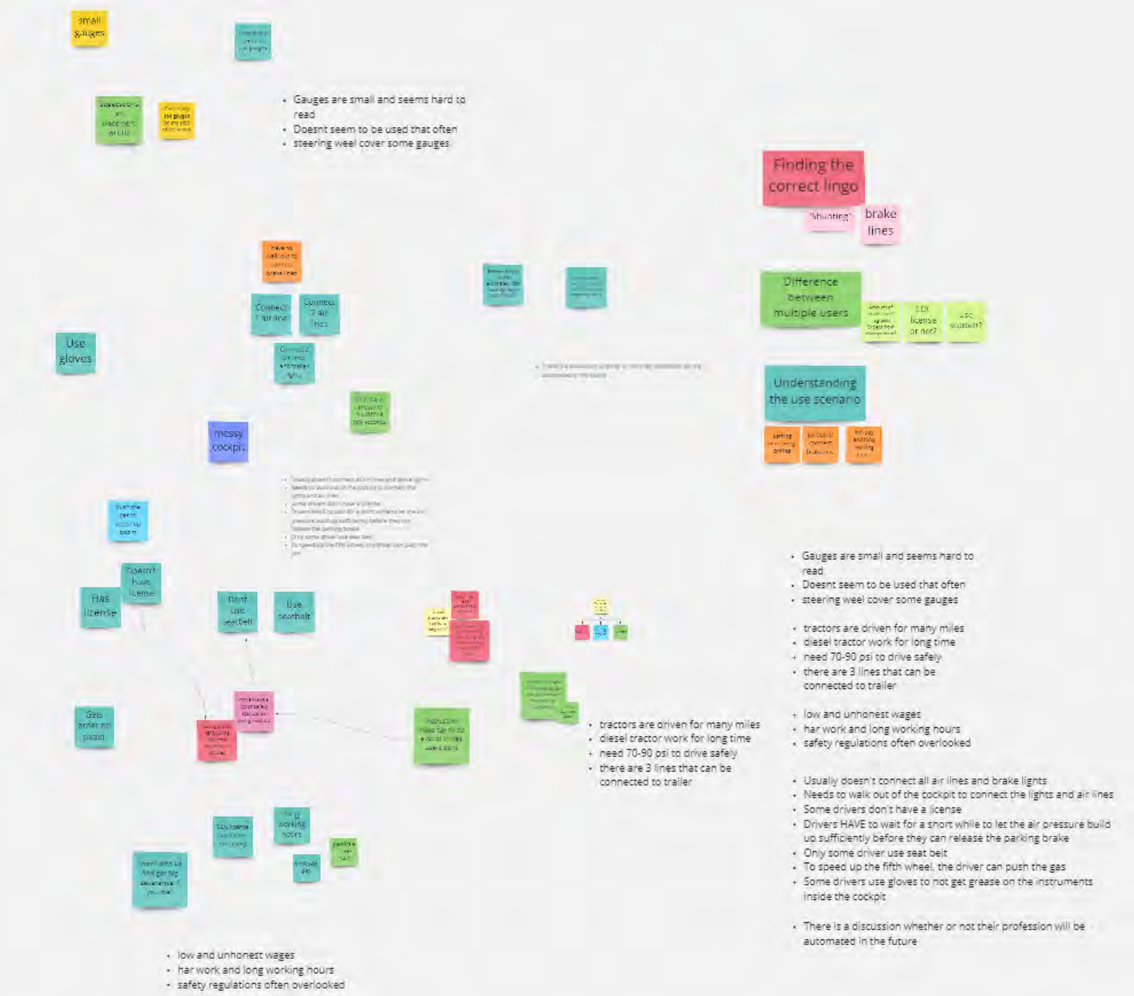
Some pages on the social media Facebook posted informative material about the operation of terminal tractors, which assisted our understanding of the vehicle. Additionally, several job listings were also posted, which explained the expectation of drivers.

YouTube

From the videos on YouTube, we got a good understanding of the responsibilities and behaviour of operators. In the videos' respective comment sections, commenters often critiqued specific actions in the video or asked for advice on how to operate the terminal tractor from the video creator. Either way, whenever the creator replied to these comments, we were able to understand the reasoning behind their course of action. As the videos often were filmed in a first-person view, we could see what the operator was looking at while driving, notice each action they took while working, as well as listen to their live commentary of what they were doing. We got a great understanding of how the tractors were operated, and how the drivers often took shortcuts when they were working, such as not using the seat belt or only connecting the emergency air pressure line to the trailer.

6.3.1 Ethnography Insights

To assess what we have learned from our social media ethnography, we created an affinity diagram that summarised everything we had gathered so far, see Figure 6.2. We used Miro to place notes and snippets of text which we then could freely move around and categorise into overarching themes. We managed to compile a list of 19 specific insights to guide us in the transition to the next phase of the project. These insights are presented in Table 6.2. For example, operators do not generally follow guidelines and regulations like connecting the air pressure brake lines properly, they also tend to wear gloves all day, which could prove troublesome as we only consider touchscreen interactions in the new dashboard.



- Gauges are small and seems hard to read
- Doesnt seem to be used that often
- steering weel cover some gauges

- tractors are driven for many miles
- diesel tractor work for long time
- need 70-90 psi to drive safely
- there are 3 lines that can be connected to trailer

- low and unhonest wages
- har work and long working hours
- safety regulations often overlooked

- Usually doesn't connect all air lines and brake lights
- Needs to walk out of the cockpit to connect the lights and air lines
- Some drivers don't have a license
- Drivers HAVE to wait for a short while to let the air pressure build up sufficiently before they can release the parking brake
- Only some driver use seat belt
- To speed up the fifth wheel, the driver can push the gas
- Some drivers use gloves to not get grease on the instruments inside the cockpit

- There is a discussion whether or not their profession will be automated in the future

- Gauges are small and seems hard to read
- Doesnt seem to be used that often
- steering weel cover some gauges

- tractors are driven for many miles
- diesel tractor work for long time
- need 70-90 psi to drive safely
- there are 3 lines that can be connected to trailer

- low and unhonest wages
- har work and long working hours
- safety regulations often overlooked

Figure 6.2: A screenshot in the process of creating our social media ethnography affinity diagram in Miro. The post-it notes are specific learnings taken from our studies of operators in social media. [Authors contribution]

Theme	**Insight**	**Source**
Gauges	Analogue gauges are small and hard to read	YouTube
Gauges	The drivers rarely check the gauges	YouTube
Gauges	The steering wheel obstructs the visibility of the dashboard	YouTube
Tractor	The tractors are heavily used and travel many miles	Reddit
Tractor	Diesel tractors have a long life-span	Reddit
Tractor	The tractor needs 70-90 psi to drive safely	YouTube
Tractor	There are 3 lines that connect to the trailer	YouTube, Facebook
Conditions	The wages are generally quite low but some drivers earn much more than others	Reddit, Facebook
Conditions	Some drivers are not honest with their superiors about how much they work	Reddit
Conditions	Operating a terminal tractor is physically heavy work and days are often quite long	Reddit
Conditions	Safety regulations are often overlooked	Reddit, YouTube, Facebook
Behaviour	Drivers rarely connect all the lines to the trailer	YouTube
Behaviour	Drivers have to leave their seats to connect the air pressure lines with the trailer	YouTube
Behaviour	Some drivers do not have the appropriate drivers' license	Reddit, Facebook
Behaviour	Drivers need to wait for air pressure to build when they start the tractor	YouTube, Facebook
Behaviour	Most drivers don't use the seat belt	YouTube
Behaviour	Drivers push the accelerator to speed up the raising of the trailer	YouTube
Behaviour	Some drivers wear gloves outside to avoid grease on the instruments in the cockpit	YouTube
Perspective	Drivers are aware of the plans to automate their profession	Reddit

Table 6.2: The 19 specific insights that were drawn from the social media ethnography. Each insight is presented with a theme and the source it was taken from. The themes are derived from the affinity diagram. [Authors contribution]

6.4 Continuously Building an Understanding of Users

While our approach to understanding users through social media proved successful, there are notable limitations that caused serious impairment to the user-centred design process. The lack of any direct contact with operators of terminal tractors meant that any evaluation of our designs would need to be conducted with engineers who are resorted to making educated guesses. Therefore, we decided to continue developing our understanding of the users by employing user research methods during the create-phase as well. This allowed us to start generating designs and move on with the process instead of waiting for contact to be established with operators. We approached this strategy with caution, as it would mean that our initial concepts would be based on an understanding of the user without ever being in contact with them.

6.5 Defining Our Understanding

Before we set out to start the second phase of the project, we had gained a basic understanding of the user, their challenges, and the design of dashboard interfaces. We were able to define a list of insights from the social media ethnography that could aid us in making design decisions, these are presented in Table 6.2. Additionally, we compiled a list of features that the dashboard had to include. From our own research of how dashboards display these features, as well as by discussing with stakeholders at CPAC, we could also start speculating which of these features would be most important to present to the driver. This list of requirements is presented in Table 6.1

7

Create Phase

The process is divided into three phases: *Understand*, *Create* and *Evaluate*. This chapter describes the second of these phases, namely *Create*. In this phase, the ultimate goal is to develop a final design concept that can be evaluated by terminal tractor operators. This phase is split into three iterations, each of which deepened our knowledge of the user and further converged on a final design. This phase began after we concluded the *Understand*-phase, in which we built a foundation of knowledge on social media ethnography and investigated dashboard interface designs, sufficient enough to start generating ideas and concepts.

The process of the *Create*-phase has been far from linear, and the following sections in each iteration are structured to emphasise readability. The real process was much more convoluted, which may become evident in reading our descriptions of each activity.

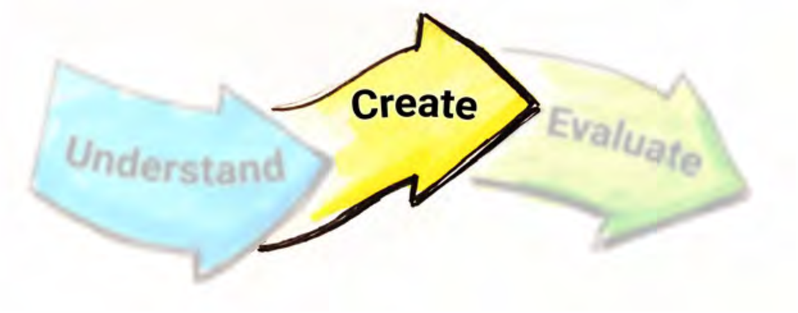


Figure 7.1: The project process is divided in three phases. This chapter describes the second of these process phases, the *Create-Phase.* [Authors contribution]

7.1 Iteration I

The goal of the first iteration was to understand the general direction of the interface. First, several ideation methods were conducted, including brainstorming and braindrawing sessions utilising both whiteboard and paper, and Crazy-8 sessions. From these early sketches, several concepts started taking form, and at the end of the iteration, five divergent concepts were evaluated with an operator and other stakeholders of the project.

7.1.1 First Ideation Sessions

The research from the previous process phase had given us a decent understanding of how a terminal tractor operates and the most essential features of the dashboard. Furthermore, we had a solid understanding of how the driver operates the terminal tractor. However, we were oblivious to what operators think about the design of traditional interfaces. Do they want to keep the dashboard just like it is? Do they want to radically change the design?

With these questions in mind, several ideation sessions were conducted. Most sessions focused on a specific element or layout of the whole interface. These sessions usually started as brainstorming, but often turned into braindrawing sessions. We constantly generated sketches of our ideas to visually communicate potential designs with each other. We tried not to focus too much on details, but rather be divergent and try to make the interface and its elements effective, yet comfortable in a transition.

During these sessions, we were able to both get an idea of the value that each element in the traditional dashboard interface has, as well as ideate several new speculative features that could be valuable to the drivers, such as a clock, a graph for tracking power usage, and a fleet management system. Speed, effect, and state of charge quickly became the foci of several sketches, as we believed these would be important values for the driver to monitor. We also learned that it is very difficult to postulate what makes a comfortable transition for an operator. How could we possibly decide what is more comfortable in a design that focuses heavily on legacy bias?

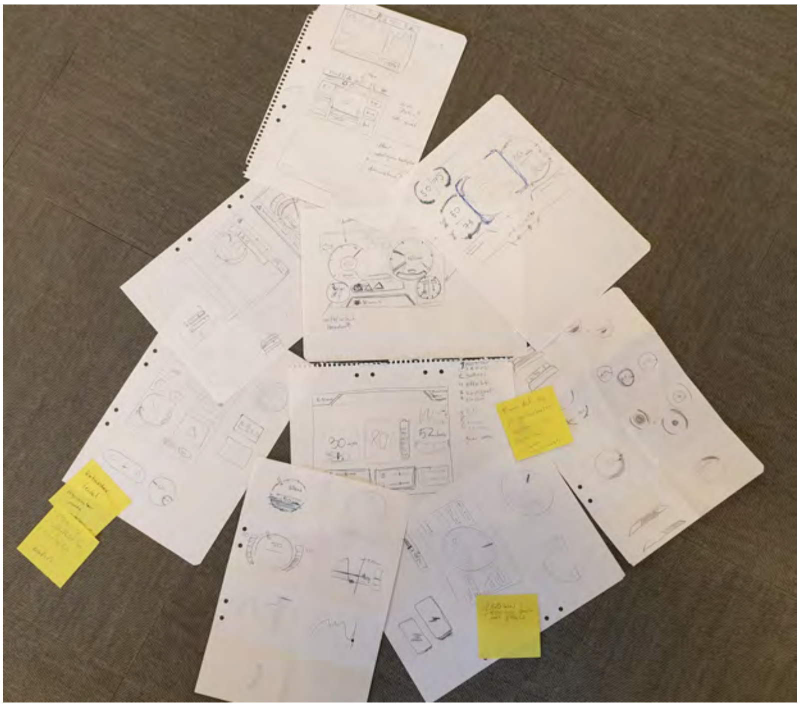


Figure 7.2: A collection of paper sketches. The sketches are ideas from ideation sessions using either braindrawing or Crazy-8 as methods. [Authors contribution]

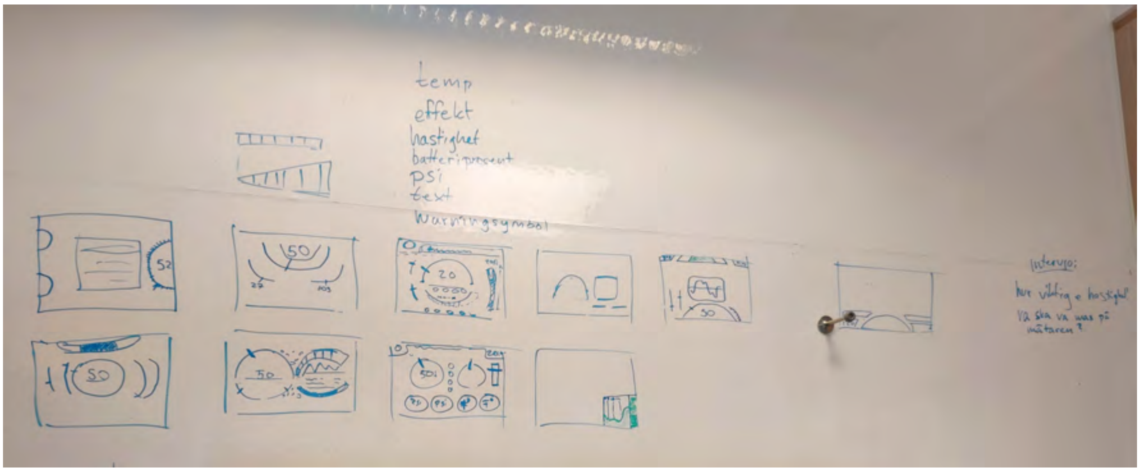


Figure 7.3: A picture of a whiteboard with multiple sketches, which was a medium to discuss design concepts. These were some of the first sketches created, exploring which elements would be most valuable in a terminal tractor dashboard. [Authors contribution]

We also conducted several Crazy-8 sessions, which focused on producing designs for either a specific element of the interface or the general layout. The result of the sessions was a lot of ideas, illustrated as paper sketches, see Figure 7.2.

7.1.2 Digital Sketches

Having produced a wide range of ideas and paper sketches in our initial ideation sessions, the next step in the process was to combine the most interesting sketches with more defined ideas. To increase the fidelity of this new round of sketches, digital prototyping tools were introduced. Adobe Illustrator, XD and Photoshop were used at first, but we quickly found that Illustrator was more lenient and effective for the tasks at hand. Furthermore, the display that we are designing for, see Figure 2.3, is rather low-resolution, and it was more comfortable to work in Illustrator with vector graphics than noticing the pixels and pixel restrictions when working in Photoshop. This could be compared to an ostrich approach (i.e hiding from the problem), as a vector element that is placed in between two pixels on a raster image like the final display would become blurry. However, Illustrator was able to perfectly align elements to the pixels with the click of a button, minimising blurry elements once implemented in the display.

In this part of the first iteration, several concepts emerged, with plenty of variances. As previously mentioned, it was hard to know how legacy bias will affect the design in regards to creating a comfortable transition, as some gauges and features in traditional dashboards are bound to be more appreciated than others. We believed that the best way to know how digital or analogue each gauge should be is to be divergent in the concepts that we evaluate with operators and show multiple concepts of digital, analogue and redundant gauges. In addition to that, a wide range of features, that were ideated during the initial stages of the Create-phase, was prototyped in some of the concepts to evaluate how valuable they would be in the new dashboard, with some being more speculative than others. Therefore, the five most divergent concepts and representative of different design choices were picked to be finalised for evaluation.

7.1.3 Playful Hacking Sessions

During the process of making digital sketches, plenty of good ideas were created by mistakes or through playful methods. If we wanted to try something different in a concept, that would make for a fun or engaging addition, we would explore that idea - often ending up with something horrible. But in our playful attempts, we would sometimes also find good ideas, learn something about the design space, or expand our knowledge of the tools we worked with.

One example of playing around with tools was using Adobe XD in an attempt to create an interactive dashboard prototype that could display the behaviour of the interface with animations. Both of us had some experience working in XD, but the playful session helped us find new or more effective ways to use the program for our specific purpose, even though we did not produce any directly useful results.

We also developed two apps as a side project, to learn Android Studio. It was suspected that some level of implementation in Android Studio would be done in the project but it was not established. Therefore, to prepare for eventual implementation, the app development was done by playful sessions, outside dedicated time for the thesis whenever it felt like fun. Having a project that is not bound to results, did make it more motivating and fun, and provided a lot of insights. For the interested reader, one example of the apps was a match-tracker for ping-pong matches.

7.1.4 Implementation in Android Studio

In playing around with different tools, an implementation for a concept was done in Android Studio. Since the final dashboard application will run on the Android operating system, learning and understanding how to implement a concept into a functioning prototype is valuable both for evaluation and designing. Since an implemented prototype could be run in a terminal tractor cockpit, it opened the possibility to evaluate a concept later in a more real context. Additionally, learning this practice teaches us how to better integrate our interaction design practice with a development team, as we could for example understand the limitations of Android Studio and how to produce elements that are easy to implement. It shaped the way we created design concepts afterwards, as we would create designs that would also be possible to implement.

7.1.5 Final Concepts from Iteration I

From the early sketching sessions, we built up an adequate understanding of terminal tractor dashboard interfaces and were able to produce the first set of diverging concepts. The goal of this activity was to explore legacy bias in the concepts, presenting different speculative features, and finally just investigate different design languages in general, to get a feel for what works in the terminal tractor dashboard. The speculative features that were presented are:

- **Clock** - Concepts 1, 2, 3, 4, 5
- **Trip runtime** - Concepts 1, 2, 3, 4, 5
- **Selected gear** - Concepts 1, 2, 4, 5
- **Diagnostic messages** - Concepts 1 & 2
- **Ambient temperature** - Concept 4
- **Fleet management system** - Concept 4
- **Settings menu** - Concept 2

Many of our design decisions were inspired by the research on dashboard interface design that we investigated. For instance, many of the gauges in our concepts utilise redundant gauges (Francois et al., 2017) and are often displayed as either circular or horizontal (François et al., 2019), and the state of charge is displayed as a percentage (Lundström and Hellström, 2015).

In the following sections, we present each of the five concepts and shortly describe the intention of their design. Each concept consists of an image which can be observed in Figure 7.4 Here, the concepts are presented as subjects of the process, whereas in Chapter 9 - *Results* the contents of the concepts are more clearly presented.

Concept I.1

The first concept, see Figure 7.4 (a), is an attempt to preserve the analogue gauges from a traditional terminal tractor dashboard in the new digital display. Barely any values are displayed with a digital number, and the analogue gauges are inspired by the dashboard from the client company's previous terminal tractor model. This concept has two major gauges that display speed and effect, with two smaller, secondary gauges, that display air pressure and temperature. The state of charge can be seen in the bottom part of the effect gauge, and in the lower centre part of the interface is a box that displays diagnostic messages.

Concept I.2

The second concept, see Figure 7.4 (b), is more playful, sporty and compact. It combines the use of large analogue gauges with a digital representation of their value. The concept consists of three large circles, of which the centre gauge shows speed, the left shows the effect, and the right displays air pressure as well as coolant temperatures. In this concept, the state of charge can be seen below the three circles, additionally, the bottom part of the screen displays a settings menu, with four arbitrary buttons.

(a)

(b)

(c)

(d)

(e)

Figure 7.4: The finished concepts for Iteration I. Each concept is developed with a different idea in mind, to trial different levels of legacy bias and speculative features in an evaluation. [Authors contribution]

Concept I.3

The third concept, see Figure 7.4 (c), is a simple, minimalistic, and bold interface. The analogue gauges are reduced to small details, giving room for large numbers that display the values in a space-efficient grid layout. The centre gauge is the speedometer, while the secondary gauges to the left and right are displaying air pressure, and state of charge and effect respectively. This concept has a bar at the bottom for lesser information, such as trip runtime, clock and coolant temperatures. At the top of the interface is a box for diagnostic messages, as well as a button to open the settings menu.

Concept I.4

The fourth concept, see Figure 7.4 (d), is a speculative design of how a fleet management system could be incorporated into a terminal tractor dashboard design. We noticed in our social media ethnography (see Section 6.3) that the current fleet management systems that are in place in many ports and terminals, could be frustrating to use for the operator, which is why this concept tries to alleviate that struggle. The approach to implementing the system can be seen in the centre of the interface. This concept also investigates how important the speedometer is to the operator since it's moved much further down in the interface. Hugging the speedometer gauge, to the left and right, is the effect gauge and the state of charge respectively. Along the left edge of the interface is the battery and engine temperature, and along the right edge is the air pressure.

Concept I.5

The fifth concept, see Figure 7.4 (e), places the gauges in a circular shape around the centre of the screen. This concept takes inspiration from several different car dashboards that we encountered in our study of dashboards (see Section 6.1). This concept puts a roughly equal amount of emphasis on analogue and digital gauges. In the centre of the interface is the speedometer, underneath which is the effect gauge and the state of charge. Circling the centre are two pressure gauges and two coolant temperature gauges.

7.1.6 Evaluations and Feedback Sessions

To evaluate the different concepts, our priority was to interview American or Swedish terminal tractor operators to get the assessment of end-users. However, our initial attempts to contact operators at the client company and local terminals were futile. This led us to instead use the resources we had available, which mainly consisted of employees at CPAC and the client company. However, in our conversations with the client company, we were able to arrange an evaluation with an operator at the end of the first iteration. The following sections will describe the different approaches to evaluations we conducted in Iteration I.

Most sessions were conducted as semi-structured interviews, utilising the think-aloud method to discover what the subjects were thinking about the design. Combined with using the laddering method, we repeatedly asked the subjects their opinion, often reflecting their questions, e.g. on what a certain element was, back at them, to build an understanding of how the interfaces were perceived.

7.1.7 Sporadic Feedback Sessions

During this iteration, feedback sessions and evaluations were scattered throughout the process. Some of these sessions took place spontaneously in the downtime between other activities. Many of our insights and conclusions derive from sporadic conversations and e-mails. Worth mentioning is a session run with two other students, in which we performed a pilot test of the planned evaluation with an operator. Furthermore, we also demonstrated the concepts in a conference call with employees at CPAC. In this session, we described the concepts shortly and let participants vote for their favourite. While these results were possibly heavily biased due to the informal set-up, they did show that the concepts were somewhat equally appreciated. Finally, the concepts were discussed with our supervisor at CPAC, mainly regarding the feasibility of their implementation. See Figure 7.1

Session	**Participant(s)**	**Affiliation**
1	2 Students	Chalmers
2	>30 Engineers	CPAC
3	1 Engineer	CPAC

Table 7.1: During the first iteration, several sporadic feedback sessions were conducted. This table presents three noteworthy sessions. Session 1 was a pilot test of another evaluation. Session 2 was a demonstration of our five concepts for over 30 engineers in a conference call. Session 3 was a discussion with our supervisor at CPAC. [Authors contribution]

7.1.8 Evaluation with Industry Experts

At this point, we reached out to two industry experts at CPAC who had experience working with digital interfaces. One of the experts was a Human–Machine Interface (HMI) engineer, while the other was a project manager, both being employed by CPAC. This spontaneous evaluation was mostly a group discussion about each concept, where they could challenge our design choices. This helped us to understand how the concepts are perceived by someone with general expertise in interfaces. Some of the insights from this discussion were to consider our choice of font, colour scheme, and the overall feeling of 'depth' in the concepts. An exhaustive list of the insights we gained from this evaluation can be seen in Table 7.2.

7.1.9 Evaluation with Client Company Engineer

After evaluating with industry experts, an interview was arranged with an engineer at the client company, who was our main contact in the USA. The meeting was conducted online, in a video conference call. The interview subject was located in the USA, while we, along with our supervisor and project manager, were participating

Concept	**Insight**	**Originator(s)**
1	This concept resembles the first digital interfaces used for industrial purposes.	Both
2	The battery takes up too much space	HMI engineer
2	Maybe place tell-tales where the battery is?	HMI engineer
2	This concept is the most appreciated	Both
2	The concept has a very simple and fun design	Project manager
3	The concept has great glanceability	Project manager
3	It looks like an interface that would be placed immediately on the engine	Project manager
3	The concept is not very fun or engaging	HMI engineer
3	Gives the operator exactly what they want	Both
4	The design is not holistic, everything seems disconnected	Both
4	The speedometer is far down, but the road they need to look at is above the interface	Both
4	The needles need to be more differentiated from the gauge itself, or incorporate a bar that fills up	HMI engineer
4	Fleet management system looks nice	Both
4	The opacity used in the fleet management system gives the concept an overall sense of depth	HMI engineer
5	Reminds you of a fighter jet cockpit	Project manager
5	All the gauges look the same, so you can't clearly differentiate between them	Both

Table 7.2: An exhaustive list of insights that were drawn from the evaluation with industry experts. Each insight is presented with the concept it is directed towards, and the originator of the insight. The two participants in this evaluation was an HMI engineer and a project manager, both employed by CPAC. [Authors contribution]

from Gothenburg. Before the interview, the five concepts were sent to the subject to be reviewed with stakeholders at the client company, as per their request. The list of participants can be seen in Table 7.3.

Participant	Affiliation	Occupation	Participation
1	Client company	Both	Remote
2	CPAC	Engineer	In-person
3	CPAC	Project manager	In-person

Table 7.3: The list of participants during the evaluation with an engineer from the client company. No demographic information is provided to avoid disclosing the identities of the participants. Each participant is numbered for referencing, and each participants' affiliation and occupation is presented. In total, there were three participants and two interviewers, one being the facilitator and the other being the notetaker. [Authors contribution]

The interview was semi-structured and was divided into two parts: user research and evaluation. First, questions were asked regarding operators, the values of the client company, and what the interface design should express to the driver. In the second part of the interview, we asked questions about the concepts, trying to understand the user and also evaluating which concept to take further based on the opinion of the client company. It was clear that the feedback given by the interview subject was not the opinion of operators, but rather, the opinion of their sales team and other engineers. We tried to specifically ask them to consider how operators would perceive the interface, to which they responded that they wouldn't know, as they rarely interface with operators.

They were certain, however, that the third concept, see Figure 7.4 (a), would be the best way forward, as they believed that a simple concept with minimal clutter would be the easiest to use for operators. Additionally, they could provide a lot of insights on interface elements that are related to the engineering of the terminal tractor. For instance, the speedometer should only go up to 50mph, which most concepts exceeded.

We also created questionnaires for both the members of the project at the client company, as well as for operators, as a continuation of the user research, that was sent after the evaluation meeting. After this initial evaluation, we were hopeful that we would be able to share the questionnaire with employees at the client company. We created a different questionnaire for each group of respondents. The questionnaire for client company stakeholders investigated both how they wanted the interface to be expressed and designed, using a semantic differential scale, and how important elements in the interface would be for the operator, using a Likert scale. Unfortunately, we did not get the expected amount of responses, receiving only one response from the same client company engineer that we interviewed on the stakeholder questionnaire. The results of this response are presented in Figures 7.5 and 7.6. The full questionnaire that was sent to the stakeholders is attached in Appendix B.

Figure 7.5: The response of the semantic word scale from the questionnaire that was sent during the evaluation in iteration I. [Authors contribution]

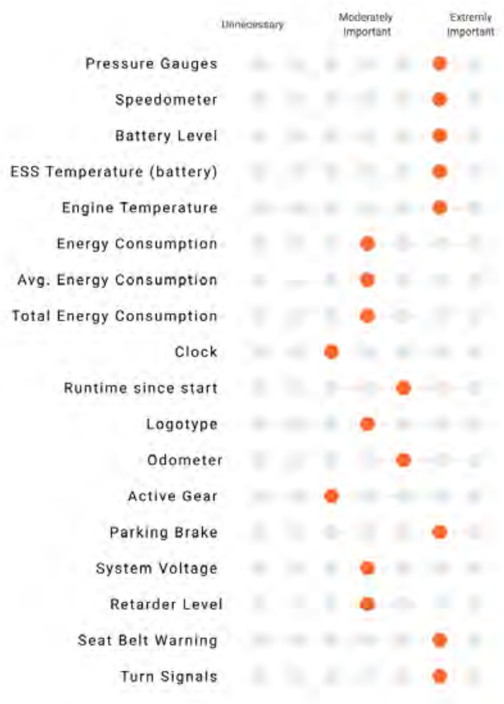


Figure 7.6: The response from the questionnaire that was sent during the evaluation in iteration I. The result show the likert-scale that evaluate how important various feature are. [Authors contribution]

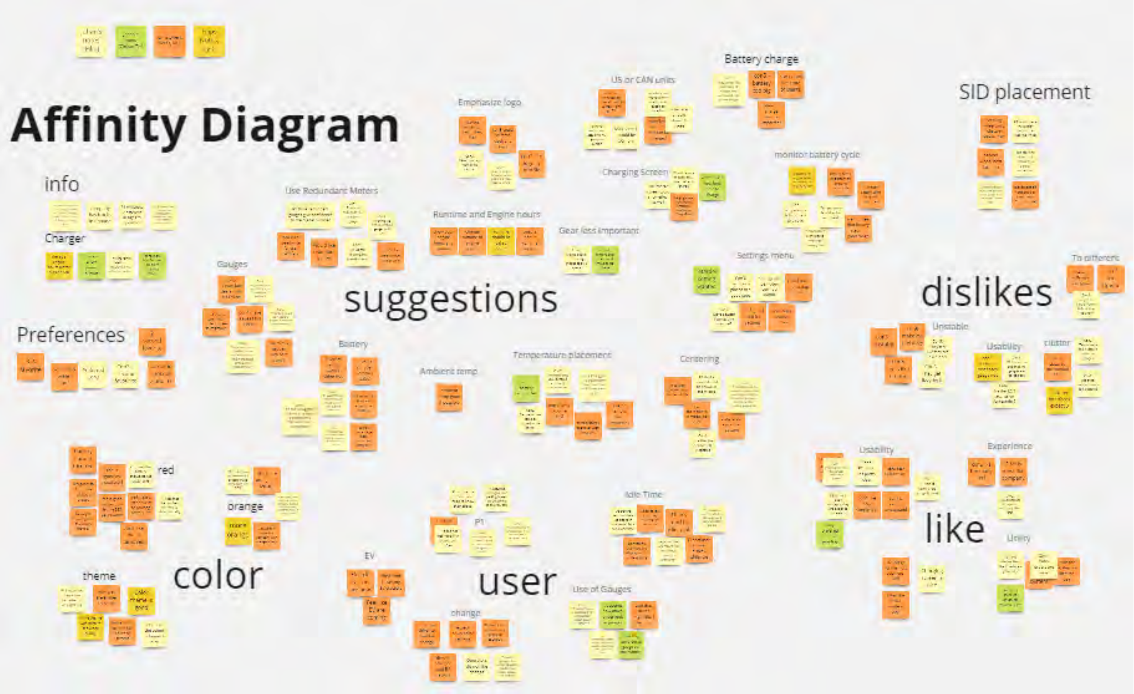


Figure 7.7: The affinity diagram that was created to analyse the data collected during the evaluation with a client company engineer. Each sticky note is a specific insight or comment made by the interview subject. The sticky notes are placed in categories that best represent their theme. The colours of the sticky notes represent from whose notes the insight was derived. [Authors contribution]

To summarise the data collected from the interview, we created an affinity diagram, as it was a relatively efficient and convenient method to analyse the data, and suitable for the small amount of data. The affinity diagram was conducted using Miro, based on the notes that were taken, see Figure 7.7. We reviewed each category formed in the diagram and took the most emphasised insights and summarised them in a list. The concrete list contained insights like *"Monitoring coolant temperatures is important to prolong the lifespan of the tractor."*, *"Redundant meters are preferred, they give confidence to the digital number, comfort the user, and can look cool."*, or *"The colour theme in the concepts are good."*. An exhaustive list of insights from the evaluation can be seen in Table 7.4.

7.1.10 Evaluation with Operator

Lastly, an experienced terminal tractor operator, employed by the client company, was interviewed. This interview subject was experienced with driving terminal tractors and has worked with terminal tractors for a considerable amount of years. They were confident in voicing the opinion, of not only themself but terminal tractor operators in general. The original plan was to interview at the beginning of the project for user research, but we were unable to set up a meeting until the end of the first iteration. Therefore, the interview became a combination of user research and concept evaluation.

The interview was conducted online, in a video conference call. Apart from the interview subject and ourselves, five other people took part in the interview, four of which were in the USA with the interview subject, while we were situated in Sweden together with another project member. The meeting participants, excluding ourselves and the interview subject, were members of the project, some being project executives, from both CPAC and the client company. They mainly listened to the interview silently, but occasionally chimed in to answer questions regarding the project as well as ask questions of their own. Oral consent was given to record the entire interview, and for using quotes in this report. For the interview, one of us took the role of the main interviewer while the other took notes and asked probing questions. A laddering technique was used to gain further insights, but could not be utilised to its full potential, mainly as the time was limited. Additionally, think-aloud was used to discuss the concept designs, evaluating how the operator perceived the interfaces. The interview took 45 minutes in total.

The five concept images were presented using a Miro canvas, which allowed a great degree of freedom since we were able to dynamically focus on the elements that came into discussion. The interview subject was able to evaluate both the concepts and the prototype terminal tractor which they had an opportunity to drive, as well as explain the operation of terminal tractors in general, from their perspective. They explained that terminal tractors are vehicles that take a lot of jarring, and as such, drivers are concerned about the health of the vehicle. They would consistently scan the dashboard to make sure that coolant temperatures and air pressure levels are in an acceptable range, as well as no critical tell-tale lights being active. They told us that due to these harsh working conditions, terminal tractors breaking down

Theme	**Conclusion**
Critique	Interface should not be too different from traditional tractors
Critique	The usability is not so good for some of the gauges
Critique	The interface should not be too cluttered
Critique	Concept 5 feels "unstable"
Display	The display should be placed behind the steering wheel
Preference	The "sporty" feeling of concept 2 looks good
Preference	The interface should resemble the theme of the company
Preference	A simple and intuitive interface is preferred
Preference	A modern interface is preferred
Preference	The concepts include most of the required features
Preference	Concept 3 is the most appreciated, followed by concept 2
Preference	Concept 3 should be combined with concept 2
Users	Operators will be cautious of electric vehicles and change
Users	Participant 1 does not generally interact with operators
Users	Operators tend to idle a lot
Users	Operators will look at the interface more when they idle
Users	Users will not be used to driving electric terminal tractors
Colour	Using more orange colour will embody the client company
Colour	Red colour should be used as a visual alert for gauges
Colour	The colour theme looks good
Colour	The interface could have an alternative light theme
Info	There is an active motor hours tracker outside the cockpit
Info	The charger of the terminal tractor displays a lot of information
Suggestion	The logo should be bigger and placed more centrally
Suggestion	Interface should only show US units or metric units
Suggestion	Speedometer should show 50mph as the maximum value
Suggestion	The state of charge is important and should be emphasised
Suggestion	Coolant temperatures should be easy to monitor
Suggestion	The driver should be able to change the level of motor brake
Suggestion	Settings should be accessed with a button
Suggestion	Gear status is not important to the driver and should be smaller
Suggestion	Total active motor hours is more important than runtime
Suggestion	Redundant meters give confidence to the digital number
Suggestion	Battery percentage is more important than its associated bar
Suggestion	Ambient temperature is a nice addition
Suggestion	Speedometer should be placed in the centre of the interface

Table 7.4: An exhaustive list of conclusions that were drawn from the evaluation with an engineer from the client company. Each conclusion is presented with a theme derived from the affinity diagram. Each conclusion is based on comments made by the client company engineer. [Authors contribution]

Participant	Affiliation	Occupation	Participation
1	Client company	Terminal tractor operator	Remote
2	Client company	Engineer	Remote
3	Client company	Engineer	Remote
4	Client company	Executive	Remote
5	CPAC	Engineer	In-person
6	CPAC	Project manager	Remote
7	CPAC	Executive	Remote

Table 7.5: The list of participants during the evaluation with an operator in Iteration I. No demographic information is provided to avoid disclosing the identities of the participants. Each participant is numbered for referencing, and each participants' affiliation and occupation is presented. In total, there were seven participants and two interviewers, one being the facilitator and the other being the notetaker. All remote participants were co-located in the same conference room. [Authors contribution]

was no rare occurrence, and would be frustrating for the drivers. When we started evaluating the concepts with them, one point of reoccurring feedback was that critical information needs to be displayed further up on the screen. When we started probing them further on this very specific suggestion, we were told that many terminal tractor drivers were overweight and needed to adjust the steering wheel to the uppermost configuration to fit in the driver's seat. When they were driving the prototype electric terminal tractor, they noticed that by pushing the steering wheel to this configuration, the view of a large portion of the lower dashboard display was obstructed.

Among many other points of feedback, the interview subject reacted positively to many speculative features in our concepts, such as the clock, ambient temperature and fleet management system. When asked about introducing the selected gear in the interface they responded:

> *"Oh man that would be nice."*

They then turned to client company executives and expressed to them directly that they really would like it to be implemented. The interview subject also expressed that they preferred the clean and bold interface of concept I.3, see Figure 7.4 (c). Even though this concept reduced the traditional analogue gauges to a detail accompanying a much more emphasised digital number, they argued that digital numbers are much more preferred by operators in general. When probed further why they thought this was the case, we were told that by displaying large numbers, all the information they needed was clearly visible right in front of them. They added:

> *"You can't mess that up!"*

Additionally, they argued that presenting total active engine hours and total miles travelled is important, as those are statistics that operators are required to note down during their workday.

7.1.10.1 Analysis

To get the most out of the interview, we wanted to analyse it in-depth. We therefore first began to transcribe the recording of the interview. This was done with the help of a transcription tool in Microsoft Word. The sound quality from the meeting was, however, quite poor, and the automatically generated transcription of the recording was not perfect. It was, however, accurate enough to use in combination with the original audio recording for the sake of our analysis. The tool also had a hard time identifying which person was talking whenever people other than the interview subject said something, which we had to do manually.

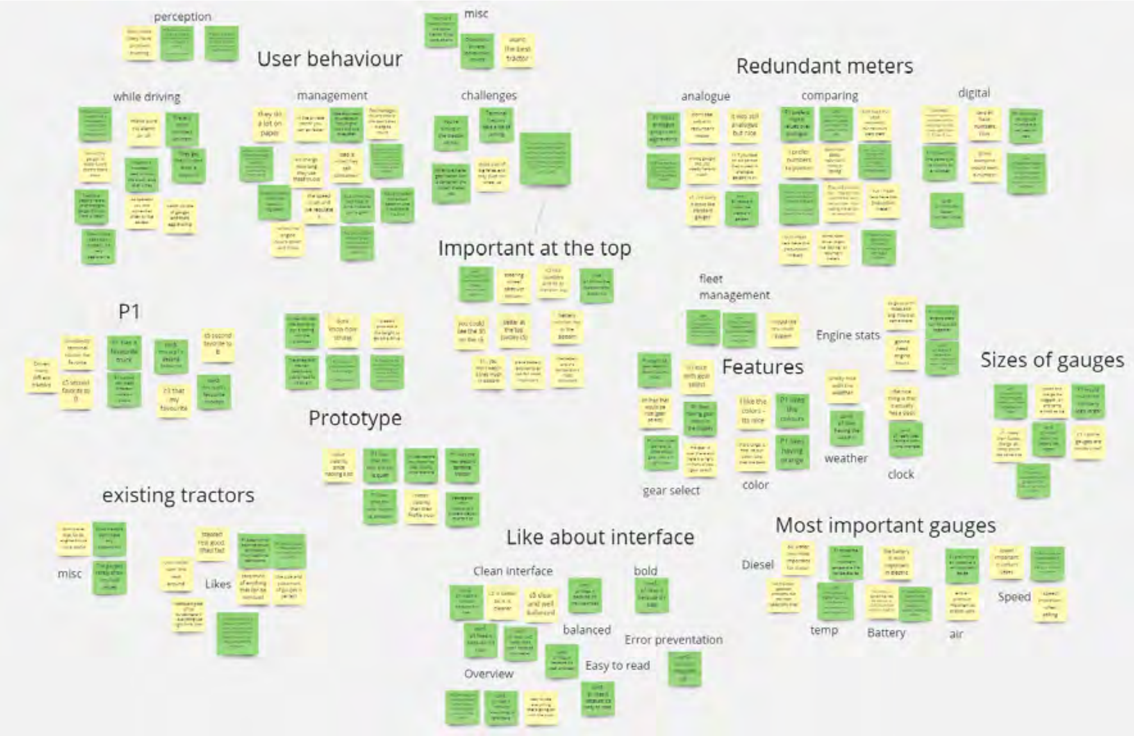


Figure 7.8: Affinity diagram of the results from the operator evaluation at the end of the first iteration. The diagram was constructed in Miro, with each sticky note representing a specific insight. The sticky notes are placed in categories that best represent their theme. The different sticky note colours represent who made the note, as we both worked in parallel. [Authors contribution]

Next, to analyse the data we used both the recording and the transcribed text to construct an affinity diagram. We choose to use an affinity diagram as it was relatively simple and convenient compared to other analysis methods, and also suited for the amount of data we collected. We used Miro to create virtual sticky notes, one for each thought, insight or quote, see Figure 7.8. Next, we organised the notes into categories and tried to look at specifics from a wider perspective. These categories helped us to summarise the findings into a list, as displayed in Table 7.6. This time, we could also note five key takeaways from the analysis, that would be our main focus in the next iteration. These were:

- There should be no critical information in the bottom 1/3 of the screen.
- Emphasise coolants and battery.
- Odometer and total engine hours should be made accessible for the operator.
- Gauges should be redundant, with emphasis on digital values.
- Include more features; Gear select, Clock, Weather.

Theme	**Conclusion**	**Originator**
Gauges	Coolant temperatures were the most important gauge in traditional tractors	Participant 1
Gauges	In the new tractor, drivers will be uncertain what the most important gauge is	Participant 1
Gauges	The battery temperature will be the most important gauge in the new tractor	Participant 4
Gauges	Air pressure is second-most important after coolant temperatures	Participant 4
Gauges	Speed is limited in public sector, speedometer will only be important in private sector	Participant 1
Gauges	Make gauges of equal importance the same size	Participant 1
Gauges	Heavily preferred numbers over analogue gauges, most operators will probably do	Participant 1
Gauges	Analogue parts of redundant gauges could be good for older people or for aesthetics	Participant 1
Praise	Clean interfaces are easier to read	Participant 1
Praise	Bold numbers clearly present the values and look nice	Participant 1
Features	Total active motor hours and travelled miles should be clearly visible in the same place	Participant 1
Features	There should be a clock	Participant 1
Features	There should be ambient temperature	Participant 1
Features	The current colour theme is good, maybe more orange?	Participant 1
Features	Gear select is really nice to have	Participant 1
Features	Fleet management would be very nice to have, but the infrastructure does not exist yet	Participant 1
Display	Steering wheel obstruct bottom view of screen, especially for larger drivers that push the wheel up	Participant 1
Display	About the bottom 1/3rd of the display is obstructed	Participant 1
Assume	Concept 3 is the favourite, followed by concept 5 and 2	Participant 1
Assume	Operators hope to drive the same tractor each day, but drive what they are given on the day	Participant 1

Theme	Conclusion	Originator
Assume	Operators mostly monitor the dashboard just to make sure nothing is malfunctioning	Participant 1
Assume	They are concerned about the tractor working properly at all times	Participant 1
Assume	Gauges are not observed that much when driving, some dashboards are aggravating to interpret	Participant 1
Assume	Most operators will come to trust the new tractor	Participant 1
Assume	Operators blame the tractor for not working properly	Participant 1
Operate	Drivers have to report on total active engine hours and travelled miles to their managers	Participant 1
Operate	Terminal tractors take a lot of jarring, some don't have suspension	Participant 1

Table 7.6: An exhaustive list of conclusions that were drawn from the affinity diagram that was created from the data collected in the evaluation with an operator during the first iteration. Each conclusion is marked with the theme it was categorised as in the diagram, and the originating participant. The participant numbers are derived from the participant list, see Table 7.5. [Authors contribution]

7.2 Iteration II

The first iteration concluded with the analysis of the operator evaluation. At this point, we had a lot of feedback and insights to work with to develop the dashboard interface further. Our goal for the second iteration was to create three concepts that evolve from concept I.3 which, overall, was the most appreciated concept from the first iteration. We still wanted to create more than one concept, as it would allow us to compare and contrast multiple designs against each other in evaluations. However, since these concepts would be more detailed, it was not realistic to create more than three in the time we had available.

Before we could start designing the concepts, we needed to work with the insights we gained from the first iteration. Furthermore, since our concepts would resemble each other much more closely than the previous iteration, we had to decide which icons to use in gauges and tell-tales, as these would be critical for interpreting the dashboard correctly. But first of all, we wanted to investigate the placement of the display in the terminal tractor, as we had recently uncovered its sub-optimal placement in the dashboard.

7.2.1 Display Placement in the Tractor Dashboard

We got the opportunity to visit the prototype that was being built by Volvo and CPAC in Gothenburg. This provided us with insights regarding how it feels to sit in the terminal tractor cockpit, and, most importantly, the feel and visibility of the display. We learned how the visibility of the screen is affected by the placement of the display and the user. To summarise and visualise the results, we created heat maps that show the visibility of the display, both for the current placement and for the placement we proposed.

The tractor prototype could not be driven, and the screen was not installed. However, we had brought a display like the one that will be installed and could get a feel for how different placements of the screen will affect the visibility of the screen. We checked how the visibility was affected by different configurations of the steering wheel and how the height and sitting position of the driver would affect the visibility of the screen. The seat could not be adjusted at the time, but we assumed it would be possible in the final prototype and tried to simulate that as well. The steering wheel can be adjusted between two settings, see Figure 7.9

(a) Down most position. **(b)** Uppermost position.

Figure 7.9: Two images that show the different steering wheel configurations available to drivers in the new terminal tractor. The uppermost configuration in (b) is more spacious than the down most configuration in (a), although it further obstructs the view of the dashboard display, as can be seen in Figure 7.10. [Authors contribution]

The screen placement was determined to be behind the steering wheel at this point in the process, however, how it will be fitted and integrated with the dashboard is not decided. Currently, there is a "lip" that acts as a sun shield on the top of the dashboard. The placement of the display in the terminal tractor at the time was underneath this lip, which was where the interface was located in traditional terminal tractors. Due to the feedback from the first iteration that this placement was inadequate, we were told that the placement of the display can be adjusted to allow for better visibility, including cutting away the lip or other parts of the dashboard if required.

In our study of display visibility, we tried to consider anthropometry and adiposity, to think about how the visibility would differ for drivers concerning their physical attributes. In our discussion with an operator during the first iteration, see Section 7.1.10, we were told that many overweight operators had to drive with the steering wheel in the uppermost position, see Figure 7.9, since this was the only way they would be able to fit in the driver's seat. We could observe, just as stated in the interview, that the visibility of the dashboard was considerably lower in this configuration, see Figure 7.10. The steering wheel would obstruct the bottom part of the screen in this position, and the shape of the wheel makes it particularly hard to see the centre part of the screen. Figure 7.9 shows an estimate of the view for a tall user driving with the steering wheel in the uppermost position, and resting against the backrest.

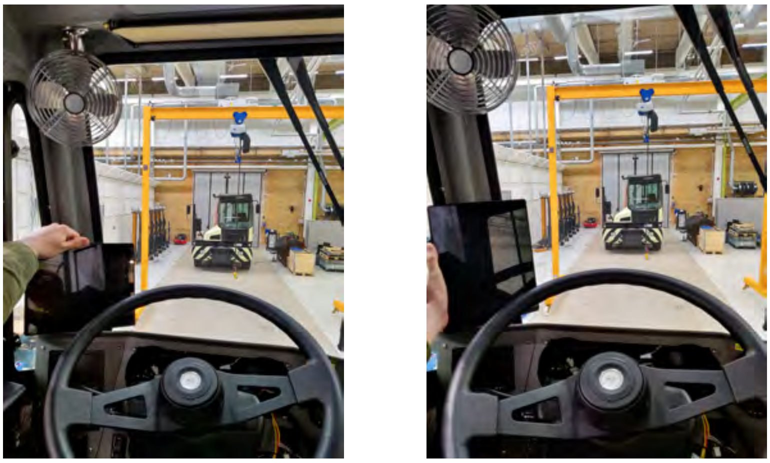
(a) Down most position. **(b)** Uppermost position.

Figure 7.10: Two images that show how the visibility of the display changes between the down most and uppermost steering wheel configurations, as seen in Figure 7.9. The display is placed underneath the upper edge of the dashboard, held in place by the hand visible in the bottom right. [Authors contribution]

In our attempt to increase the visibility of the display, we noticed that it would have to be raised. However, if the display was raised too much, the visibility of the area in front of the tractor would decrease. Realistically, the display would not be able to be raised more than a couple of centimetres above the sun shield. We were able to conclude that by raising the display a few centimetres and integrating it in the dashboard, which will move it a few centimetres forward, the visibility of the dashboard would be greatly increased. Figure 7.12 shows an estimation of how a driver of average height would see the screen in our proposed placement, with the steering wheel in the uppermost position. One can observe how the bottom portion of the screen is still somewhat obstructed. However, it is possible to see the whole screen if you lean forward a bit. Furthermore, the visibility is perfect with the steering wheel in the down most position.

Additionally, we experimented with other placements, such as on the left windscreen pillar. This placement would have superior visibility of the display, for all users, but could infringe upon the comfort of the user, as it would be an unusual location for a dashboard. However, this was deemed to be out of scope for our project, and after proposing this alternative solution as an idea to the company we did not investigate the solution further.

To visualise our findings from this study we created heat maps, see Figures 7.13



(a) Landscape. (b) Portrait.

Figure 7.11: Two images that show alternative placements of the display. Both placements are on the left windscreen pillar, altering between landscape and portrait orientation. This placement provided the maximum visibility but could prove troublesome for drivers to get used to. [Authors contribution]

and 7.14, that show the areas of the display with better and worse visibility. As the visibility changes for different users driving conditions, the heat maps are created to represent the visibility of users who decide to operate the tractor with the steering wheel in the uppermost configuration. The red areas are sections of the interface that some users may never see, even if they move slightly, yellow indicates sections of the screen that would be somewhat obstructed but observable, and green indicates sections with good visibility for the vast majority of users.

Figure 7.12: Estimation of how our proposed screen placement will look like from the user's point of view, the steering wheel is in uppermost position. Although parts of the display remain obstructed, drivers would be able to lean to view the rest of the interface. Furthermore, we could refrain from placing important information and gauges in these obstructed sections. [Authors contribution]

Lastly, during our investigation of the display placement, members of the client company also performed experiments of their own with placement in the USA, and seem to have come to the same conclusions.

Figure 7.13: Heat map of the worst-case visibility if the interface would remain in the location at the time of our study. The red area is the section which some drivers may never see, even if they make small movements. [Authors contribution]

Figure 7.14: Heat map of the worst-case visibility if the interface would be raised and integrated with the dashboard. The red areas are sections of the interface that some users may never see, even if they move slightly, yellow indicates sections of the screen that would be somewhat obstructed, but observable, and green indicates sections with good visibility for the vast majority of users. [Authors contribution]

7.2.2 Designing Icons

Considering which icons to use has been an important aspect of the project, and in this iteration, several design decisions had to be made. Should we follow guidelines set by standardisation organisations, use an icon the user is familiar with, or design something entirely new? Additionally, how are tell-tales supposed to appear in the interface? Using a separate position for each, or clustered in one position dynamically? When fixed, should they be noticeable in their inactive state? And how are multiple status icons handled when they appear dynamically?

An advantage of icons in this project is that they are not as permanent as in an analogue interface. CPAC can update the interface continuously in the future, and icons can be changed. This made it possible to disregard how icons should be designed considering what will be most commonly adapted in the future, and instead focus on what is best received at the time.

Allocating Space for Tell-Tales

Many, long, discussions have been held regarding if tell-tales should be placed statically or dynamically. That is, whether each tell-tale should be allocated a specific location in the interface, or be displayed dynamically in one shared space for all tell-tales. In the latter case, the question arose as to how several tell-tales should be displayed at once.

There are pros and cons to both methods. Analogue interfaces typically used a static placement for all tell-tales due to the technical limitation that each tell-tale had to be displayed using a small LED. That means that there may be benefits to displaying them statically, as that is how most drivers will expect the interface to work. Interfaces with digital screens can, however, display different tell-tales in the same physical space on the screen. This way, the interface can display the same amount of tell-tales much more space-efficiently. However, when several tell-tales need to be displayed at once, they will either have to take up more space or cycle through the same location.

Taking inspiration from modern interfaces in cars, there are often both static and dynamic tell-tales. Those that are used more regularly, like the seat-belt warning, often have a static location, while other warnings, such as engine fault, can be shown at a shared location. Unlike analogue interfaces, a digital interface can also use text to further explain the meaning of tell-tales that appear, which is often the case in modern cars.

Air Pressure Icons

A design consideration that came up during the prototyping phases was which icon should be used for the air pressure tanks. When investigating different brands of terminal tractors we found that the icon is not standardised between brands. The different choices all have pros and cons, and it became a question of reasoning which would be the most useful to operators. The client company has previously used one type of icon in their earlier model of terminal tractors, and the icon that ISO proposes (ISO, 2022) is different. They both refer to the tanks as "1" and "2", while other brands either write "Front" and "Rear" for the tanks or use "F" and "R" respectively to make it easier to understand the axle it affects. Knowing which axle the brake controls could be important for the driver as if a scenario occurs where a tank rapidly loses pressure, the braking behaviour would be affected by which axle is disengaged.

Below are five different icons for air pressure that were regarded as potential options, see Figure 7.15. The bar gauge is only used to give the air pressure icons a context.

(a) **(b)** **(c)** **(d)** **(e)**

Figure 7.15: Five different designs for the air pressure gauges, which each test a different icon. The icon in each design indicates that the gauge is showing the air pressure in one of the two tanks, and which of these it refers to. [Authors contribution]

Figure 7.15 (a) is the icon that has been used previously by the client company, in their analogue pressure tank gauges. Figure 7.15 (b) is a stripped variant of this, where the psi marking has been moved from the icon to inside the round bar. Figure 7.15 (c) is what the proposed ISO standard looks like. Lastly, Figure 7.15 (d) and (e) refer to the tank as F and Front respectively, which is the most commonly used approach in the terminal tractors that have been investigated during the project.

This question was discussed with project members at CPAC, helping us make a qualified decision before evaluations. One project member said that they would prefer Front/ Rear over 1 or 2, as it makes it easier to map the gauge to which axle it will act on. We also considered the comfort of transitioning users, and since they are likely to have driven an older truck from the client company before the new electric, using an icon similar to the older tractors would afford a more comfortable transition. Despite this, we decided to use the icon proposed by ISO. It is in our belief clearer, simpler, and the most versatile. We believe the negative effect it would have on users having to relearn that icon is minimal relative to the positive aspects the standardised icon would have.

Battery Icon

In the consideration of which icon should portray the propulsion battery, where we had two options: a standardised icon or a common icon. The proposed ISO standard icon, see Figure 7.16 (a), is used to indicate the state of charge for a propulsion battery (ISO, 2021). However, the icon does not seem to be widely used in electric vehicles, despite being an ISO standard. We rarely observed the icon during our investigation of electric vehicle dashboards. The icon that was more commonly used resembles a battery cell and is also used for a wide range of other applications, such as displaying battery levels in mobile devices. In this case, both icons would be new to the driver in the context of terminal tractors. However, users will most likely be more familiar with a variation of the battery cell icon for the state of charge. Additionally, the battery cell can be developed to effectively portray the state of charge in the icon itself. For these reasons, we chose to opt for the battery cell icon in our concepts but were open to evaluating the decision with stakeholders at both CPAC and the client company.

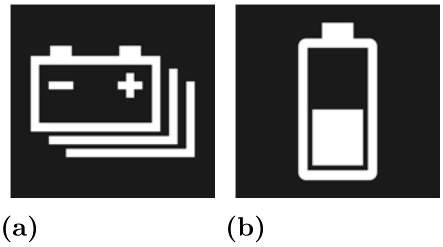


Figure 7.16: Two proposed icons for battery state of charge. (a) is an adaptation of the ISO standard for the application, while (b) is a variation of the more commonly used battery icon. [Authors contribution]

Temperature Icons

Deciding which two icons should be used for coolant temperatures faced the same problem. One of the icons needed to refer to the temperature of the electric motor, and the other icon refers to the temperature of the energy storage system.

Regarding the energy storage system, we found examples of simply placing a temperature icon inside a battery icon. The ISO standard agrees with this design concept, but utilises the propulsion battery icon, as seen in Figure 7.16 (a), instead of the more commonly used battery icon, as seen in Figure 7.16 (b). The distinction between the icon as proposed by ISO, or as we found examples of in other electric vehicles can be seen in Figure 7.17.

We believed that the same battery icon should be used to both indicate temperature and state of charge, and as we already had decided to use the more common variant of the battery icon, see Figure 7.16 (b), we decided to use the same battery icon for the energy storage system temperature gauge, as seen in Figure 7.17a.

When deciding which icon to use for the electric motor temperature, we noticed that the ISO standard icon for this application, ISO 7000-3607 (ISO, 2019), see Figure 7.18a diverged a lot from what is more commonly used in vehicles. ISO themselves do not recommend the icon in the ISO standard for dashboard icons (ISO, 2021). Instead, our solution was to use the same icon that vehicles with internal combustion

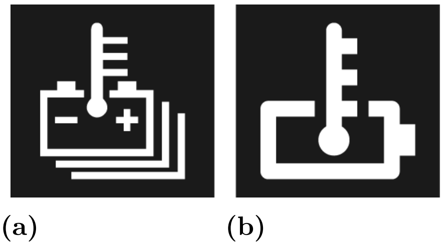


Figure 7.17: Two proposed icons for the temperature of the electric energy storage system. The left one is an adaptation of the ISO standard for the application, while the right is a variation of the more commonly used battery icon. [Authors contribution]

engines use to indicate engine coolant temperature, namely ISO 7000-0246, as can be seen in see Figure 7.18b.

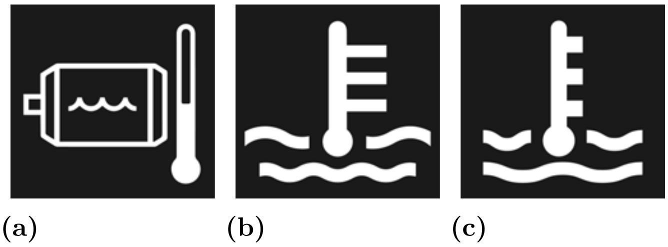


Figure 7.18: Three different icons for the temperature of the motor coolant. (a) and (b) being adaptations of ISO, and (c) being an alteration of (b). [Authors contribution]

Using an icon that is designed for vehicles with an internal combustion engine could confuse when used on an electric vehicle. Although, both the engine and motor use coolant fluid, the icon fits the purpose. We reasoned that the icon will also be easy to understand and transition to, as users are used to it. The icon which was implemented in our concepts is altered slightly from the proposed ISO icon to be more aesthetically in line with the rest of the interface, see figure 7.18c.

Retarder Level Indicator

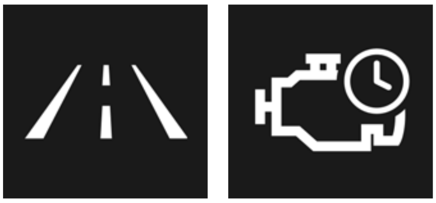
At this point, we had not established how the drivers would interact with the retarder level. We were told the user should either be able to change the setting often or very seldom. The concepts, therefore, explored two possible solutions, one where the user could see the retarder level and change it directly on the interface, and the other where the user could see the level in the interface, but change it through a setting in the menu.

The retarder would have three levels, and what these levels should be called had not been agreed upon by the project stakeholders. Therefore, the final concepts of this iteration explored three options, where they either were named lv.1-lv.3, B0-B2, or simply 1-3.

Odometer and Engine Hours

The last icons to be brought up in this section are the icons for odometer and engine hours. These are values that normally appear without icons in dashboard interfaces. However, we believed that it would be a nice addition, aesthetically, and could alleviate the transition to the new dashboard interface. ISO has no proposed standard for these applications.

The icons that were designed can be seen in Figure 7.19. The odometer, Figure 7.19a resembles the road icon used in lane-keeping assist icons. However, being placed next to a number with miles as a unit of measurement was deemed to be clear for the driver. In designing the icon for total active engine hours, we simply combined an engine and a clock to indicate engine hours. An option we had was to use an icon for an electric motor instead of an engine, but we ruled it out as the icon that ISO had proposed for electric motors was deemed to be too ambiguous and looked very similar to a battery. We believed that an engine would be more understandable for the user for this purpose, and make for a more comfortable transition.



(a) **(b)**

Figure 7.19: Two proposed icons for the odometer, (a), and total active engine hours, (b). Neither exists in any ISO standard, albeit, engine hours uses the ISO icon for engine as a base. [Authors contribution]

7.2.3 Designing Important Features

Two additional features that were important for the interface at this stage of the project were the menu button and dialogue box. Our considerations when designing for these features will be described in the sections below.

Menu Button

The menu button would be used in future interface development to display additional information and configurations that weren't in the main interface. For example, the user can access settings, past error messages and vehicle statistics. How much the user needs to interact with this menu is not clear, depending on the scope of the features it will contain. The content of the menu was out of scope for the project, but how to access it would nevertheless be available in the interface.

In the final concepts of this iteration, three different menu button options were explored, using either of the right corners of the interface. We assume that these corners will be the easiest to reach in the tractor cockpit, depending on the final placement of the display. Additionally, we would like to avoid having the user reach the display through the steering wheel, as it could potentially pose a risk, and rather have them reach the interface around the steering wheel. Having the menu in any of the right corners will be the easiest option for the driver.

Dialogue Box

One of the most important features of the interface is the ability to convey critical information about the vehicle to the driver. These messages should pop up clearly, and if several would be active at the same time, they should all be visible, and the user must be able to toggle between them. All three final concepts of this iteration explore different ways to display warnings and dialogues, however, the implied interaction of each concept remains quite similar. In the concepts, each piece of critical information is symbolised with a tell-tale at the top of the interface, which can be tapped to toggle its corresponding message in a dialogue box underneath it. Whenever a new tell-tale appears, the dialogue box would display its message, and if several appeared at the same time, the messages would automatically cycle through the tell-tales that have not yet been interacted with.

7.2.4 Developing Concepts

Having worked with the issues of screen placement, icons, and some design features, we once again began a diverging phase of creating plenty of concepts for a new design iteration. This time, concept I.3 was used as the basis for each developed concept, as it was the most appreciated concept of the first iteration. As concept I.2 was appreciated by the operator as well, we were inspired by its design as well.

Ideation

This new design iteration began with brainstorming sessions. We discussed how to progress the concept, and if it could be merged with concept I.2. We also discussed the general layout and position of elements. We conducted several sessions of ideation, alternating between designing and braindrawing, starting over with pen and paper. The development of concepts in this iteration focused much more in-depth on the functionality of specific features, making sure warnings and tell-tales could be displaced in a good manner. and that all the necessary functionality was in place. The result of these sessions were four main concepts, each having a lot of variants that we wanted to continue exploring in the process.

Feedback & Design Session

To converge on all those sketches we had, we employed the help of one HMI engineer and other Chalmers students at the CPAC office. Three feedback sessions were conducted in total, two sessions involving students, and one session with an HMI engineer from Volvo.

In the sessions, we used paper prototypes and asked participants questions regarding these. These prototypes had been developed in illustrator and then printed out in 1:1

Session	Participant(s)	Affiliation
1	2 Students	Chalmers
2	2 Students	Chalmers
3	HMI Engineer	Volvo

Table 7.7: Three feedback sessions were conducted in total. Two of the sessions involved two students, and one session involved an HMI engineer from Volvo.

size as they would appear on the final display. The sessions were highly informal and semi-structured, we used a set of questions for all sessions, from which we deviated by probing the participant on interesting topics. Other than helping us decide upon which variants of the concepts we should develop further, the feedback sessions had the added benefit of spotting mistakes that we made in the concepts.

The paper prototypes were printed versions of our digital concept and variants, which made for 12 paper prototypes in total. During the sessions, we could switch or overlay the concepts with their variations to ask questions regarding specific features and show the dynamic states of the interface. These sessions gave us additional ideas, and insights into problems of the concepts, and helped narrow down the concepts into three concepts that we should take further.

One example of insights from these sessions was that it was not intuitive to place air pressure gauges on different sides of the speedometer. It made more sense to group these and, therefore, all the final concepts of this iteration placed both air-gauges on the left side of the speedometer. Additionally, we were inspired by the HMI engineer to use arrows instead of dials on some of our gauges, as they could potentially be more clear and more aesthetic. We decided to use this design on one of our concepts, see Figure 7.24.

Refining sketches

After our feedback sessions, we used the newly gained ideas and insights to further develop the three concepts we had decided on. We made some new design decisions based on the feedback and decided on which of their variations to use. We also made sure to include two images of each concept. One that could show how the concept would look like during normal driving conditions, and one that would show as many features and icons as possible all at once.

Furthermore, we developed a proposal for how the interface would display whether it was currently running on a low-voltage system or high-voltage system, that is, if the motor is off or on, respectively, see Figure 7.20. In addition to these two states, the tractor could also be completely turned off. In our proposal, the interface screen would be completely dark when the tractor is off. Once the low-voltage system was activated, the interface would appear on the display, but with greyed-out gauges and once the high-voltage system was turned on, the colour would return to the gauges.

Figure 7.20: The three stages of ignition that we proposed during the second iteration of the process. In the leftmost image, the display is completely dark, symbolising that the tractor is turned off. The centre image displays a greyed-out interface, which symbolises that the low-voltage system is active. The rightmost image displays the interface once the high-voltage system is active, which returns the colour to the interface. [Authors contribution]

7.2.5 Final Concepts of Iteration II

This second iteration resulted in three design concepts, each with higher fidelity and detail than the concepts from the previous iteration. Since the overall most appreciated concept from the previous iteration was I.3, see Figure 7.4 (c), the three new concepts inherited much of its design. Layout-wise, all three concepts were almost identical to I.3 and shared many of the deviations. The effect gauge was moved in all three concepts, emphasising the temperature gauges that inherited its previous location. The effect and temperature gauges were also appropriately redesigned to fit their new locations. Some requested additions were made to the concepts, namely gear status, retarder level, engine hours, odometer and ambient temperature.

Two different versions were developed for each concept, one to show the normal driving state, and one to show as many features as possible. These features include, for example, how information lights, warnings and messages are displayed. The three concepts can be observed in normal state in Figure 7.21 or in more detail in Figures 7.22, 7.23 and 7.24 below. In this section, the concepts are presented as subjects of the process, whereas in Chapter 9 - *Results* the contents of the concepts are more clearly presented.

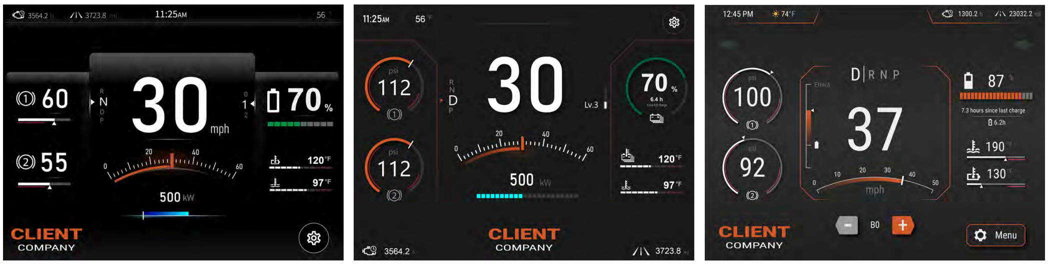


Figure 7.21: The three different concepts that is the result from iteration II, in a normal operating state. [Authors contribution]

Concept II.1

The first concept, see Figure 7.22, was developed to closely resemble the third concept of Iteration I, see Figure 7.4 (c). In doing so, we made sure that participants still could relate and compare to the old design in the coming evaluations. The same gauges for pressure, speed and state of charge were used, albeit with some small modifications. The clock was moved to the new top bar, which also houses the total engine hours, odometer and tell-tales. The settings button was moved down to the bottom right corner.

This concept also differentiated itself from concept I.3 through the addition of a subtle separation between the three columns of gauges. This helps to visually isolate the different sections of gauges from each other, which could prevent the interface from feeling cluttered. Additionally, some elements in the interface were stylised with a glow effect, e.g. the speedometer gauge dial. This change was purely made to look fancy.

Engine is burning!

(a) Normal operation

(b) Showing features

Figure 7.22: Concept 1 out of the three concepts created in Iteration II. The left image depicts how it will appear in a normal operating state, the right image is created to show additional features such as tell-tales and critical values. [Authors contribution]

Concept II.2

The second concept, see Figure 7.23, further deviated from the third concept of Iteration I, see Figure 7.4 (c). Many of the gauges native to concept I.3 were redesigned to trial alternative versions of the gauges. Most evident were the changes made to the pressure gauges and the state of charge, which were made circular instead of horizontal bars.

In an attempt to increase the visual cohesion of the concept, two lines were introduced that separate the secondary gauges from the speedometer. Furthermore, most gauges are stylised with a drop shadow to increase contrast with the background.

(a) Normal operation **(b)** Showing features

Figure 7.23: Concept 2 out of the three concepts created in Iteration II. The left image depicts how it will appear in a normal operating state, the right image is created to show additional features such as tell-tales and critical values. [Authors contribution]

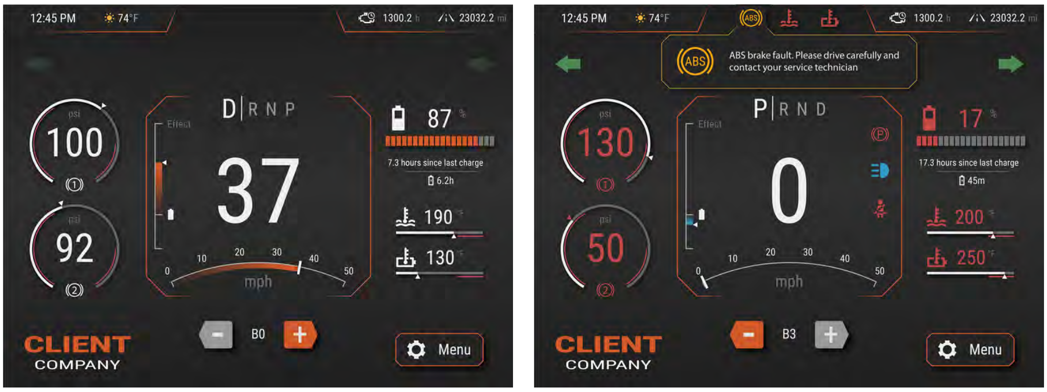
Concept II.3

The third concept, see Figure 7.24, was developed to be the most divergent from concept I.3, see Figure 7.4 (c). All the gauges have been redesigned, some being more different than others. The pressure gauges were made circular instead of horizontal bars, and the effect gauge was redesigned to more clearly highlight the difference between energy consumption and regenerative braking. In this concept, the ability to change the retarder setting was added in the main interface, rather than being an option in the settings menu. The menu button was also much more emphasised, placed in the bottom right corner. During the *Feedback & Design Session*, see Section 7.2.4, we were encouraged by the interviewed HMI-Engineer to use arrows instead of dials in some gauges, since they could potentially be more visually clear. In this concept, several dials have been replaced with arrows, to trial this theory.

Additionally, this concept attempts to implement a range estimator on the state of charge gauge. Lundström (2014) found that traditional range estimators are often found unsatisfactory by drivers, where an estimation of how far the vehicle can travel on the remaining battery is presented to the driver. We believe a distance range estimation would provide little utility to the operator of an electric terminal tractor, as they travel very short distances during the work day. We introduce a range estimator that displays the number of working hours left with the current state of charge, based on the average energy consumption.

7.2.6 Feedback From CPAC

After creating the concepts we received some feedback in informal discussions with project members at CPAC, whom all appreciated the concepts and found them intuitive. They also pointed out that they decided that the low voltage-state and high voltage-state needed to have an icon or text to differentiate the states even



ABS brake fault. Please drive carefully and contact your service technician

(a) Normal operation (b) Showing features

Figure 7.24: Concept 3 out of the three concepts created in Iteration II. The left image depicts how it will appear in a normal operating state, the right image is created to show additional features such as tell-tales and critical values. [Authors contribution]

more clearly for the driver. After this feedback, a "READY"-label was added to the concept showing the possible states, and evaluated in the next evaluation.

7.2.7 Evaluation From Client Company

What followed was a rather short evaluation from the client company. It did, however, prove sufficient for creating a final concept later. The evaluation consisted of two parts: emails and an interview. We were not able to interview an operator during this concept evaluation, resorting to the expertise of stakeholders at the client company.

Evaluation by Email

At first, it was not certain if an evaluation meeting would be possible, and we were requested to send the concept images in an email. The concepts were sent to the client company, without any further explanation than the pairs of images themselves.

After having sent the finished concepts, we received feedback in several emails from the engineering team at the client company, their sales team, as well as one of their customers. The occupation of the customer was not disclosed to us, but we were told that it was not an operator. Most of the feedback received here was direct feedback or proposed changes, and we did not see the need to perform an analysis of the collected data. An exhaustive list of insights can be seen in Table 7.8. Some of the most important points that were brought up in these emails can be summarised as the following:

- Concept II.2 is overall the most appreciated by the client company
- There should be a text or icon accompanying the power gauge to not confuse

power (kW) and energy (kWh)

- The tell-tales and dialogue box of II.3 should replace its equivalent in II.2
- The interface should be shifted down
- Switch location of the power consumption gauge and gear status
- The horizontal bar for the state of charge gauge in II.3 is better, but the text should be bigger
- Miles and hours should be spelt out in the odometer and engine hour, so the values do not get confused

Theme	**Insight**	**Originator(s)**
Praise	Concept 2 is the most appreciated overall	Engineers
Praise	Concept 3 is the most appreciated overall	Customer
Praise	The prominent gear selection in concept 3 is nice	Sales team
Praise	Nice that the gear selection is above the speedometer and that it is bold for which mode is selected	Customer
Praise	The battery bar in concept 3 looks nice	Customer
Praise	Nice to see the range estimation as runtime left in concept 3	Customer
Praise	Nice to see the time since the last charging session	Customer
Praise	The centred power consumption under the speedometer in concept 1 and 2 is nice	Customer
Praise	The dialogue box that further explains the tell-tales is nice	Customer
Suggestion	Add a "Power Consumption"-label to the effect gauge, to clear up the confusion between power (kW) and enegy (kWh)	Engineers
Suggestion	The interface should be shifted downwards. The current solution to the display placement problem which was identified in the first iteration places the display so high that the steering wheel slightly obstructs the top of the interface	Engineers
Suggestion	Concept 2 should incorporate the dialogue box from concept 3	Engineers
Suggestion	Switch the location of the gear selection with the power consumption gauge. Seeing which gear is selected is more important than the power consumption	Sales team
Suggestion	The state of charge number should be big, like in concept 1	Customer

Theme	Insight	Originator(s)
Suggestion	The battery bar should be green while over 50%, and then transition to yellow and red in the remaining 50%	Customer
Suggestion	The power consumption bar should be displayed in yellow, orange and red while using power, and blue or green while regenerating power	Customer
Critique	The driver should not be able to change the motor brake level	Customer

Table 7.8: An exhaustive list of insights that were drawn from the feedback given in emails from the client company engineering team, sales team and one of their customers. Each insight is presented with a descriptive theme and the originators of the insight. The originators of the email are either the engineering team or sales team at the client company, or one of their customers, whose occupation was not disclosed, other than not being a terminal tractor operator. [Authors contribution]

Most of this feedback could easily be implemented to create a final concept. However, some of the evaluations were contradictory, like which concept to move forward with, or how one of the parties wanted to shift the gear and power, while the other preferred the power bar where it was. To discuss these discrepancies, and to gain more insights for the final iteration, we compelled CPAC and the client company to allow us a short interview to evaluate the concepts.

Evaluation Interview

The evaluation interview consisted of a short (20 min) semi-structured interview. The interview was conducted at the beginning of a hybrid meeting between CPAC and the client company and, as such, the room was full of various members of the project. A longer, one-to-one meeting with only the client company engineer would have been more effective but was not possible. Other stakeholders in the meeting provided some useful insights but also contributed to unnecessarily lengthy discussions on certain topics, taking away from the time that was available to us.

Participant	Affiliation	Occupation	Participation
1	Client company	Engineer	Remote
2	CPAC	Engineer	In-person
3	CPAC	Executive	In-person
4	CPAC	Project manager	In-person

Table 7.9: Four participants were present in the second iteration evaluation meeting, whereas we and participants from CPAC were co-located in a conference room, and the engineer from the client company was connected through a video call. [Authors contribution]

To further investigate the feedback that was given over emails in the previous evaluation, we prepared a series of questions for the interview, which acted as a basis for laddering. During the meeting, the three concepts were presented by sharing our screen where we had set up the concepts on a virtual canvas in Miro. As the participants had already familiarised themselves with the concepts, we deemed that they did not have to be thoroughly explained. The questions first regarded the overall feeling of each concept, why concept II.2 was regarded as their favourite, and why they proposed to incorporate certain features in concept II.3. Next, we went through each element of the design to understand how they perceived them, and to make sure that the choice of moving forward with concept II.2 did not come with undesired compromises in the features that are included in the concept. Finally, we discussed all the icons we proposed in the interface and some of the possible alternatives that were considered. During the interview, one of us led the questions, while the other acted note-taker and provided probing questions. This meeting was not recorded or transcribed.

After the interview, the notes taken during the meeting were translated into Miro, to get a better overview. An exhaustive list of insights drawn from these notes can be seen in Table 7.10. A summary of the most important insights are the following:

- The interface looks nice, the colours are good and it's clear and intuitive
- They like that the air gauge is circular and "gauge-like"
- The READY-icon is good and should be placed above the gear selection. Using green as the colour for it is good
- Retarder levels should be named High, medium, low, of
- Retarder setting should be in the menu and not accessed directly in the interface
- The battery icon should be used for state of charge and battery temperature, but ISO icons should be used for tell-tales
- The icon for operating hours could be confusing as it uses a symbol for an engine. The symbol should be changed to a motor symbol and we should maybe write "Motor Hours" in text as well

7.3 Iteration III

This final section will describe the third and last iteration of the *Create*-phase. In it, the results of the evaluations from the previous iteration will be used to converge into one final concept. This section will be short compared to previous iterations, partly since we spent less time in this iteration on diverging designs, and partly due to that the resulting concept and final evaluations will be described in Chapter 8 - *Final Concept* and chapter 7 - *Evaluate.*

Theme	Insight	**Originator**
Gauges	Using circular gauges for air pressure is nice, since it looks like a traditional air pressure gauge	Participant 1
Gauges	The state of charge could be displayed either as a circular or horizontal bar, along with a number	Participant 1
Gauges	In the state of charge gauge, being able to see the amount of time since last charging session is nice	Participant 1
Gauges	The effect gauge is clear and intuitive	Participant 1
Icons	The icons that are used for coolant temperatures are effective	Participant 1
Icons	The icon for the odometer is clear and looks nice	Participant 1
Icons	The icon for the odometer looks like it could be proposed by ISO as a standard	Participant 1
Icons	The icon for engine hours may be confusing since the tractor does not have an engine	Participant 3
Icons	The icon for engine hours should be swapped out for either an electric motor icon, or just a text that spells out "engine hours"	Participant 1
Icons	The tell-tales should use icons that are proposed by ISO	Participant 1
Icons	The propulsion battery icon proposed by ISO looks like symbolises a 12-volt battery	Participant 1
Icons	The battery icon in the battery coolant temperature gauge should match the battery icon in the state of charge gauge	Participant 1
Icons	The battery cell icon is more clear for the driver	Participant 1
Features	The retarder levels should be named "High, Medium, Low, Off" instead of "0,1,2,3"	Participant 1
Features	The retarder levels should be changed in the settings	Participant 1
Features	There should be a label that says "READY" when the high-voltage system is activated in the tractor	Participant 4
Features	The company logo looks nice in the bottom centre	Participant 1
Features	The orange accent of the concept is appreciated	Participant 1

Table 7.10: An exhaustive list of insights that were drawn from the evaluation interview with a client company engineer. Each insight is presented with a descriptive theme and the originator of the insight. The participant numbers are derived from the participant list, see Table 7.5. [Authors contribution]

7.3.1 Design Changes

From the evaluations in Iteration II, it was concluded that concept II.2 was overall the most appreciated, but needs a few changes. There were no major revisions, and each change could be implemented relatively quickly. However, some different diverging variations of the concepts were created, mostly to try different layouts and ways to design the effect meter and gear select that was switched based on the feedback. Of these variations, we could choose one, based on which one looked the most appealing.

A summary of the changes made is listed below. The most prominent changes are then discussed further in the following subsections.

- Made the state of charge into a horizontal gauge like in concept II.3
- Changed the engine hours icon into a motor hours icon
- Wrote "Motor hours" and "Miles" above respective icon
- Added an ignition indicator
- Redesigned effect and re-positioned power meter
- Redesigned and changed position for the gear select
- Added an icon for the current weather next to the ambient temperature
- Changed the tell-tales and dialogues to appear like in concept II.3
- Changed position and level names for the retarder
- Changed position of tell-tales and turn-signals. P-brake is now next to P
- Speedometer values go from 0-50 and mph are added
- The interface is shifted downwards slightly

Motor Hours

In the evaluation, it became apparent that the engine hours icon, which we believed was intuitive, needed to be changed. Since the terminal tractor doesn't have an engine, we were recommended to instead call it "Motor hours", and use an icon that best reflected this change. It was easy to redesign the icon, as instead of using the engine icon, we instead used the electric motor icon. Even though we were apprehensive about using the electric motor icon at first, we believe it worked quite well, and to make it extra clear what the icon represents, we also added the text "Motor hours" above the icon. The same addition was made to the odometer on the other side of the interface.

Switch Power Meter and Gear Status

A request from the evaluation was to switch the location of the power meter and gear status to make the latter more prominent. It was also mentioned that the power meter is not that important to the user. The gear status of concept II.3 was preferred, which was used in the final concept, but placed under the speedometer where the power bar was placed. The power bar was then placed into the speedometer, resembling concept II.3 but placed to the right of the speedometer and inverted, as the ignition status was decided to be left of the speedometer.

Refining Elements

Once the concept design was finalised, it was time to go ahead and refine the design concept. This meant cleaning up vector graphics, making them pixel-perfect, and consistent, and using the same fonts and colours uniformly. This made us recreate most elements from scratch, as most elements had not survived the several design iterations without a few bruises.

This also included redesigning some elements to make them look better. The battery icon, for example, was refurbished to be more clear and in line with the rest of the interface design. The menu icon also got some love, in the form of a more defined shadow and lighter colour to make it pop and intuitively afford interaction. As it was confirmed that weather information could be available for the tractor, it was also decided to bring back the weather icon together with the ambient temperature, as we had in concept II.3. This was a nice addition, as it made the ambient temperature more distinct.

7.3.2 Interface States

The interface can be in multiple different states, depending on the context. These states are OFF, IDLE, ACTIVE, CHARGING, and MENU. We created some design proposals for the CHARGING and MENU, although these were never evaluated, as they were deemed to be out of scope for the thesis. The other three states, however, were redesigned for the final concept and are evaluated together with the concept. See Figure 7.25 for the different states.

To indicate to the driver that the ignition is active, there are two main distinctions. The first is that the whole interface turns darker and less vibrant. Additionally, The "READY" label appears in bright green when the interface is ACTIVE and turns grey when it is IDLE.

Based on how the prototype for the terminal tractor is constructed right now, the screen will most likely have power even when the tractor is off. However, the system that reads values such as air pressure and the battery level is inactive. For this reason, we considered either using a "screen saver" consisting of the client logotype, or a completely black screen for the OFF-state. In discussions within the team at CPAC, it was proposed to show some values in the off-state. The values for odometer and operating hours are stored in the display memory and could potentially be shown

(a) OFF **(b)** IDLE **(c)** ACTIVE

Figure 7.25: Three images that show the three different states for the interface; OFF is when the terminal tractor is turned off, IDLE is for when the low-voltage is turned on, and ACTIVE is when the high-voltage that drives the motor is on. [Authors contribution]

in the OFF-state, which would be useful for operators as they would be able to take notes of the values without starting the ignition. However, we decided not to display any information on the OFF-screen as we believed it would be confusing whether or not the tractor was turned off or not.

7.3.3 Final Concept and evaluations

The final concept is presented in Figure 7.26. It is described in detail in Chapter 8 - *Final Concept*. The evaluations of the final concept are presented in the next chapter, 7 - *Evaluate*, which describes the next phase of the project process.

Figure 7.26: The final concept of the *Create*-phase. This concept is presented in more detail in Chapter 8 - *Final Concept*, and evaluated in Chapter 7 - *Evaluate*. [Authors contribution]

8

Evaluate Phase

The process is divided into three phases: *Understand*, *Create* and *Evaluate*. This chapter describes the final phase, namely *Evaluate*. It describes the final concept evaluation, the subsequent analysis of the data we collect during said evaluation, and how we propose the commercial project should continue.

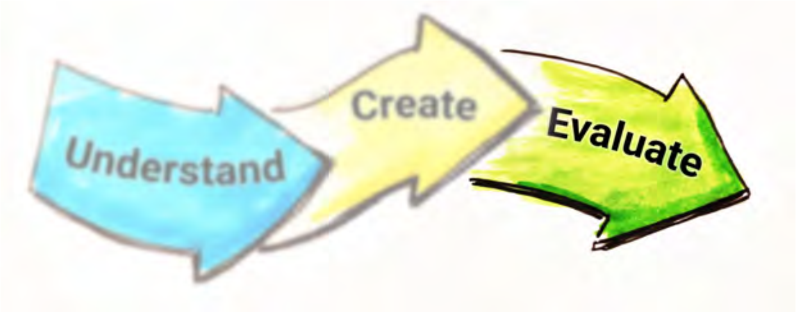


Figure 8.1: The project process is divided in three phases. This chapter describes the third phase, *Evaluate*. [Authors contribution]

8.1 Study Design

In the final evaluation, the aim was to validate the design decisions that were made in the development of the final concept. Specifically, we set out to investigate the core aspects of our research aim; how the design decisions affected the user experience and contributes to a comfortable transition. Rather than attempting to build a greater understanding of our users, the core goal of this activity was to investigate how the concept is perceived by the users.

Originally, the plan for evaluating the final concept was to conduct live observations of the design in action, together with operators in Gothenburg terminals. We also had plans to evaluate the concept in a simulator, which allows testing of dashboard interface applications with input devices and sensors similar to the actual terminal tractor. However, we underestimated the time and effort required to implement an interface in the Android application and overestimated the availability of operators in Gothenburg. Performing observations live with operators was not possible, since no contact was successfully established with operators in Gothenburg, and the simulator could not be used for testing the final concept, as the implementation of the concept would not be possible in the amount of time we had available. We were, however, able to once again arrange a meeting with an operator.

The final concept was evaluated in an interview with the same operator that we evaluated the initial five concepts within Iteration I, see Section 7.1.10. The optimal layout for this evaluation would be a longer one-to-one meeting, to discuss the concept, and all of the design decisions that went into it, with minimised influence and bias placed upon them by other participants in the meeting. However, due to circumstances at the time, we were only allowed a 30-minute discussion during a formal meeting between CPAC and the client company.

To accommodate the circumstances, we adapted the evaluation plan to a semi-structured interview that focused on a set of core questions that allowed the operator to freely share their thoughts on the design, using the think-aloud method. Consequently, we did not exhaustively employ the laddering method on every attribute that got identified. This meant that we could access a wide set of attributes, but would miss out on most of their consequences and underlying core values. As this would be the final evaluation, we deemed this approach to be suitable, as understanding the core values of users would arguably be more important in the early stages of a project, rather than in the final evaluation.

We were allowed to record the meeting to accurately transcribe what was said. Additionally, we were also able to focus more on conducting the interview, rather than noting down exactly what was said. However, we still chose to assign one of us to take notes during the meeting, as it helped us to revisit previously made comments since we more easily could keep track of what was being said during the meeting. We assigned the other one of us to facilitate the interview.

8.2 Participants

Excluding ourselves, there were eight other people in the discussion, all of whom were stakeholders of the project. Since the evaluation was conducted during a meeting between the two companies, most participants were project members that were already present from the previous discussion. Other than inviting the operator to the interview, we were unable to affect which people were present. The exhaustive list of participants is presented in Table 8.1. Since both CPAC and the client company are relatively small companies, no demographic information about the participants, except their affiliation and occupation, is not disclosed in this report, as that would further challenge the confidentiality of their identities. The affiliation, occupation, and whether or not they were present in person or participating through a conference call, are interesting aspects of the participants since these factors would be the most likely to have affected the results of the evaluation.

Participant	Affiliation	Occupation	Participation
1	Client company	Terminal tractor operator	Remote
2	Client company	Engineer	In-person
3	Client company	Executive	Remote
4	CPAC	Engineer	In-person
5	CPAC	Engineer	In-person
6	CPAC	Engineer	In-person
7	CPAC	Project manager	In-person
8	CPAC	Executive	Remote

Table 8.1: The list of participants during the final evaluation. No demographic information is provided to avoid disclosing the identities of the participants. Each participant is numbered for referencing, and each participants' affiliation and occupation is presented. In total, there were eight participants and two interviewers, one being the facilitator and the other being the notetaker. Participant 1 and 3 were co-located in the same conference room.

8.3 Apparatus

The meeting was conducted in a conference call, with participants 2, 4, 5, 6, and 7 being present in Sweden, in the same conference room as ourselves, participants 1 and 3 being co-located in a conference room in the USA, and participant 8 participating from a private location. The evaluation was run in Miro, on a computer that the interview facilitator had full control over. This computer shared what was shown in Miro to the conference call, which was shown on large displays in both conference rooms. Each participant in the conference rooms had a full view of what was presented in Miro.

Miro allows for full control during the presentation, so if any specific detail came into discussion during the meeting, the facilitator was able to redirect the presentation to that specific detail. Each feature that was planned to be presented during the evaluation was placed in proximity to each other, to accommodate these redirections, see Figure 8.2.

The evaluation targeted comments of praise, critique, and insight as to the resulting data. Since the meeting was recorded, each point of feedback could be derived from its specific quote and originator.

8.4 Procedure

The plan for the evaluation was a semi-structured interview, with multiple themes of discussion. The interview script that was prepared before the interview can be seen in Appendix A. We wanted to relate the interview questions as much as possible to the research aim of the project. Therefore, the majority of questions that were prepared in the script discussed how design choices affected the transition from

Figure 8.2: The setup in Miro for the final evaluation. The figures in Miro were separated into three different stages, as highlighted by 1, 2 and 3. The first stage was used to present the main interface of the concept, the second stage explored deeper how each feature was perceived, and the third stage showcased the three different ignition states of the interface. [Authors contribution]

traditional tractors and the overall user experience. To design effective questions, we considered the utility and usability of the user experience and could design questions to specifically focus on each of those aspects. Furthermore, even though there were eight participants in the evaluation, each question was specifically directed towards participant 1, the operator, as their input would be the most relevant. Insights provided by the other participants derive from discussions that erupted based on feedback given by the operator.

The meeting started with some small talk between the participants to get everyone to feel a little bit more comfortable before the interview started. We made sure that each participant consented to us recording the meeting and using their quotes in our report. Furthermore, we informed them about the plan for the interview, and that the interview intended to evaluate the final concept of the dashboard interface. The interview then started with questions about the user experience of the concept, either directly or through the use of laddering. While asking these questions, we presented two different states of the main interface in the concept, as seen in Figure 8.2. A few examples of asked questions were:

- How do you feel about the concept? What are your thoughts and impressions?
- Is there anything in the interface that can be misinterpreted?
- Do you think the information in the interface can be interpreted efficiently?

We repeatedly asked the operator to think aloud when they observed the concept, to hear their thought process. This was particularly useful when presenting the main interface, as it best represents how the interface will be perceived by drivers in the future. After discussing the user experience of the concept, we moved on to investigating how the interface contributed to a comfortable transition. These were some of the questions for this section of the interview:

- Do you find it difficult to adapt to the new interface?
- Say a port was to only buy a couple of these new electric tractors, and a driver would have to switch between using an electric and a diesel-driven tractor. How comfortable would that switch be for the driver?
- Does the use of redundant gauges make transitioning to the electric tractor easier?

Discussing the user experience and transition were the core topics of the interview, but investigating how the specific gauges and different ignition states of the interface were perceived by the operator was also deemed to be important. Therefore, we started by going through each gauge individually in Miro, asking generally how they liked each gauge, and if they could interpret it easily. The same was then done with the different stages of ignition. The figures we used for presenting the gauges and ignition stages can be seen in Figure 8.2.

8.5 Results

The concept was received well by the operator and was praised both generally, and specifically, by complimenting the entire concept and certain features explicitly. They made sure to tell us several times that the interface was clear and intuitive. And when asked whether or not the interface had all the necessary features, they responded that it covers everything, and proceeded to point out the most important gauges, and finished by saying:

> *"I mean, you even got a clock on there, and what degree temperature it is! That's pretty nice."*

However, when asked if anything could be misinterpreted in the interface, they pointed out that on the *brake level*-gauge, whenever the retarder is turned off, the interface reads "Brake level - Off", which could be interpreted as the brakes being unavailable. Furthermore, they were initially confused by the power gauge, but after explaining its behaviour they said:

> *"After y'all explained it, it's pretty simple. Yeah, that makes sense to me."*

We made sure to specifically probe the operator on how they believed the transition between traditional and electric tractors would be affected by the interface, as it relates directly to our research aim. Generally, they told us that the concept is pretty self-explanatory, doesn't look too different from traditional dashboards, and it would be easy to adapt to the new interface. They told us that, however, older generations of terminal tractor operators may slightly distrust the new interface. They were however implying that transitioning for the older generation operators could not be too troublesome, and followed up by saying:

> *"They gonna have to get used to electric anyway."*

The operator, who is middle-aged, said that their generation is used to interfaces resembling the final concept. They believe that keeping the analogue gauge in the interface was a good design choice to make it easier for older generations to interpret the dashboard. When asked about how using redundant gauges could affect the transition between tractors, they told us:

> *"Yeah, [redundant gauges] does make it easier."*

We concluded the interview by talking about the different stages of ignition in the interface. They liked having most elements greyed-out to portray that the tractor is inactive. At this point in the interview, we were informed by the executives of the project that they had decided to switch the greyed-out "Ready"-label in the idle-state interface to a greyed-out "Off". Unfortunately, we were unable to get an unbiased opinion on this decision from the operator, as the unanimous opinion of the executives was clearly stated before we asked about the operator's opinion. They agreed with the previously stated opinion.

To summarise the data collected from the evaluation, we conducted a thematic analysis, see Figure 8.3. We started by transcribing the recorded meeting with the help of a transcription tool in Microsoft Word, as done after the operator evaluation in Iteration I, see Section 7.1.10.1. We then printed out the transcribed interview and started coding the text with the following labels:

- Praise
- Intuitive
- Criticism
- Suggestions
- Uncertainty
- Transition
- Operator perspective

After having coded the interview, we transferred the highlighted sentences and phrases to Miro, where we created a sticky note for each. By moving and grouping these coded phrases around the virtual whiteboard, we could visualise the inherent themes of the sticky notes. The largest identified themes touch on the topics of transition, colours, praise and proposed changes.

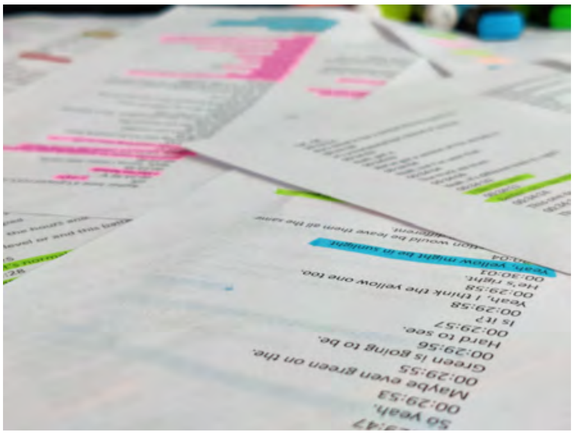


Figure 8.3: An image from the thematic analysis conducted on the final evaluation. The various colours show phrases that have been coded. [Authors contribution]

By using the thematic analysis we could draw some specific conclusions from the evaluation. An exhaustive list of these conclusions are presented in Table 8.2.

Theme	**Conclusion**	**Originator**
Transition	The interface does not feel too different from old dashboards	Participant 1
Transition	Operators will trust the new interface equally	Participant 1
Transition	It's easy to adapt to the new interface, and switch between them	Participant 1
Transition	The new interface is self-explanatory and intuitive	Participant 1
Transition	Older generations of operators may distrust the new interface	Participant 1
Transition	"[the older generation] will have to get used to electric either way."	Participant 1
Transition	Redundant gauges makes transitioning more comfortable	Participant 1
Colours	The colour palette is good	Participant 1
Colours	The colours used in gauges are intuitive	Participant 1
Colours	Sunlight may affect the visibility of certain colours	Participant 3
Icons	All icons and tell-tales are clearly interpreted	Participant 1
Icons	The static tell-tales should be grouped together	Participant 1
Praise	The interface is generally appreciated	Participant 1
Praise	The interface is clear, intuitive, and easy to read	Participant 1
Praise	The interface feels safe	Participant 1
Praise	The interface covers all necessary features	Participant 1
Praise	The more tight grouping of gauges is better than in old dashboards	Participant 1
Praise	The redundant gauges look good	Participant 1
Praise	Air pressure looks better as a circular gauge	Participant 1
Praise	The power gauge is only clear after explanation	Participant 1
Praise	The power gauge will be easier to understand when driving	Participant 5
Praise	By removing the unit, the power gauge gets less confusing	Participant 1
Change	Brake level is not important to display to the driver	Participant 1
Change	Brake level should be changed to motor brake	Participant 1
Change	The READY-label should be changed to "OFF" in the OFF-state	Participant 7

Table 8.2: An exhaustive list of conclusions that were drawn from the thematic analysis performed on the data we collected from the final evaluation. Each conclusion is marked with the theme it was categorised as, and the originating participant. The themes are derived from the thematic analysis, but "Proposed changes" has been shortened to "Change" in the table. The participant numbers are derived from the participant list, see Table 8.1. [Authors contribution]

8.6 Project Continuation

This section describes how we propose the commercial project should continue regarding the final concept. Much of the work in this project aims to create an interface that visually comforts the user in their transition from traditional terminal tractors to electric. Due to the amount of time it takes to implement an interface to a working prototype, we have been unable to evaluate both the visual aspects of the interface and its behaviour in the context of driving a terminal tractor. Rather, we have trusted the expertise of one operator and the many stakeholders of the project to accurately assume how the interface would behave and be perceived once it's in production. Therefore, we identify user testing of an implemented prototype as the most important future work in this project. Doing this could validate the findings of our project.

From the final evaluation, some suggestions were made to improve the interface further. Namely, revising the naming of "Brake level" to "Motor brake", as well as considering its placement. Furthermore, the "Ready"-label that identifies the ignition status of the vehicle should be changed to "Off" whenever the vehicle is idle.

9

Final Concept

The final concept is the result of design sprints in three iterations, see Chapter 6 - *Create.* The concept was evaluated with an operator and stakeholders from both CPAC and the client company, see Chapter 7 - *Evaluate.* This chapter presents the final concept as it was designed in Iteration III, going into more detail on its behaviour and features. First, we will introduce the concept both as it would be perceived during normal operation, and with all hidden elements visible. Then, each feature of the concept will be described in detail, starting with gauges and concluding with the different interface states. Finally, a design specification is provided to describe the colours and fonts used.

Note: Some of the numbers used in the concept do not represent the performance of the final product, and are solely used for visual comparison.

During normal operation, see Figure 9.1, the interface efficiently presents vehicle information to the driver. Large, bold digital values, combined with analogue dials and bars, makes the gauges both easy to glance at, and easily adopted. The speedometer is centrally located in the interface, along with the ignition indicator to the top left of the speedometer and retarder level on the bottom left of the speedometer. To the right of the speedometer is the effect gauge, and underneath the speedometer is the gear status. In the left section of the interface are the two air pressure gauges, and in the right section are the state of charge as well as coolant temperatures for the battery and motor. In the bottom left and bottom right corners are the motor hours tracker and odometer respectively. The clock and ambient temperature are placed in the top left corner, and the button to access the settings menu is placed in the top right corner.

Figure 9.1 only displays the most commonly observed version of the interface, as some elements only appear during specific, infrequent, moments of operation. In Figure 9.2 are the otherwise hidden elements of the vehicle displayed.

The interfaces utilise a dynamic system for displaying most tell-tales. The top section of the interface is reserved for displaying tell-tales that are uncommonly encountered, each of which allows for the opening of a dialogue box underneath it. The tell-tales for high beam, seat belt and parking brake are instead placed in the rest of the interface, as these are more commonly encountered and would only

Figure 9.1: The final concept for an electric terminal tractor dashboard display. This it the same design as in Iteration III, and how it was evaluated in Chapter 7 - *Evaluate*. [Authors contribution]

restrict the space of critical tell-tales if they, too, were placed in the top section. The turn signals are placed along the sides of the dialogue box.

ABS brake fault. Please drive carefully and contact your service technician

Figure 9.2: The final concept. In this Figure additional elements that are hidden during normal operation are presented. [Authors contribution]

9.1 Features

The final concept contains multiple different gauges and elements that monitor a wide range of information which must be displayed to the driver. To best portray each source of information, every interface element needs to look and behave in a specific way. In this section, we will describe each major feature of the interface and how they behave to display information to the driver. To describe each feature, we start by explaining the value which is addressed by the element, after which we introduce the design of the gauge. Finally, we describe how the design of the feature will behave based on the different states of information it intends to display.

9.1.1 Speedometer

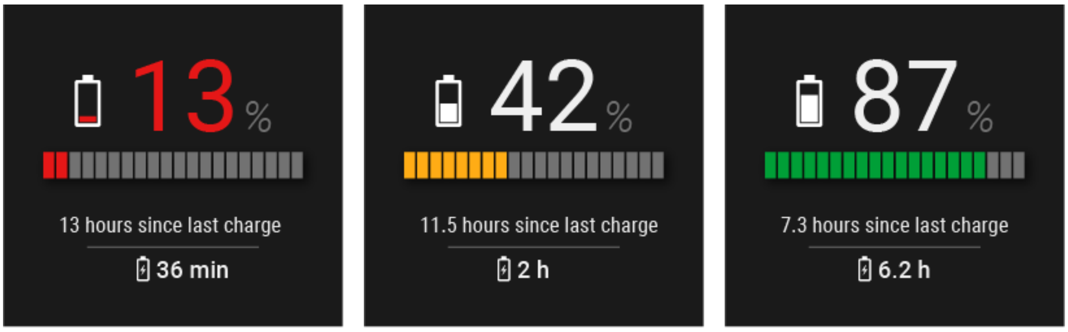
The value of the speedometer describes the speed that the terminal tractor is travelling in. The speedometer is important to know for the driver to make sure they do not drive too fast and stay within the legal speed limit. The speedometer gauge has two components: the digital number and the analogue dial, see Figure 9.3. The unit of speed is displayed to the right of the number, which is miles per hour (mph) in the final concept. The new electric terminal tractor will be able to reach speeds just over 30 mph under normal conditions, however, the analogue gauge ranges between 0 and 50, as specified to us by stakeholders. Rather than having superfluous animations or delays, both values update immediately to accurately tell the speed of the vehicle at all times. The bar trailing the dial in the analogue gauge always extends between 0 and the current value, stylised with a soft gradient. The bar and dial are separated by a small distance, to make the dial more visually distinguishable. This means that when the dial points to 0, this bar will effectively be invisible.

(a) 0 mph **(b)** 25 mph

Figure 9.3: Two versions of the speedometer. The rightmost figure depicts the speedometer at 25 mph, with a bar trailing the dial from 0 to 25. The leftmost figure, however, is at 0 mph, without any bar. [Authors contribution]

9.1.2 State of Charge

This value describes how much charge is available in the propulsion battery of the vehicle, that is, the battery which is used to operate the terminal tractor. The rate at which the battery depletes is directly affected by how the tractor is operated, as displayed by the adjacent effect gauge. The gauge is displaying the state of charge with a number, a battery icon, as well as a horizontal bar with 20 cells, see Figure 9.4. Furthermore, the time since the last charging session, and a range estimation in hours, are provided to the operator. The number accurately describes the current state of charge in the battery, while the icon and horizontal bar visualise the state of charge more abstractly. The cells in the horizontal bar only show full or empty, which means that they can only visually represent 5% increments or decrements in charge. This way, whenever a cell turns grey, the driver is more likely to notice the difference. The cells are rounded down from the value, which means that only a full 100% charge will return a full set of cells. Likewise, at 0-4% battery, all cells will be empty. When the state of charge reaches 50%, the battery bar will switch from green to yellow, and once it reaches 20%, the number, icon, and bar will all be displayed in red, with the intent to alert the driver about the critical state of charge.



(a) 13% charge **(b)** 42% charge **(c)** 87% charge

Figure 9.4: Three versions of the state of charge element. From right to left, the figures depict a progressively more depleted state of charge. The charge is presented with a number, the volume inside a battery icon, and a horizontal bar with 20 cells. The remaining lit cells in the bar go from green to yellow to red, and in (a), the text and battery icon volume are also red. In all versions, underneath the bar, are the time since the last charge and range estimation displayed with arbitrary values. [Authors contribution]

9.1.3 Effect

Traditional terminal tractor dashboards usually have tachometers to display the engine speed, which is not relevant for an electric motor. Instead, the electric tractor will display the effect of the motor.

The effect meter is located to the right of the speedometer. It is a vertical meter that fills up with a blue bar when power is applied to the tractor. When the tractor is braking, it starts regenerating power, and the effect meter then goes below the horizontal line. When this happens, the bar turns green, and an icon that symbolises that the battery is regenerating energy is displayed next to the meter. See Figure 9.5 to observe the different states of the power meter.

The meter does not show any unit, although it is measured in kilowatts. Users will hopefully understand the meter quite intuitively as it correlates to the speed they drive and the amount of pressure they apply to the accelerator. The effect can be understood in an abstract sense and adding a unit was deemed to only make it more confusing.

9.1.4 Pressure

The air pressure gauges display the amount of pressure in each of the two pressure tanks on the terminal tractor. They are crucial to observe while driving, as the air pressure controls the brakes of the tractor and trailer, and low pressure means the brakes cannot operate properly.

The gauges use a circular bar with a dial, that visually represents the pressure, additionally, the large number inside the circular bar accurately tells the current

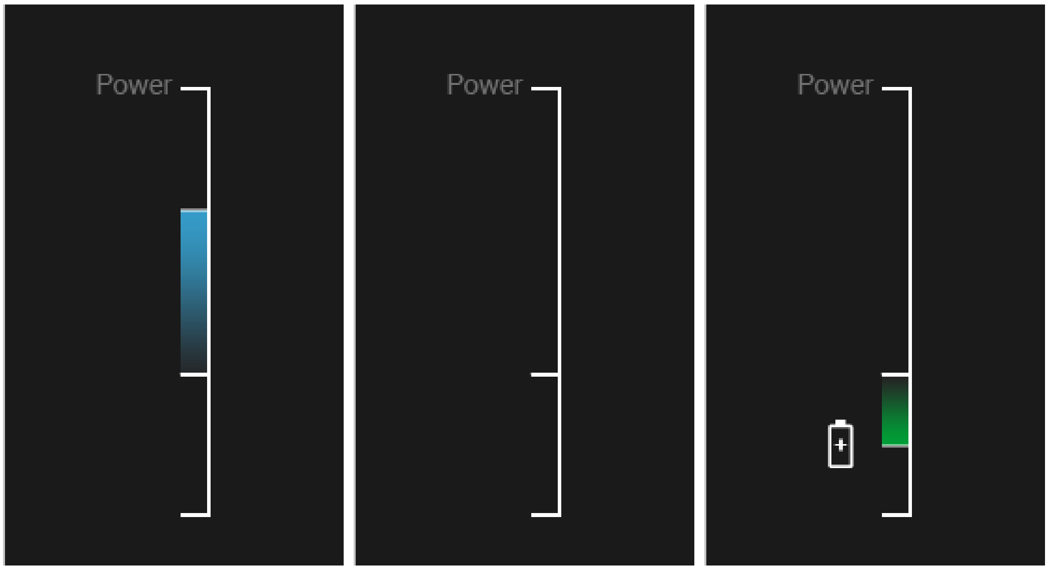


Figure 9.5: The effect meter. It fills up with blue when power is used. When braking the tractor regenerates power and the bar goes negative, while turning green and a battery-regenerating icon is displayed [Authors contribution]

value, above which the unit of measurement, psi, is described. The visual bar has a cut-out at the bottom of the circle, with which an icon that describes which air tank the gauge corresponds to. Above the icon are the values which the gauge spans between, which is 0-150 psi in the new terminal tractor.

(a) Normal value **(b)** Critical value

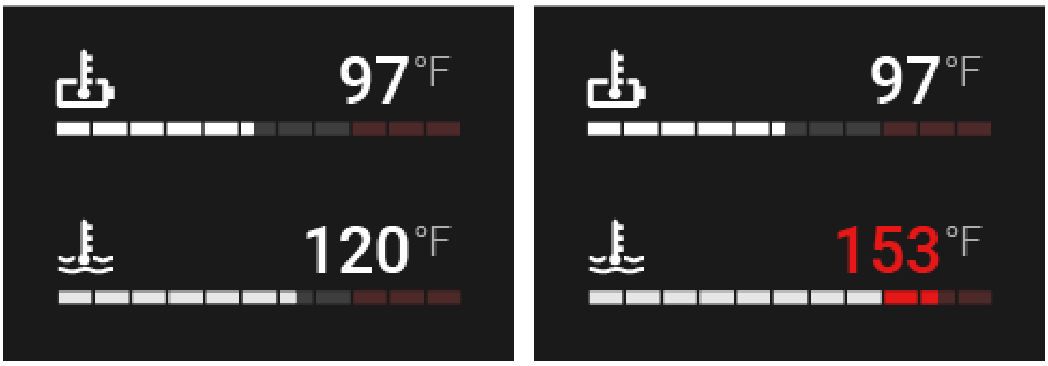
Figure 9.6: Pressure gauges. The left gauge is for the first tank, and the right for the second, distinguishable from the 1 or 2 in the bottom icons respectively. In this example, the first gauge displays a normal value, while the second is running low, displayed by the dial being in one of the red zones, as well as the central number and icon turning red. [Authors contribution]

Inside the circular bar are two red lines which indicate the critical values outside a good working range. See Figure 9.6 for an example of how the gauge changes for a normal and critical value. These critical ranges are whenever the air pressure goes below 90psi or above 120psi. These values are derived from specifications provided to us by stakeholders. When values are in these critical zones the number and icon in the gauge will turn red to draw more attention. The interface also shows a dialogue warning message, and an alarm will sound.

9.1.5 Temperature

The temperature meters are located in the bottom right part of the interface and display the temperature of both the motor coolant temperature and the temperature of the batteries. The meters consist of a horizontal progress bar that fills a set of short cells, an icon, and a number to show the temperature, with its corresponding unit of measurement. See Figure 9.7.

The icon for motor coolant temperature is the icon commonly used to represent engine coolant temperature, which was found to be intuitive for motor temperature as well. The icon for battery temperature consists of a battery-cell symbol with a thermometer, inspired by the icons proposed by ISO (ISO, 2022).



(a) Normal values (b) One critical value

Figure 9.7: Temperature meters. In both images, the top meter represents the battery temperature and the bottom represents the motor coolant temperature. The left image shows both temperatures within normal values, while the right image shows the motor temperature at a critical value. The numbers presented are for visual reference and do not represent the actual product specification. [Authors contribution]

The visual part of these meters consists of a bar divided into 11 grey cells that progressively light up as the temperature increases. Each cell can either light up partially or completely. At critical temperatures, the number will turn red, and the part of the bar that is over the critical level threshold lights up in bright red, see Figure 9.7b.

The progression bar does not, however, have a defined maximum and minimum value in the concept, as it has not been defined by the stakeholders. Working temperatures and critical values are not known. It should therefore be noted that the values presented are probably not reflective of the actual working temperatures.

9.1.6 Brake Level

The regenerative braking level, or retarder level, of the electric terminal tractor, can be adjusted to three different settings, each applying progressively more braking force. The interface informs the driver which brake level state that is active with the brake level indicator which is placed to the bottom-left of the speedometer, see Figure 9.1. The different levels of braking force, which can be observed in Figure 9.8, are Off, Low and High.

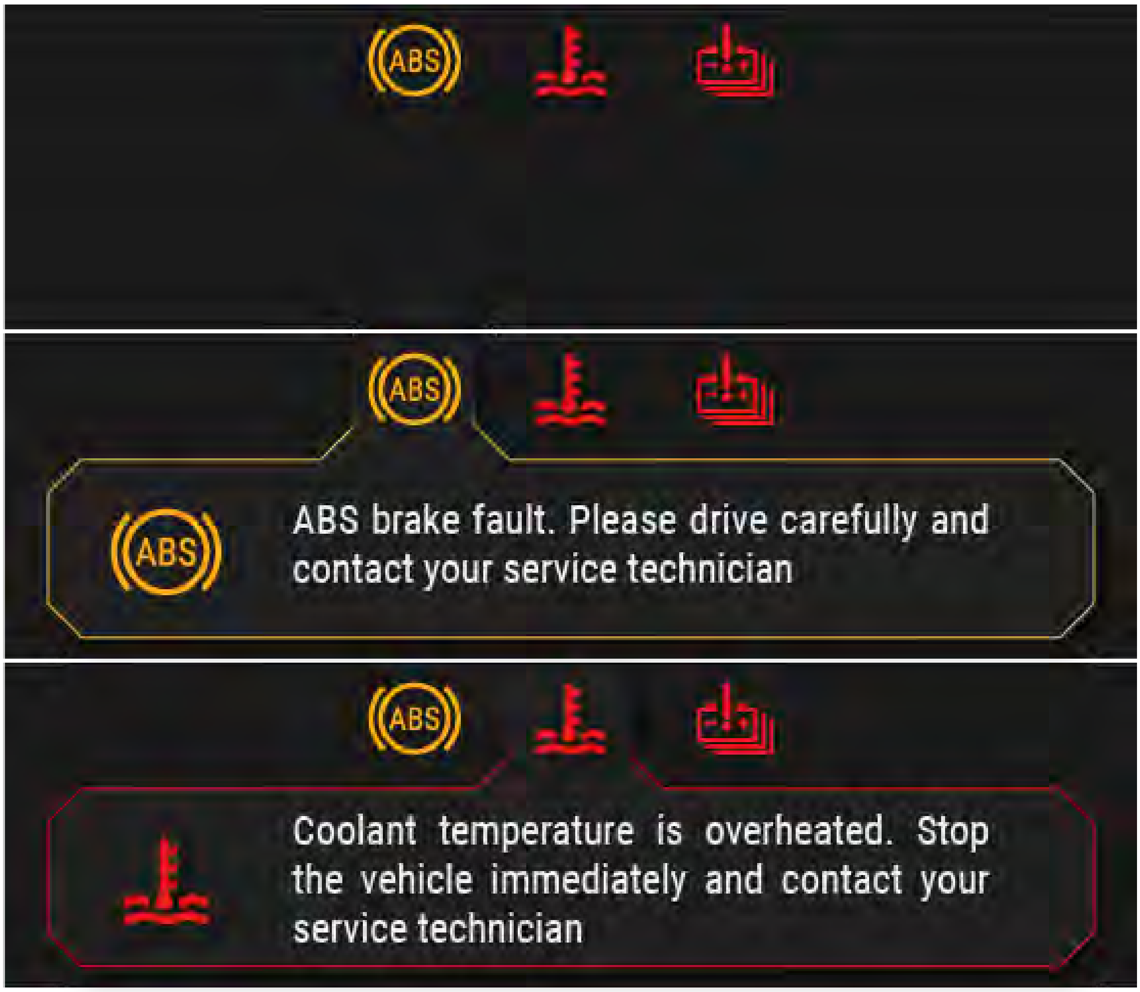
Figure 9.8: The brake level indicator. The three levels that can be selected can be observed in the image. These levels are Off, Low and High. [Authors contribution]

The level "Off" will provide no braking force, and the level high is speculated to have such a strong braking force that the interface potentially needs to present a warning dialogue when the tractor has this setting active. In the final concept, the driver can change the brake level as a setting in the menu. However, much about the retarder is unknown to the stakeholders before the prototype is developed further and tested in more depth. Therefore, the number of brake levels that will be in the final product, and how the user will be interacting with them, is unspecified.

9.1.7 Tell-tales and Diagnostics

During the operation of a road vehicle, the driver must be informed about its status and health. By using a set of tell-tales that light up to alert the driver of a specific hazard, critical information can be delivered at a moment's notice. These tell-tales range from low-impact informational indicators like reminding the driver about their currently set brake level to critical warnings like the battery overheating. Colour is frequently used to categorise tell-tales by their implication. Red implies that the vehicle can not, or should not, continue driving, e.g. whenever the parking brake is engaged. Yellow, or amber, implies that the vehicle has encountered a malfunction, e.g. the ABS brakes have disengaged. Blue simply notifies the driver about the vehicle status, e.g. to refill the washer fluid.

The concept displays uncommonly encountered tell-tales at the top of the interface, see Figure 9.9. In this section, all tell-tales share the same location dynamically, aligning any active tell-tales to the centre of the interface. By not having a static



ABS brake fault. Please drive carefully and contact your service technician

Coolant temperature is overheated. Stop the vehicle immediately and contact your service technician

Figure 9.9: Three figures showing different states of the tell-tales at the top of the interface. The uppermost figure shows tell-tales as they would appear without any dialogue box. The centre figure shows the same three tell-tales, with an amber tell-tale having an open dialogue. The downmost figure, instead, displays the dialogue of a red tell-tale. *Note: The messages shown do not represent the messages in the final product.* [Authors contribution]

location for the over 20 tell-tales available, tell-tales can be increased in size and always be displayed in a clearly visible location. However, the final concept displays the tell-tales for the parking brake, high beam and seat belt in static locations on the interface, as these are commonly encountered and if they were placed with the other icons at the top, they would only restrict the space of more critical tell-tales.

Whenever a new tell-tale is activated, a dialogue box will appear underneath it, describing the icon further. The warnings can be manipulated by the driver by tapping the tell-tales to open or close the dialogue box. The tell-tales remain at the top of the interface until they are dealt with. If two or more tell-tales would occur at the same time, their respective dialogue boxes would cycle every few seconds until they are manually closed or the problem is dealt with.

9.1.8 Ignition states

The interface has three different stages that it can be in, depending on if the tractor is turned on and if the high-voltage system is active or not. These three states are OFF, IDLE and ACTIVE. The interface is in the OFF-state whenever the vehicle is not turned on. The IDLE-state is activated once the terminal tractor is turned on, but only with the low-voltage system active. In this state, some of the features of the tractor and the interface can be accessed, but the tractor cannot be driven. The last state, ACTIVE, is engaged when the high-voltage is active, which allows the tractor to be driven.

(a) OFF **(b)** IDLE **(c)** ACTIVE

Figure 9.10: The three stages of the interface, namely OFF, IDLE, and ACTIVE. The interface is OFF when the tractor is off, in IDLE when its turned on but the high-voltage inactive, and ACTIVE once the high-voltage is active. [Authors contribution]

The interface for the OFF-state consist of a simple black screen, see Figure 9.10a. To enter the next state, and interact with the interface, the user would turn on the tractor with a key. In this state, most of the interface is greyed out and the colour of the pressure gauges is removed, see Figure 9.10b. Some of the features, like the battery state of charge, odometer, motor hours and clock, are clearly visible, as we believe these are still useful for the driver while in the IDLE state.

To enter the ACTIVE-state, see Figure 9.10c, the driver cranks the key like they would start a traditional terminal tractor, which turns on the high-voltage system in the tractor. The colour of the interface will then return and the ignition-state label to the top-left of the speedometer will turn from grey to bright green, see Figure 9.11, indicating that the tractor can drive.

Figure 9.11: State of ignition indicator. The icon will be grey in the IDLE-state and turn green to indicate the ACTIVE-state. In the ACTIVE-state, the tractor is able to be driven, whereas in the IDLE-state, the interface only displays some information. It's important for the driver to know which state the tractor is in, to not mistakenly press the accelerator when they believe that the tractor is idle. [Authors contribution]

9.2 Design Specifications

In this section, some of the technical information about the design styles for the interface are presented. These include the type of font that is used, along with their sizes, and the colour palette.

Colours

There are only a handful of main colours in the interface. The base of the interface is built using black, white and grey. Then there are four additional colours used. The orange and blue are immediately derived from a catalogue produced by the client company. The green and red colours were selected to match those.

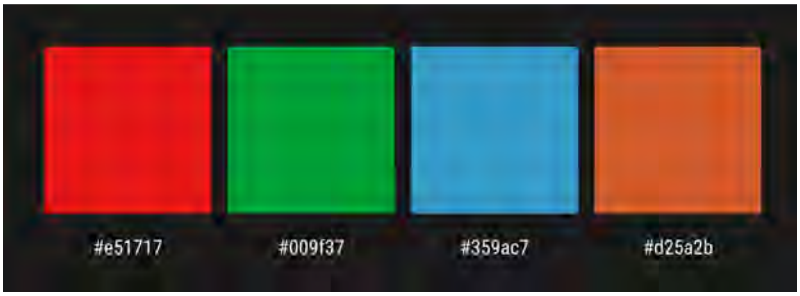


Figure 9.12: A colour palette showing the main four colours that were used in the design of the interface: red, green, blue, orange. The exact hex codes are appended to the colours. [Authors contribution]

Apart from these more primary colours, blue, amber and red are used for tell-tales and dialogues. These are standard colours to use for information, malfunctions, and critical errors respectively in dashboard interfaces.

Font and Text Sizes

The entire interface is created using the font families Roboto and Roboto Condensed. Both are free fonts that are developed to be efficiently read on digital screens, which makes them a suitable choice for creating simple and effective interfaces. Roboto condensed is used for longer text in the interface, namely the "time since last charge"-label and text in the dialogue box.

Different font weights, font sizes and shades of grey were used for various text in the interface. Figure 9.13 shows a collection of the different combinations of font, weight, and colour for different parts of the interface. The specification is not exhaustive, as a few elements differ from it.

Figure 9.13: A specification of the fonts used in the interface for numbers, text, and units. Each font is categorised in either "Text", "Number" or "Units", with each category also presenting its range of font sizes. [Authors contribution]

The numbers in the interface are white to contrast the black background. Bigger numbers use regular weight, while some smaller numbers have a higher weight to stand out more. The units, for example, the psi in the pressure gauges and the % in the state of charge, are coloured grey to be less prominent and make the interface less cluttered. These do not need to be monitored, as they would effectively never change, but still prove important for the completeness and understanding of the interface and adds an aesthetic bonus.

10

Results

This chapter presents the concepts which were produced in the first two iterations of the project, as well as the insights gained from the design process. The final concept has already been discussed in the previous chapter, so in this chapter, each concept leading up to the final iteration will be presented, and then discussed with regard to any valuable feedback derived from its evaluation. Finally, the insights and learnings derived from having conducted this design process will be brought up, stemming from evaluations and personal takeaways from working on the project.

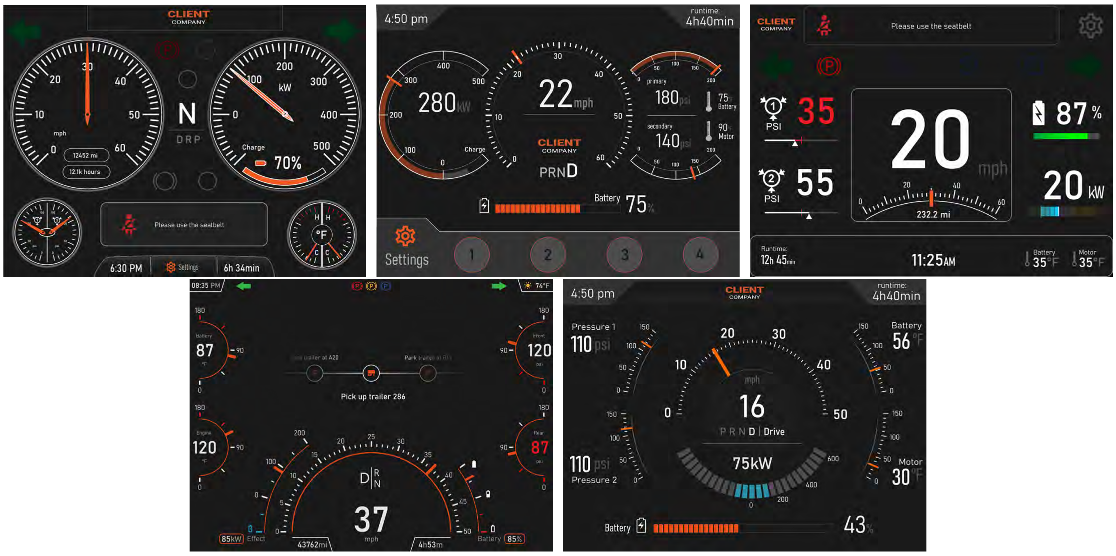
10.1 Earlier concepts

The process consisted of three iterations. For the first two iterations, several concepts were developed for the sole purpose of giving a wide basis for discussion during evaluations. These portray the progression towards what later became the final concept in the third iteration. They are an important part of the result as they explain what worked, and what didn't, in the context of designing an interface for a terminal tractor.

10.1.1 Iteration I

In the first iteration, the goal was to be divergent and explore the design space of terminal tractor dashboards. Therefore, the concepts from the first iteration aimed to portray a wide range of directions in which the project could progress. As we had little to no information to go about regarding how the interface should be designed, the solution was to be divergent and try a lot of ideas. Several concepts were developed, and five of these, which could resemble a good divergent design space, were selected for evaluation.

These five concepts can be seen in Figure 10.1. Each concept is experimental in one way or another, and by evaluating all of them together with stakeholders and a user we could figure out what ideas and elements to discard or keep for the next iterations.



Please use the seatbelt

Pick up trailer 286

Figure 10.1: The five concepts that have been created in the first iteration of the Create-phase. They are developed to be divergent and exploratory of the design space. [Authors contribution]

Concept I.1

The first concept (Figure 10.2) in this iteration is an attempt to preserve the analogue gauges from a traditional terminal tractor dashboard in the new digital display. Most values from the operation of the vehicle are displayed with an analogue gauge that borrows its design from gauges in the client company's previous tractor model. The two largest gauges show speed and effect, respectively. In the speedometer, there is also an odometer and engine hour tracker. In the effect meter, the state of charge is displayed with a bar and the exact value. The bottom left gauge is showing the values in the front and rear pressure tanks, whereas the bottom right gauge displays the engine and battery temperature. In the centre of the interface, a gear selection feature has been introduced. At the bottom of the interface is a small bar with a clock, a button for accessing a settings menu, and the current runtime. Above this bar is a box for displaying diagnostic messages.

Concept 1 gave many insights into how analogue gauges are regarded. We expected that analogue meters would be less efficient and would not be perceived as modern, but would still be preferred by the user due to their legacy bias. However, we ultimately concluded that operators prefer the gauges to be more digital in an electric tractor, as analogue gauges were frustrating to use.

This concept design was also helpful in understanding the importance of the air pressure and temperature gauges. During the interview with the operator, they firmly stated that these gauges were too small, and should be increased in size for the final product.

Please use the seatbelt

Figure 10.2: Concept 1 from Iteration I. This concept focused on preserving analogue gauges from the traditional terminal tractor dashboard interface. [Authors contribution]

Concept I.2

Concept 2 (Figure 10.3) tries to encapsulate a sporty feeling in how it portrays its information. It uses redundant meters for most values, with equal emphasis to the analogue and digital counterparts. The left, central and right gauges display the effect, speed, and combined pressure respectively. The state of charge is placed as a very prominent bar and percentage below the gauges. Furthermore, concept 2 also introduced how a settings menu could look in an interface, albeit with arbitrary settings at this point. Below the speedometer value in the centre is an odometer. Above the state of charge bar is the gear selection. In the top left and right corners of the interface are a clock and a runtime tracker.

This concept was generally received well as a sporty concept. The operator concluded that it was much clearer than the first concept, whereas stakeholders from the client company argued that it was confusing what each gauge represented, as well as the temperatures were too cluttered.

Figure 10.3: Concept 2 from Iteration I. This concept tries to encapsulate a sporty feeling, heavily adopting the use of redundant gauges to both clearly present the information while giving a dynamic feeling to the interface. [Authors contribution]

Concept I.3

The third concept of the iteration (Figure 10.4) is a stripped, minimalistic version that aimed to reduce the amount of clutter and size of analogue gauges while increasing the size of their digital counterparts. The leftmost gauges display the air pressure, the central gauge displays the speed, and the rightmost gauges display the state of charge and the effect. At the bottom of the speedometer is an odometer, and at the bottom of the interface is a bar that displays the runtime of the tractor, a clock, and the coolant temperatures. At the top of the interface is a box for displaying diagnostic messages, to the right of which is a button for accessing settings.

This concept was the most appreciated in both the evaluations with the client company, as well as with the operator. They valued the readability and simplicity of the design, as well as its boldness. It was, however, criticised for not emphasising the temperature value enough.

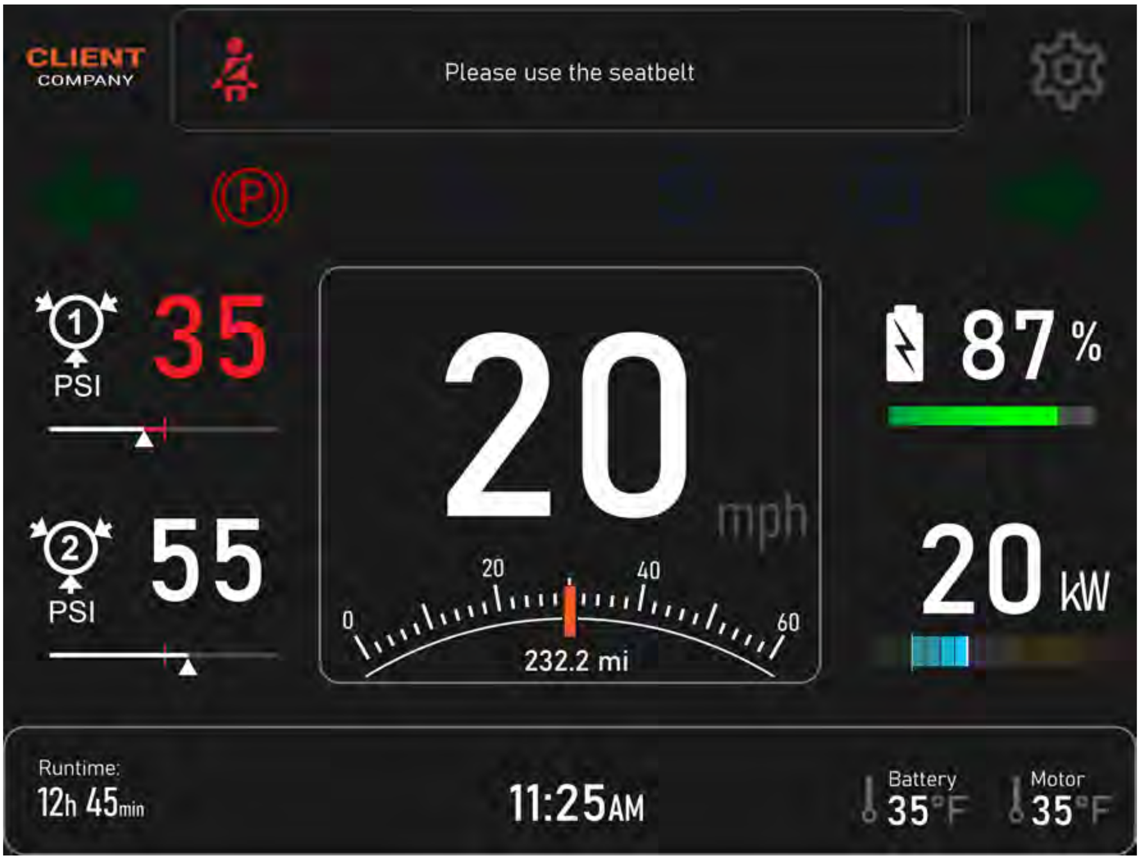


Figure 10.4: Concept 3 from Iteration I. This concept is a stripped and minimalistic interface that focuses on clearly presenting the information with large, bold numbers, instead of using analogue dials. [Authors contribution]

Concept I.4

Concept 4 (Figure 10.5) speculates with its design on how a fleet management system could be incorporated into a terminal tractor dashboard interface, which can be seen in the centre of the interface. Conveniently, it also experiments by moving the speedometer to the bottom of the screen, investigating if it could be placed in a less prominent location of an interface. The air pressure gauges and temperature gauges are placed along the edges of the display, to the right and left, respectively. The state of charge and effect is also reduced in size and placed along the side of the speedometer. At the bottom of the speedometer is an odometer and a runtime tracker, and above the speedometer number is the gear selection. In the top left and right corner of the interface is a clock and the current outside weather, respectively.

While the fleet management system would be a nice addition, according to the operator we interviewed, they believed that the amount of infrastructure needed for the system is far into the future. Other than that, the concept had several issues like the speedometer being too low, the gauges being too spread out over the interface as well as the gauges being too confusing due to their appearance neither resembling traditional dashboards nor being clear enough.

Figure 10.5: Concept 4 from Iteration I. This concept speculates how a fleet management system could be incorporated in a terminal tractor dashboard interface, taking up a central location in the interface. [Authors contribution]

Concept I.5

The fifth and final concept of this iteration (Figure 10.6) tries to efficiently use the circular shape of traditional gauges to combine all the gauges in a singular shape. The central gauge displays the speed, underneath which is the effect meter. The leftmost gauges display the front and rear air pressure levels, and the rightmost gauges display the temperatures of the battery and engine. At the bottom of the screen is the state of charge, displayed as a bar and a corresponding number. Below the digital number of the speedometer is the gear selection. In the top left and right corners of the interface is a clock and the runtime.

Insights collected from the evaluations of concept 5 were contradictory. On one hand, the operator argued that the concept was well-balanced and clear, and on the other, the client company complained that the concept made them feel dizzy and that the effect meter was too emphasised.

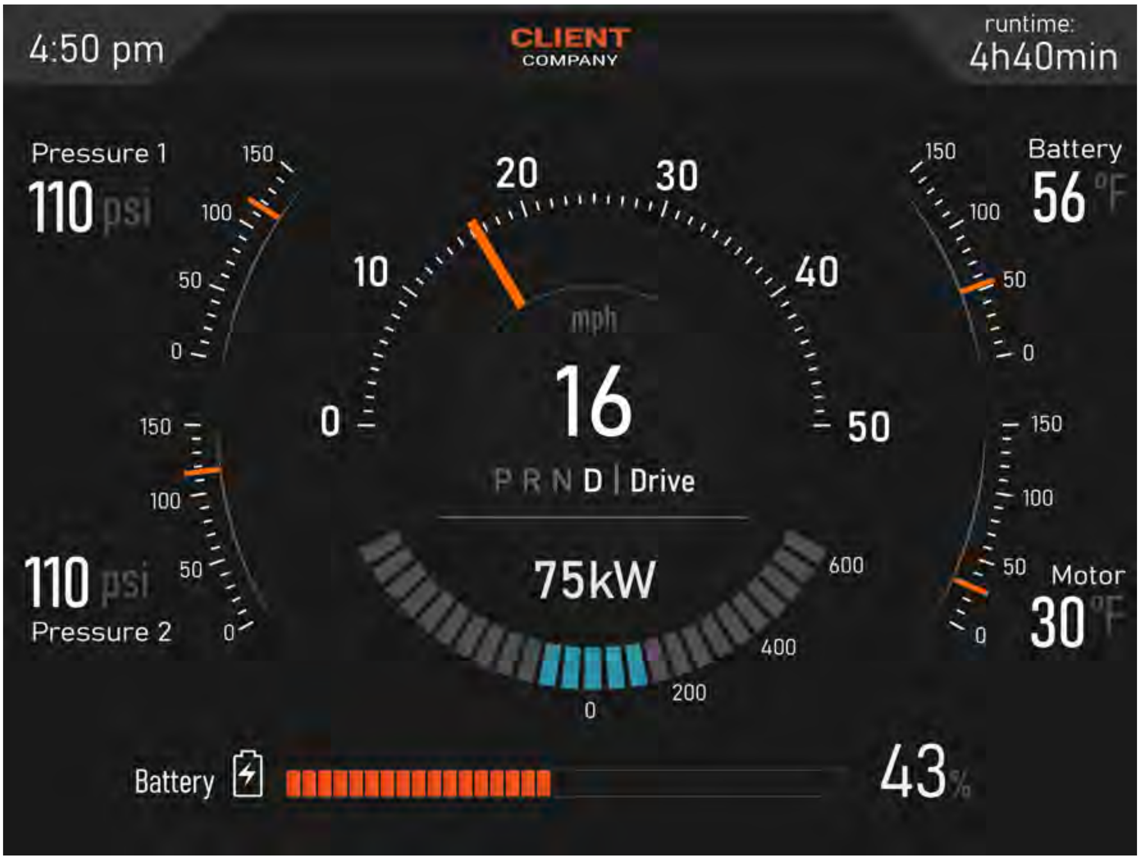


Figure 10.6: Concept 5 from Iteration I. This concept equally emphasises analogue dials and digital numbers to display information, placing the redundant gauges in a circular pattern around the center of the interface. [Authors contribution]

Concluding Iteration I

In the evaluations of the first iteration, stakeholders of the project and terminal tractor operators concluded that the third concept (Figure 10.4) was the most suitable contender. This concept was very different from the others in that it drastically reduced the sizes and complexity of analogue gauges in favour of their digital counterparts. During the operator evaluation session, we asked them why this was preferable, to which they responded "Everything is right there!". They further added that this simple style of interface would be received well by most operators because:

> "You can't mess that up."

Concepts 2 and 5 were also generally received well. From our discussions with stakeholders at both CPAC and the client company, we concluded that they were much more visually cohesive, and were therefore much more enjoyable to operate. However, they were too cluttered to be able to compare with concept 3.

Most interview subjects were indifferent about the importance and design of the effect gauge. In the questionnaire that was used to evaluate the importance of different elements in the interface, the client company even ranked the effect gauge to be as important as the client company logotype. Furthermore, the client company and operator agreed that engine temperature and battery temperature would be important to effectively display to the driver, as it provides important information about the health of the vehicle.

10.1.2 Iteration II

Coming from the first iteration, the goal was to rework Concept 3 (Figure 10.4), which was the 'winner' of the first iteration, based on the insights we gained during the first set of evaluations. Since we still had conflicting feedback regarding certain designs, as well as a new batch of required features being handed to us, we decided to develop three different concepts to evaluate their differences. The ultimate goal was to be able to, in the third iteration, combine the feedback and learnings of this iteration in a final design.

What all designs of the second iteration have in common are new gauges for effect, engine temperature, and battery temperature. Furthermore, the odometer and total active engine hours have been prominently introduced, as they would be important statistics for the operator to access. The new gauges for engine temperature and battery temperature are also given a much more noticeable location in the interface, as per the feedback from the first iteration. The interfaces also show the gear status, retarder level, ambient temperature, clock, a box with diagnostic messages that further explain tell-tales, as well as a button for accessing a menu with settings and additional settings, all of which were features that were requested to be added to the interface by the client company, as they would aid the operator in understanding the current state of the vehicle.

All concepts feature a dynamic system for displaying tell-tales to the driver. Each possible tell-tale that could potentially show up on the dashboard does therefore not have a static location, rather, they all share a certain amount of space. This means that the interface only makes room for a fraction of the tell-tales at the same time, and could emphasise the tell-tales in a prominent location whenever they show up, instead of reducing large parts of the interface to only waiting for a critical condition to occur. Furthermore, by utilising a dynamic space for the tell-tales, they can be much larger, aiding the driver in recognising critical vehicle conditions. Some tell-tales, however, have a static location due to the frequency that they appear, to not infringe on the location used for the dynamic tell-tales. These include the parking brake, seat belt, and high beam tell-tales.

Engine is burning!

Figure 10.7: Concept 1 of Iteration II. Out of the three concepts presented in this iteration, this concept resembles concept I.3 the most. It uses a greyscale gradient to separate each column of gauges from each other. [Authors contribution]

Concept II.1

The first concept, see Figure 10.7, bears the closest resemblance to the third concept from the previous iteration. It uses the same gauges for pressure, speed, and state of charge, with some small modifications. It also introduces the gear status and retarder level next to the speedometer, the temperature gauges under the state of charge, and the engine hours, odometer, clock and ambient temperature in a bar at the top of the interface. This same top bar also houses tell-tales that open their respective dialogue boxes. The effect gauge has been moved under the speedometer, and in the bottom right is the settings button, in which the retarder level can be adjusted.

This concept experiments with using a subtle separation between the three columns of gauges, using a greyscale gradient to highlight each section. Additionally, some elements in the interface have been stylised with a glow effect, e.g. the speedometer gauge dial.

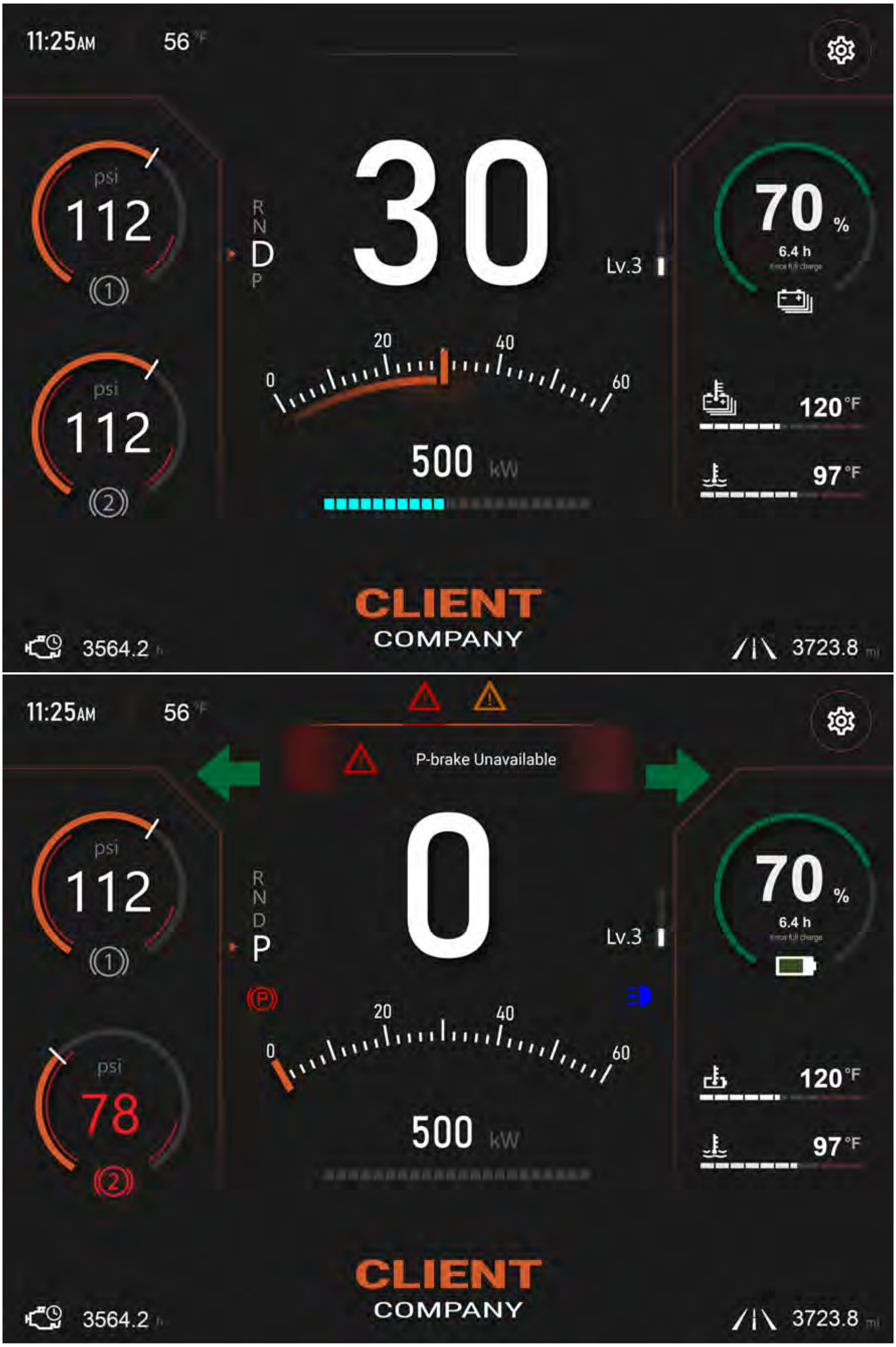
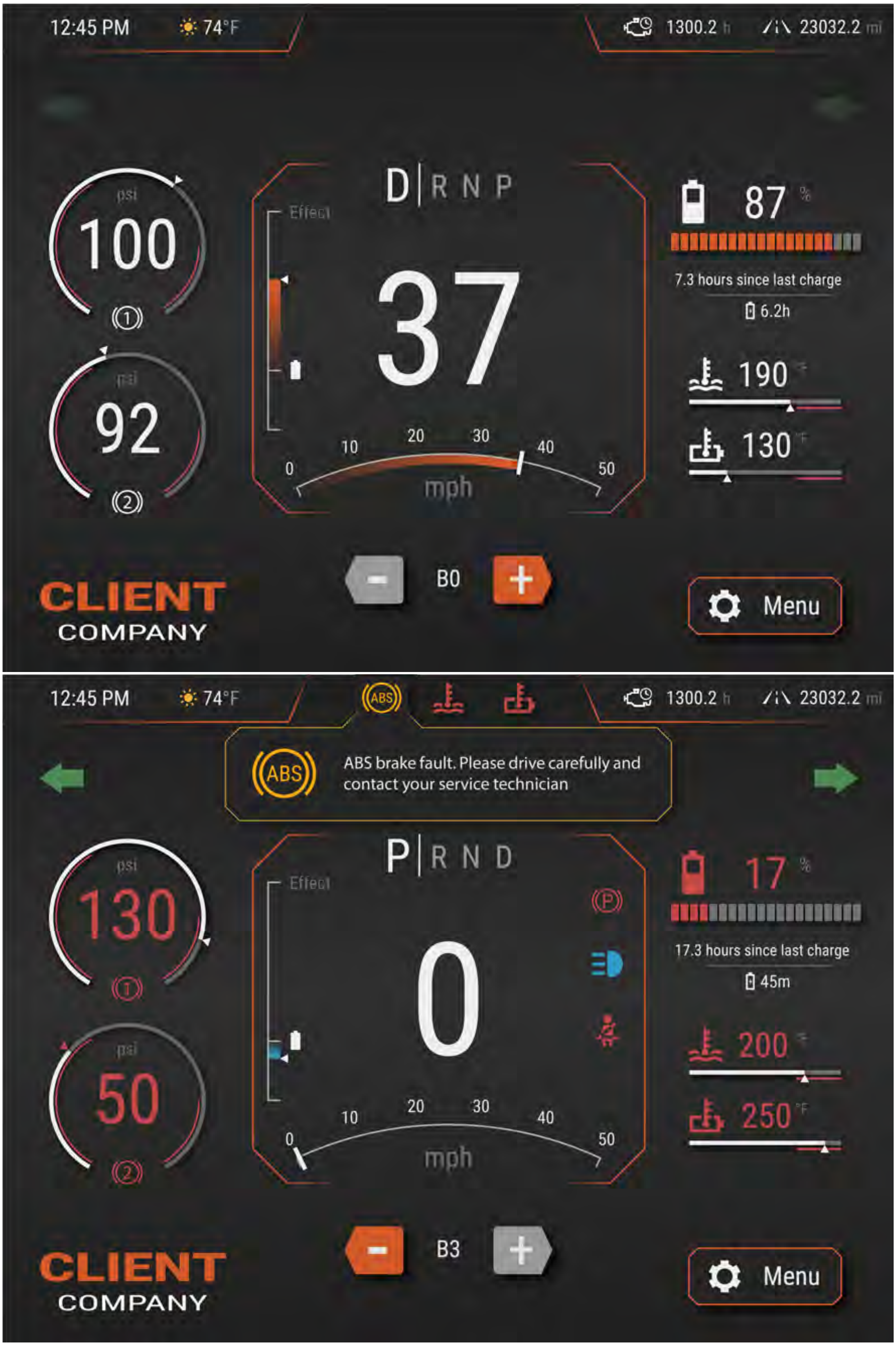


Figure 10.8: Concept 2 of Iteration II. This concept experiments with a circular gauge for the battery, and uses two lines to separate the secondary gauges from the speedometer. [Authors contribution]

Concept II.2

The second concept (Figure 10.8) introduces some further changes, including a new design for the state of charge, pressure gauges and effect meter. State of charge and pressure levels are now displayed with a circular gauge, which is much more visually engaging than the simple bar gauge. The gear status and retarder level are placed next to the speedometer gauge, underneath which is the effect gauge. The engine hour tracker and odometer are placed in the bottom corners. At the top of the interface are a clock, the ambient temperature, a bar for tell-tales and the button for accessing settings, among which the retarder level can be changed. The tell-tales in the top bar can be interacted with to open and close a dialogue box which further explains the status of the vehicle.

To increase the visual cohesion of the concept, two lines were introduced that separate the secondary gauges from the speedometer. Furthermore, most gauges are stylised with a drop shadow. This concept was the favourite one that the client company wanted to progress with.



ABS brake fault. Please drive carefully and contact your service technician

Figure 10.9: Concept 3 of Iteration II. This concept was very divergent in its design, changing the background colour of the interface and redesigned every gauge in the interface. Some gauges use an arrow instead of dial. [Authors contribution]

Concept II.3

The third concept (Figure 10.9) is visually the most divergent from the third concept of the last iteration. It introduces a new design for pressure gauges, speedometer, effect and state of charge. The pressure gauges are circular, similar to what was described in the previous concept. The speedometer is stripped down further to experiment with minimising stylised elements in the speedometer. Since the effect gauge now is placed together with the speedometer, we deemed it important to reduce visual excise in this area of the interface. The effect gauge is similarly designed, removing the digital representation of the effective value and only showing an analogue bar. We believed that an accurate measurement of the current energy consumption could be regarded as unnecessary by the driver since the number of kilowatts consumed would not be easily understood.

The state of charge gauge includes additional information to alleviate range anxiety in the driver, namely, a timer which tracks the time since the last charging session and a timer which estimates the range with the current state of charge in hours of driving. The gear status is displayed over the speedometer, and the retarder level is both displayed and adjusted underneath the speedometer. In the bottom right is the button that accesses settings, and at the top of the interface is the clock, ambient temperature, tell-tales, engine hours tracker, and odometer. The box for diagnostics is placed underneath the top bar, which is displayed by interacting with tell-tales, further explaining the status of the vehicle.

Some elements were favoured by the client company in this interface. Specifically, they liked the prominent gear status and preferred the warning status box symbol from this interface over the one in the other concepts. This interface also seemed to be the preferred choice of the sales team in the client company.

10.2 Concluding Iteration II

In this iteration, the client company decided to progress with concept II.2. However, they wanted to use the warning dialogue box and state of charge from concept II.3. They liked the icon for the state of charge, odometer, motor and battery temperature, but they wanted to change the operating hours' icon to reflect a motor instead of an engine. It was also decided that the interface should include a bright green READY label, placed in the top-left of the speedometer.

The name for the retarder levels should be changed to High, Low and Off, and be accessed from the menu, instead of using buttons immediately in the interface. They also proposed to switch the location of power consumption and gear selection, to make gear selection more prominent as in concept II.3. They argued that the effect would not be important for the drivers to monitor. Lastly, it was proposed to spell out miles and motor hours to clarify it further for the users.

10.3 Final Evaluation

The result of the final evaluation was a list of insights, derived using the thematic analysis. A summary of these results is presented in the section below. The exhaustive list of insights is presented in Table 8.2, in Chapter 8 - *Evaluate.*

To begin, the concept was generally appreciated and perceived as clear, intuitive and easily read. The operator also stated that it feels safe to use and covers all the necessary features, with a few praised additions. They commented on how a digital interface allows for a more compact and effective interface, which they claim to be more comfortable when driving. However, the label "Brake level" should be changed to "Motor brake", and the "READY"-label in the IDLE-state should be changed to "OFF". There was also a proposal to group static tell-tales.

Continuing, the operator argued that the interface does not feel too different from a traditional terminal tractor dashboard, and the redundant meters both look good and contribute to a more comfortable transition. They also commented that it would be easy to adapt to this new interface as it is intuitive and self-explanatory. Switching between the electrical tractor and a traditional one would not be troublesome either. It was brought up however, that older drivers might distrust the interface, and the operator also claimed that these drivers would just have to get used to it since the future of most vehicles will be electric.

Finally, the operator claimed that the colour palette was very good, and the red colour was effective at drawing attention to critical values. However, it was concluded that the visibility of all colours must be evaluated in bright sunlight to make sure they provide enough contrast and are visible enough. It was also found that the power bar is clear only after explanation, but that it should be intuitive when someone is actually driving the terminal tractor.

10.4 Considerations for Digital Dashboard Design

Approaching the problem of creating a digital dashboard for a new electric terminal tractor, our intent is two-fold. On one hand, as designers, we want to create an interface that successfully creates a comfortable transition from traditional terminal tractors to the new electric tractor. On the other hand, as researchers, we want to investigate how our design actions create new knowledge in the context of electric terminal tractor dashboard design. In this section, we focus on the latter, attempting to establish what new design knowledge we have created by investigating the design actions we have made during the process. The knowledge that we contribute to with our project will be formalised as considerations for the design of digital dashboards in a user-centred approach, to achieve a comfortable transition from traditional to electric terminal tractors.

During our project, we noticed a repeated disregard of the driver when making decisions for the design of the new terminal tractor. In an evaluation session with our main contact at the client company (see Section 7.1.9), we repeatedly asked them to relate their answer to how they think operators perceive the interfaces. The answer we got was that they would not know, as they rarely interface with operators. We realised that the disconnect between operators and the contacts that we had available to us would be disastrous in a user-centred design approach, so we compelled the client company to invite operators to our discussions. Thanks to their cooperation, we managed to set up an evaluation with an operator. During this meeting (see Section 7.1.10), we were among other things told that many terminal tractor drivers are overweight, and to be able to fit in the driver's seat of the terminal tractor they were forced to adjust the steering wheel to the uppermost configuration. In this configuration, the steering wheel effectively blocked the visibility of the majority of the display (see Section 7.2.1). This came as a surprise to both CPAC and the client company and resulted in an invigorated effort to change the placement of the display in the cockpit.

At every step of the process, we are reminded of the apparent disconnect between companies and users. A major takeaway from this project is the importance of constantly championing the opinion of users in an environment that disregards them. It is not enough to understand the users yourself, rather, each stakeholder must be made aware of the opinion of the end-user. That way, the user-centred design will be integrated into every related aspect of the project. Regarding accessing users, we formulate the following consideration:

> *In order to further integrate terminal tractor operators in the design process, each stakeholder should be involved in the user-centred approach.*

The lacking availability of users in our project led us to employ an alternative method for user research during the first phase, see Section 6.3. Social media ethnography allowed us to investigate terminal tractor operators without establishing contact with them. However, the method only proved useful to build a basic understanding of how drivers operate their vehicles, the conditions of their profession, and their opinions on certain topics. While social media ethnography should be employed with the intent of establishing contact with users (Wang and Liu, 2021), we made the mistake of not performing the method to its full extent. Regarding how we employed social media ethnography, we formulate the following consideration:

> *Performing social media ethnography without establishing contact with users is only an effective approach to gain a basic understanding of the user. However, it can not substitute establishing contact with them.*

Legacy bias is a phenomenon that refers to the bias users show toward previous knowledge and experience. In a project that concerns the transformation of a traditional interface, the legacy bias of transitioning users is a powerful tool for prototyping. We believe that you should neither completely copy what has been traditionally used, nor disregard it entirely. It is impossible to determine how legacy bias will affect the project beforehand. By proposing a divergent set of concepts with varying levels of traditional elements, users can themselves identify the degree of transformation that works for the new design. In our case, we initially designed five speculative concepts that explored different levels of digital and analogue gauges, integration with their environment and which elements will be important in an electric terminal tractor (see Section 7.1.5). With this strategy, we were able to determine with an operator that analogue gauges are frustrating to use and should be replaced with digital values to a large extent, even though analogue gauges have been the staple. Regarding legacy bias, we formulate the following consideration:

> *Legacy bias can be effectively used in the design process to create a comfortable transition.*

How to best design gauges and visualise information in the interface have been important considerations throughout the project. To present information to the driver efficiently, we found some elements to be best represented numerically, and others visually. Although, for the most important elements, we found it best to use a combination of a visual component and a number. Visual components draw attention, highlighting dynamic changes and providing a better understanding of how the element behaves. Digital elements, on the other hand, more accurately represent information and are easier to interpret by the driver.

We found that the effect meter does not need to provide information about its exact value for it to be interpreted correctly. Rather, the understanding that the driver receives from operating the vehicle, and how that affects the meter, is sufficient. Complimenting the effect meter with a number to display the exact value was even seen as more confusing, as became evident in the final evaluation, see Section 8.5. In contrast, the value of elements such as operating hours and odometer were found to be interpreted correctly using only a numerical component. These values update very slowly, and only their precise value is interesting to the driver, therefore, using a number is the most suitable option. Regarding visual and numerical information, we formulate the following consideration:

> *Certain information in a vehicle dashboard is more effectively visualised by either excluding the numerical or visual counterpart.*

We found that, in gauges that combine a visual element with a numerical value, if the visual element was reminiscent of the analogue gauge in a traditional interface, the visual element could assist users to transition to the new interface. In the final evaluation, we learned that the operator believed that the analogue components of redundant gauges, which were developed to resemble their analogue counterparts, would increase the comfort of transitioning to the new tractor. For instance, the visual element in the air pressure gauges was more appreciated as circular rather than linear. Regarding redundant gauges, we formulate the following consideration:

> *In transitions from analogue to digital interfaces, redundant gauges can alleviate the burden of adapting to the new design if their analogue component is reminiscent of the traditional gauge.*

Choosing an icon to best represent a specific purpose was a commonly encountered challenge during our project. Generally, each case involved three considerations; if there was a standardised icon for the purpose, what users are familiar with, and which icon would be most effective.

In some cases, one option was the strongest regarding all considerations, where a familiar, effective and standardised icon existed, for instance, when choosing a tell-tale for the seat belt warning. Generally, users are familiar with the standardised icons, however, in some cases, the available options stood in contrast to one another regarding the three considerations. When deciding which air-pressure icon we would use in our final concept, we considered three icons: the proposed standard icon, an icon more familiar to drivers of the client company's tractors, and another icon that more clearly presents a vital piece of information. In this specific case, we chose the standardised icon. Designers are responsible for the designs they produce and the consequences they have, therefore, by using standardised icons, the design choices of the designers are supported by an entire organisation.

However, when considering contrasting options, picking the standardised icon should not always be regarded as the solution to the problem. When we were faced with the challenge to choose an icon for representing the state of charge in the propulsion battery, we considered two different options. One of these options was both used in the majority of vehicles that we investigated during the project and was more clearly interpreted by the operator in our final evaluation, see section 8.5. The other option was the standardised icon. Therefore, we made the conscious decision of choosing the non-standard icon. Regarding icon design, we formulate the following consideration:

> *Adopting the icons proposed by standardisation organisations is useful in most situations, but in some cases, alternative icons could prove more efficient or interpretable.*

11

Discussion

During the execution of our project, we encounter several problems that prove overwhelmingly difficult to logically determine a solution for. This chapter describes our approach to making the best of these situations, as well as our thoughts on how the final concept turned out and the ethics of the project as a whole.

11.1 The Design Process

This section describes the process of the project, and some of the tools and methods used, discussing how we believe that they have influenced our project.

11.1.1 Process

Following the design thinking process and using a user-centred approach was suitable for the project. Design thinking helped us to structure, explain and validate our approach to the design process. It helped us to formulate the three phases of our project, and what they should contain. Reflecting on activities as parts of a greater process was assisted by the five components proposed by design thinking. Although it was a struggle to perform a user-centred design approach with a lack of users, it was always helpful to consider how our process was user-centred to remind ourselves that the goal of the project is to design for the operators, not the client company.

As we only were able to interview one operator, the Understand-phase could not achieve as much knowledge as we intended. But we believe that we learned enough about our users to start generating concepts, reasoning that generating concepts and evaluating them would be far more valuable than continuing our social media ethnography or the search for operators to interview.

We were happy with how the Create-phase turned out, it allowed us to diverge and converge in both our thinking and prototyping in three iterations, slowly working our way towards a final concept. As our evaluations with the client company often got delayed, it was challenging to follow our scheduled process during the second and third iterations. As these evaluations would be the foundation for the subsequent iteration, we were essentially stuck performing secondary feedback sessions and activities until the client company evaluation occurred.

11.1.2 Time Plan

In the process, we encountered several complications which created delays and forced us to change the process in unexpected ways. A Gantt chart that was constructed in the planning of the project and presented in section 5 - Planning. This chart was continuously updated thorough out the project, and the final version at the end of the project are presented below, see Figure 11.1.

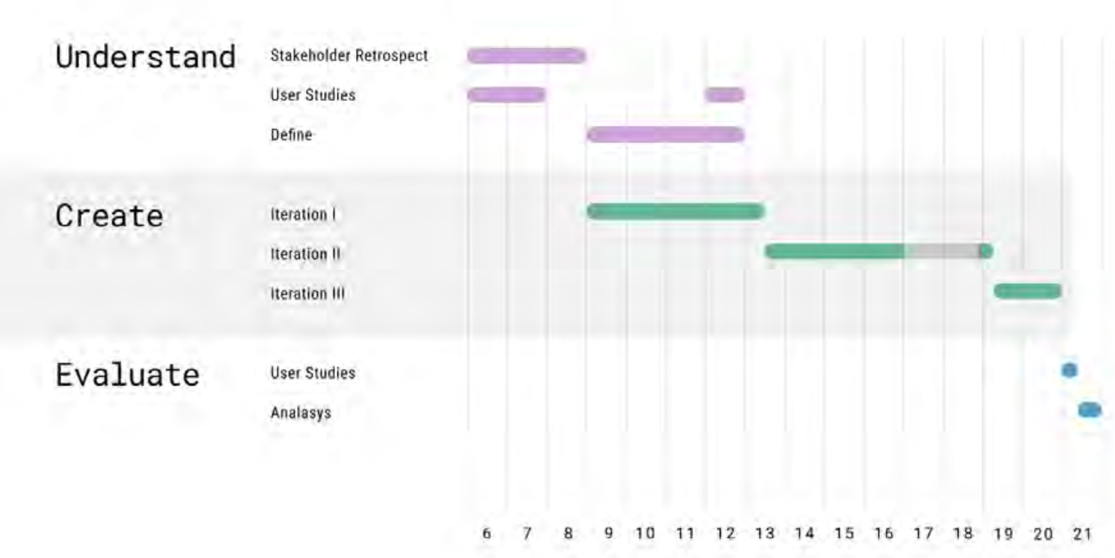


Figure 11.1: A Gantt chart of our time-plan at the end of the project. The project was prolonged for 2 weeks due to unexpected events. [Authors contribution]

The changes were mostly caused by the low accessibility of users, which were low and unreliable. The understand phase was prolonged as we had to find alternative methods without user contact, and the user studies had to be combined with the evaluation interview in the first iteration of the create-phase. (week 12 in the Gantt chart). The two first iterations were also prolonged as we had dates planned to conduct evaluations with users, but those dates were repeatedly pushed ahead due to circumstances outside our control. There was also a time of two weeks within iteration II, when we were both unable to work due to sickness, (week 17-18), however, it did not affect the project substantially as we had to wait for the client company during this time to conduct evaluations. The last iteration could be shortened by a week, as the concept was close to finished and did not require that much work. In total, the project was delayed by a total of two weeks, compared to the original plan.

The biggest effect that the complications have had on the project is that some activities, especially in the end needed to be performed in a shorter time than desired, and that a lot of unnecessary time was spent planning or preparing. We would have liked to conduct more extensive final evaluations, for example using an implemented prototype, or with other relevant people. This would of course provide us with more data regarding the final concept. We also spent a lot of time preparing for evaluations and user studies: designing interview questions and questionnaires, which would then prove unusable when the conditions for the evaluations changed. Spending time on unusable things meant less useful time spent overall.

11.1.3 Is This User-Centred Design?

It was always our ambition to involve several users in the design process. We wanted to build the design on a solid foundation of user interviews and evaluations with terminal tractor operators. However, we slowly learned during the project that coming in contact with operators, especially from the USA, is exceptionally difficult. Additionally, as this project was commissioned by the client company to CPAC, we did not have the final say in how the design should be. Several times during the project, we received feedback from the sales team at the client company, and the most consistent feedback we received was from the engineers at CPAC and the client company. So, did we even perform a user-centred design? And who are we even designing for?

We would argue that user-centred design is qualified by the approach, rather than the resulting process. If, during the execution of a project, the availability of users would be lacklustre or even non-existent, is performing user-centred design impossible? Even though there are no users to interview, attempting alternative approaches to achieve user satisfaction could be argued as user-centred. However, concepts would be hard to validate without users. In our case, we managed to discuss our results with one user, and have put the opinions of the user first and foremost, over the client company. Even though the project is commissioned by the client company, the design of the interface was always intended to be for the operator.

11.1.4 Social Media Ethnography

Our intention was to conduct detailed studies to understand and emphasise with the users, using both interviews, questionnaires, and live observations. As none of these proved possible, the plan had to be reevaluated, and other means of inquiry had to be used. We ended up trying to find information on the internet, and our research there evolved into a social media ethnographic study. It was first after we made something similar to a social ethnographic study without realising it that we understood the potential of such methods and began researching it, as none of us was familiar with the method.

Social media ethnography proved surprisingly useful. The biggest outcome of the method was the understanding we got of terminal tractors and their operators. How users operate the tractor, how the tractor works, and users' general opinions about their profession. We would argue that using this method is a cost-efficient way to gain a basic understanding of users. If we were to conduct an ethnographic study or user research of a niche group of users in general in the future, we would probably perform it on social networks first, to gain the first layer of understanding. The method can also access far more users, with little effort.

However, an ethnographic study in the wild cannot be interchanged. It was during interviews with the user and when physically interacting with a terminal tractor that we gained most of our insights. Social media ethnography also has certain limitations, for example, it may only represent a certain selection of the users, if not all users are active on social media. We have learned though, how resources must be handled with care in a commercial project, and performing research online proved little to no risk of wasting resources.

11.1.5 The Importance of Choosing Appropriate Software

A large reason why the result of the project turned out the way it did, was due to which tool we employed. Therefore, we find it important to discuss the most prevalent digital software, namely, Miro and Illustrator, and how they affected the process.

Miro

The most frequently used tool in this project has been Miro. It was used to visually collect and group all of the acquired insights and results during the process. It was also used during all formal interviews to present and discuss concepts for the users. Using Miro for interviews let us present the concepts efficiently, and we could easily adapt our presentations depending on where the interview was headed. As the interviews were held online, we noticed how crucial it became with a digital tool to efficiently present our concepts.

Illustrator

For almost all the digital concepts in this project, we have used Adobe Illustrator. It proved most effective to use when we created the features and elements of each concept, which often consisted of a lot of shapes. We used Photoshop a few times to enhance the concepts with a background or create similar effects. However, using Illustrator as the main design tool has shaped the way the final concepts turned out.

When working in Illustrator, certain effects were easier to achieve than others. Because of this, the choice to use Illustrator is one of the reasons why the interface is designed flat, simple and grid-based. If we would have opted for another program with other constraints, our concepts would most likely look different. However, the user and stakeholder exclaimed that they wanted the interface to be simple in the first iteration, and for that reason, Illustrator can be argued as being the most suitable choice of tool.

11.2 The Final Concept

This section will discuss the final concept, which is the final deliverable of the project. Generally, it was received well by the stakeholders of the project. The user experience was good according to the operator that was interviewed, and the transition was deemed to be comfortable. However, some minor changes were suggested before a final version was going to be implemented in the vehicle.

First of all, the colour of the interface worked great. The user and client company liked the orange accent that made the interface feel like it embodied their company. The other colours were good choices for the intentions they mediated. For example, the green "READY" label was easily interpreted by the operator as the vehicle being driveable.

> *"Yeah, green means go, right?"*

However, one concern was the visibility of colours in bright sunlight. The red colour, in particular, was perceived as potentially hard to distinguish in sunny conditions. At the same time, the red colour was appreciated due to its ability to draw attention when values were in critical ranges. The visibility of the colours therefore needed to be tested in a real context. And, if they are hard to see, it would be easy to make the colours a brighter shade to make them more visible, without changing the look of the interface much.

We would argue for the usability of the overall interface to be good, based on the insight from the final evaluations. Both the stakeholders and the operator repeatedly said that the interface was intuitive, clear, and straightforward. The redundant gauges and big numbers make the interface easy to read and efficient, and the user appreciated having all information in one place, unlike in a traditional analogue dashboard where gauges were more scattered around the dashboard. The power meter raised some questions but was easily understood after discussing it. We would argue that the power meter will be intuitively understood when driving the tractor for the first time, as it is inherently linked with how you drive, similar to a tachometer. The redundant gauges were originally utilised based on the findings of Francois et al. (2017) but also proved to be useful in the transition from an analogue dashboard interface to a digital.

The utility of the interface was also good, all the necessary features were in place, with a few additional features that originally were not expected. The clock, ambient temperature, weather-icon and gear selection were not requested features for the interface but proved appreciated additions.

Inspired by Lundström and Hellström (2015), the state of charge is presented as a percentage, with the addition of a horizontal bar. This gauge also incorporated a range estimation, which could aid the operator in the transition from fuel to electricity. While Lundström (2014) argues that a differentiated driving range would be most intuitively understood by users, we attempted another approach by displaying the range in hours. This approach was unfortunately not evaluated in detail, but we would argue that a time-based range estimation would be more useful to the operator rather than a distance-based estimation.

The analogue element of most gauges utilises either a circular or horizontal bar, which François et al. (2019) described as the most visually effective in dashboard interfaces. In our final evaluation, the operator specifically pointed out that the air pressure worked better visually as a circular gauge rather than a horizontal bar.

Transitioning to this new interface would also be easy, according to the operator we interviewed. Neither transitioning from a traditional interface nor rapidly switching from a traditional to electric would prove troublesome. The interface provides an intuitive experience and they argued that most features are similar to the traditional tractor. Switching back and forth between tractors was described as nothing worse than using a rental car: it takes a little bit of time to get used to but is nothing serious.

Some concerns were raised about the transition of more senior operators. However, the operator also reasoned that they would have to get used to this kind of interface anyway, as it will probably be the standard in most vehicles. Unfortunately, we were unable to evaluate why those concerns were raised, and we believe it is of uttermost importance to evaluate the interface with senior operators in the continuation of the project.

A few minor elements of the interface were not clear, namely the name of the brake-level indicator, the READY-label while the tractor was in the IDLE-state, and the placement of static tell-tales. In the evaluation interview, it was proposed to change the name brake level into something like "motor brake" to be clearer. It was seen as confusing that the brake-level indicator could be "off", as users could interpret that as the tractor not having any available brakes. "Motor brake" would better describe the behaviour, and therefore be more intuitive. Regarding the READY-label, it was discussed whether IDLE-state having a greyed-out label that reads "READY" would still be interpreted as the vehicle being in an active state. To be more clear, it was proposed to change it to "OFF" in this state.

The last proposed change was for the static tell-tales, which were regarded as being too scattered throughout the interface. Subjects in the evaluation proposed to group the tell-tales. However, we argue that this critique stems from the way we presented the interface, showing all tell-tales active at once. When the interface will be used in its context, they would rarely be lit at the same time, and make more sense being placed where we intended. Each icon is placed to make sense in a dynamic interface. For example, the parking brake icon is placed near the P of the gear status, as they will always update at the same time.

Finally, some more aspects have not been tested. The interface has only been evaluated from a computer screen and may appear different when placed in the display in the terminal tractor. As of now, it is unknown how the interface looks on the screen, which has a quite low pixel density, and imperfect colour reproduction.

11.3 Analogue, Digital or Redundant Gauges?

One of the big design decisions in this project has been whether to use digital numbers or analogue gauges to display information. Literature suggests a third approach which is to use *redundant gauges*, which is the combination of a digital number and an analogue representation. The values can then be observed both from the analogue and the digital part, making the information redundant. However, as different information is accessed better from either a visual clue or precise information, having both options may create a more efficient interface.

The result of our process seems to point to the fact that redundant gauges would be the best choice for an interface like what is described in the project. We have developed concepts with both analogue and redundant gauges, and found redundant gauges to be favoured by most people we evaluated the concepts with, including both the client company stakeholders and the operator we interviewed.

We suspected that analogue gauges would be more familiar and comfortable to the transitioning user, which is why we created a concept with exclusively analogue gauges in Iteration I, see Figure 10.2. However, in the evaluations of the first iteration, subjects would opt for some of the less traditional and modern concepts. During one of these evaluations, the operator speculated that a senior operator might be more comfortable with only analogue gauges. But, in a later interview, the same operator also stated that a redundant gauge could help with a more comfortable transition.

Almost all of the large elements in the interface use redundant gauges. The only exception is the effect gauge, which is completely analogue, without any given numbers. This is because knowing the precise number for the effect is not needed, it is enough to understand the dynamic change of effect when driving. In addition, we have speculated whether kilowatt is an appropriate unit to use for the effect. Kilowatt is calculated from the speed and applied force on the accelerator. Maybe, an abstract unit or kilowatt per distance would better match how users perceive effect, and more closely resemble how a tachometer works in vehicles with internal combustion engines. This could not be tested or evaluated, however, but was proposed to the project stakeholders.

In general, the gauges in the final concept put more emphasis on the digital number than the analogue dial. The analogue part of the redundant gauges is often reduced to a visual representation of the digital value. We would argue that this is sufficient, as the analogue part only needs to convey non-detailed information, but it would be a question for debate and further evaluation. As previous research on redundant gauges included more detailed gauges, further research is needed to know how well it applies to our concepts, even though our results showed many advantages with redundant gauges as well.

11.4 Designing Icons

While investigating dashboards of both industry vehicles and electric vehicles, we noticed discrepancies in how certain icons were designed. There seems to be no agreement on iconography for certain specialised equipment or novel features in either category. Even though several organisations propose a standardised set of icons for these specific purposes (ISO, 2021; SAE, 2010), major automotive companies opt to use alternative versions. A reconstruction of the variance that we discovered in our investigation can be seen in Figure 11.3 and Figure 11.2.

This raises the question of what icons we should use in our implementation of an interface. On one hand, following the recommendation of standardisation organisations would both enforce the association of the icon and future-proof it, since these standards are generally widely adopted and would not decrease in use. On the other hand, if another icon is much more widely implemented even after the standard has been proposed, attempting to enforce another icon could be taxing on the driver, as they would both have to learn the new association of the icon, as well as switch between the two regularly. Lastly, can a third option be considered: a more effective icon - for example showing critical information? In our case, we relied on the feedback from engineers and operators to find the alternatives that would be most appreciated by users, and create a comfortable transition. We encouraged discussions regarding this topic in evaluations and feedback sessions, which often resulted in the conclusion that both options come with equal parts benefits and drawbacks. To further discuss these considerations, three examples are brought up in the following subsections.

11.4.1 Air Pressure Icons

Choosing the air pressure icon was not trivial, and the problem perfectly exemplifies the three general considerations for choosing icons in the project. Should you choose the icon that is standardised, familiar to the user, or the most efficient one?

In our research of various terminal tractor dashboards, we found that there was plenty of variation in how to display the air pressure tanks as icons. To summarise these findings, we could see three icons being most commonly used, see Figure 11.2.

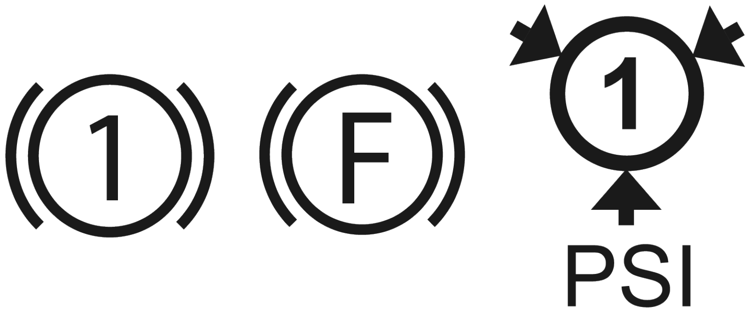


Figure 11.2: Three variants of icons that are supposed to symbolise the pressure level on the first circuit, or front axle, in a dual circuit air brake system. The first icon is proposed by ISO as a standard (ISO, 2021), the second icon is used in several other terminal tractor models, whereas the third icon is what is used in previous models of the client terminal tractor. [Authors contribution]

Using a standardised icon has several advantages, they are generally widespread and used in related applications. Because they are developed by a well-known organisation, they can generally be trusted to be a good choice. However, like in this example, the users of the client company that we target are used to another icon. And lastly, a third option is to more clearly display which axle the gauge refers to, which could potentially be critical information. A stakeholder at CPAC explained it like this:

> "I mean, if one of my tanks broke, I would very much like to know which axle pair I could still use to brake, as it determines how the braking behaviour will be. "

In this situation, we decided to use the ISO-standardised icon, as it proved as a compromise between what users are familiar with and what would be most effective. We believe the standard icon is well-associated with brakes and with the familiar number it will be intuitive. However, further evaluation on this would be useful. Moreover, we did not explore the possibility to use redundancy here, as we could potentially write out "Front" and "Rear" in the interface to explain the axles they refer to.

11.4.2 State of Charge

Another example of how we considered icons is for the state of charge. This was a critical icon for the understanding of the interface, and it was decided to use an icon of a battery cell which is more commonly used, over the existing ISO icon for propulsion battery. Both of these icons can be seen in Figure 11.3. The icon was also used as the base for the battery temperature icon.

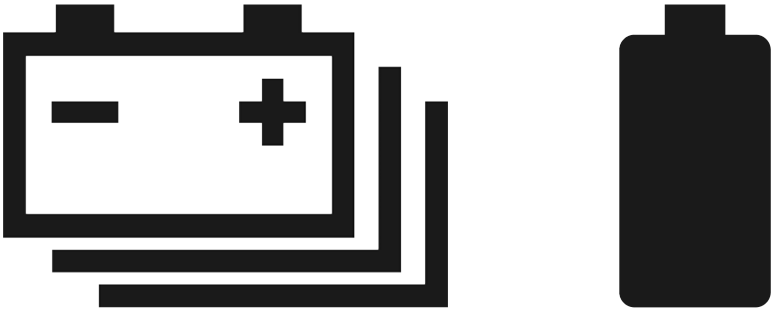


Figure 11.3: Two variants of icons that are supposed to symbolise the state of charge in the propulsion battery of an electric vehicle. The left icon is proposed by ISO as a standard (ISO, 2021), whereas a variation of the right icon appears to be in the overwhelming majority of vehicles. [Authors contribution]

This icon was chosen as it was deemed more understandable as it is commonly used for many other appliances. Moreover, during evaluations in iteration II, the alternative icon was believed to be ambiguous and when presented to an operator, they said:

> *"I would think that is a 12v battery icon."*

In this case, we deemed it best to use a more familiar icon, instead of the ambiguous and lesser-known ISO-standard icon. Continuing, during the same evaluation, it was also decided that tell-tales and warning messages should be using the ISO icons, however. This might be confusing though, as the state of charge and battery temperature use one sort of icon, and the warning tell-tales use another. Even so, this was believed to be the best solution, as it is necessary to use ISO-icons in displaying malfunctions, as these icons must accurately describe the specific part which is malfunctioning, which the battery cells do not portray.

11.4.3 Operating Hours and Total Distance

During evaluations with operators, it became apparent that displaying the total active engine hours and the odometer was important, as operators are required to report these statistics during their workday. This habit will likely remain even when electric terminal tractors are introduced, and it can be argued that displaying operating hours for the electric terminal tractor as closely as possible to engine hours provides the greatest utility for the driver.

Historically, vehicles tend to only display the value for each of these statistics without the use of icons. However, since our display will be an entirely different experience from the traditional terminal tractor dashboards, we believe that including icons to make sure the values are interpreted easily and correctly would alleviate the transition to the new dashboard interface. As no standardised icon could be found for this purpose, our own set of icons was designed, see Figure 11.4.

Figure 11.4: Icons for total active motor hours (left) and odometer (right). Both were designed specifically for this project, since there is no proposed standard or historically used icons for the purpose. [Authors contribution]

We believe these proposed icons to be understandable. The base symbol for the motor in the icon is proposed by ISO (ISO, 2021), and the road shape used in the odometer icon resembles the road shapes used in icons related to road conditions in the ISO standard. When the icons are placed next to a value with a unit of measurement ('hours' for the motor hours icon and 'miles' for the odometer), the association of the icon is assisted by the interpretation of the value itself. The odometer icon was praised for its design in an earlier evaluation, and it was implied that the operator hours would be clear with a motor symbol instead of an engine symbol. Even more so, in the final design, "Motor hours" and "Total distance" have been written out in text over the values to make them even more understandable.

Showing these values will help users feel familiar with the interface, however, they may not be the best representation of an electric tractor. Total active engine hours is an important statistic for traditional terminal tractors with internal combustion engines, as the amount of time the engine is active reflects the wear of the vehicle. However, the electric motor does not get worn out by simply being active, but rather, by the number of revolutions. More importantly, the wear on the propulsion battery is probably a much better indicator of the vehicle's health. To effectively report the health of the vehicle, other statistics could probably be introduced and accessed in the menu. We have noticed a requirement for operating hours in the interface today, and if that need change in the future, the operating hours could be changed for something more representative.

11.5 Sources of Error

In this section we will discuss some of the possible sources of error that have emerged in the process, and also the effect they had on the outcome of the project. The errors are categorised into three parts: errors because of limited data, errors in our interviews and lastly human errors.

11.5.1 Limited Data

The most prominent concern of the collected data in user research and evaluations of the concepts is the deficiency of users. Even though the qualitative data proved useful for the project, making general assumptions based on a small data set is dubious. In our original plan, we expected to conduct interviews with several operators and reach a wide range of stakeholders with questionnaires. This was not the case in the executed project, where we had access to only one experienced driver in total, and most of our feedback came from the client company engineers and sales team.

Several attempts were made to get in contact with operators outside of the client company. We called and emailed all the terminals and ports in Gothenburg, and tried using contacts within CPAC to get in touch with terminal tractor drivers affiliated with Volvo, receiving no answers. Therefore, for much of the thesis, we tried to find other relevant means of gaining knowledge or receiving feedback. In the understand phase, where we set out to gain knowledge about the user, we conducted studies online on how to operate a terminal tractor and conducted a social media ethnographic study. In the create phase, we found relevant opinions from peers and experts at CPAC, instead of users.

Using other forms of gaining user knowledge and feedback, rather than asking users themselves, proved to be more useful than expected but was still limited. It was in the actual user interviews that we found the most useful insights. Having better access to users in this project would allow us to cross-validate the findings from every method that we used, and would make our understanding of the users more reliable.

Moreover, the second liability of the data lies in the fact that most feedback comes from one of the engineers at the client company. It is possible that most of the feedback was sourced from other people at the client company, but is not possible to know. During one evaluation, the subject said that their opinions were mostly based on those of the sales team. When asked to relate their feedback to how operators will perceive the interface the client company also explicitly stated that they do not really interact much with the operators.

By being creative and utilising the limited resources we had available to their full extent, we could get a good enough amount of data to support the design process, but we were hesitant to draw bigger conclusions from the gathered data and having more users available would settle much of our insecurity.

11.5.2 Latent Approach to Data

Because of the small sample of users, we have used a latent approach in all our analyses of interviews, meaning that we have used implicit data from reading between the lines of what the user explicitly said. This, of course, can be a source of error, as it creates the possibility of misinterpreting data.

To mitigate this, we have been sure to go through the data several times, using recordings or transcripts and had discussions regarding latent data that may have been misinterpreted to make sure both of us had understood it the same way. Although, it still does not guarantee a fault-free interpretation of the data. And with a small data set, the information cannot be cross-referenced as a check for validity. Therefore, we have not been able to make great assumptions or go too deep into the data.

11.5.3 Interviews

Even though all the interviews in the project proved useful and insightful, some aspects made them less rewarding than they could have been. For example, we were not able to perform a one-to-one meeting with an operator or allocate as much time as we wanted for the interview.

The most considerable constraint for the interviews was time. It was difficult for stakeholders to allocate time for interviews, even if planned months in advance. The interviews were often crucial for the next process steps, and when they were delayed we would need to continue without the resources we planned for, which led to some backtracking in the project.

The formal interviews also had to be short, usually between 30-45 min or less. We would have to be efficient in the interview and prioritise our questions. It also meant that it was hard to use the laddering technique to its full extent, or probe in as much detail as we desired. Longer interviews would mean we could get more saturated answers and a deeper understanding. It also made the participants feel a bit stressed, which impacted the quality of the interview.

Another difficulty with the meetings was the number of people involved. Ideally, we would have opted for a one-to-one meeting with the interview subject in question. Instead, the interviews would be conducted together with various stakeholders from both CPAC and the client company. This would probably skew the answer from the subject, and limit the questions we could ask. It also added to the stress we would feel in the interviews, as we carried the responsibility of showing the value of performing UX activities to CPAC.

We speculate that the operator may have been prone to not saying anything too disapproving about the concept when executives of the client company were present. They were often quick to agree with what they said in the meetings. The hierarchy of power of the people that were present was evident in the discussions.

Moreover, all the formal interviews were held online in video conference calls, as the client company is based in the USA. This presented the extra challenge of a noticeable delay and varying audio quality. It was common to start talking at the same time in the meeting and interrupting each other. Sometimes, the video meetings were held without video, which made it easy to miss things or misinterpret, as body language is a big part of communication.

11.5.4 The Human Factor

The last source of error that will be brought up is the unintended mistakes we made during the project, and the impact of those. Humans are prone to make mistakes, and we are quite human. The mistakes mostly included the design of the concepts, where we have missed adding or editing a feature before showing them in feedback or evaluation.

For example, in concept II.1, two mistakes slipped in. The concepts had two images that first show the interface in a normal state, and then in the enhanced state that presents additional information and features. Both the power meter and the number for the motor temperature are the same in the normal and critical state, which is a mistake that may have confused the interview subjects. The intent was for the power meter to be 0 in the evaluated state - as the speed is 0. Even more confusing is the temperature bar that has risen to a critical level, but the number has remained the same, the number was intended to have risen as well. See Figure 10.9.

These mistakes are somewhat small but might have impacted the users' perception and overall understanding of the concept. Unfortunately, small mistakes like this have appeared in the entire design process. The mistakes can be justified by saying that they made the concepts appear less finished, which can make room for users to suggest more general improvements. However, it is difficult to estimate the impact these mistakes have had on the project, and they have therefore not been preferable.

11.6 Ethics

Working with, and for, people is a cause for concern regarding ethicality. During the project, we have involved people to aid us in user research, feedback sessions and evaluations. Often gathering data from these occasions, we have handled the personal data of many people. In our social media ethnography, we even gathered personal anecdotes and video logs from people unknowingly. This section will describe how we reason when faced with these, and other, ethical issues.

11.6.1 Developing Tools for a Hazardous Occupation

The implemented version of our final concept will be used in terminal tractors operating in ports and terminals. Working in these locations can be a dangerous occupation, dealing with moving, lifting and loading cargo, often under time pressure. Designing an interface that is supposed to aid an operator in this environment entails the responsibility to clearly present everything they would need to drive the vehicle. A mistake in displaying critical information could have dire consequences.

We believe that performing a user-centred design approach is the only ethical approach to this issue. Developing an interface without involving the input or expertise of operators is essentially a guessing game. Comparing our initial sketches with how the final concept turned out, we notice several discrepancies between what we believed would be important to the driver and what our user research and evaluations showed us. Visiting a port or terminal, involving more operators, or conducting user tests with an implemented version of the concept in a real context would be some suggested improvements for this ethical issue.

11.6.2 Are We Hiding the Truth From Operators?

One could argue that making the transition towards automation as comfortable as possible for the users would be the most ethical approach. However, if we adopt this belief, another potential issue of ethicality arises. One could argue that it could hide the progression towards total automation, which gives the illusion that automation is further into the future than possible. The short-term empathy derived from the user-centred design process could become a long-term deception at the expense of the terminal tractor operators.

If the interface instead would radically portray the transition towards automation, the users could make an informed decision of how they want to react to the impending evolution of their profession. However, we deem that this angle of approach would make for a poor user-centred design, as it would be impossible to create a radically different interface for a smooth transition. Furthermore, this argument assumes that the interface would be the sole source of information from which the operator would learn about the automation of their profession which, according to our user studies, is not the case.

11.6.3 Using Material Published on Social Platforms

Posting material on social platforms online makes it public information. By posting opinions and personal data in a comment on a discussion forum, the content becomes available to anyone with access to the forum. In our social media ethnography, see Section 6.3, we browsed social media, forums, and YouTube, looking for the opinions of terminal tractor operators. We found that people tend to share a lot of personal information online, both anonymously and while disclosing their identity. These people are probably aware that the content that they post will be publicly available, but maybe not to which extent it could possibly be used.

When using this publicly available content, we are not necessarily infringing on their privacy, however, these people were not aware at the time that their opinions and comments would be used as foundational research in an academic project. We reason that the nature of the content we have used in the project, and how we present it in the report, does not negatively impact its originator, and is therefore fair for us to use.

11.6.4 Integrity

Having people involved as research subjects in a project entails a challenge to maintain their privacy, integrity and confidentiality. In this project, we have interviewed several stakeholders, as well as performed ethnography on unaware subjects online. This means that we have encountered a lot of personal information that needs to be kept confidential. In our interviews with stakeholders, we always made sure the subjects were aware that the information they shared with us would be used in our project and later be published in a report. We were permitted to record sessions and use quotes from these interviews, but we chose not to disclose the identities of these subjects.

The data we collected during our ethnographic studies on social platforms were often published under anonymous pseudonyms. This was therefore a problem of maintaining the integrity of the data, rather than privacy and confidentiality. YouTube videos, however, displayed personal data in both audio and video. In the report, we approached this issue by never presenting any pictures, videos, or personal data from our ethnographic study, only the resulting conclusions.

11.7 Future Work

This section describes how future contributions could be done to validate the result of this project, as well as continue investigating the domains related to terminal tractor dashboard interfaces. In this project, we developed a concept for a dashboard interface, however, we were unable to perform user tests on an implemented version of the design. Therefore, we have no way of validating the design and behaviour of the finished product in the context of an actual terminal tractor. We propose that studies could be performed with an implemented version of the interface to test both how it would work as an interface purely for operating the tractor, and also how well it works in the transition from traditional to electric terminal tractors.

Unfortunately, we were not able to contact more than one operator during our project. Of course, had we had the opportunity to interview, and evaluate with, additional operators, the final concept could be considered more valid. Therefore, additional studies could be performed to evaluate the final concept with additional operators to both validate the concept and our insights from transitional design, as presented in Section 10.4. Especially senior operators should be considered, as it was speculated that they might be uncomfortable with the transition.

Finally, while our project did not specifically investigate redundant gauges, they were evaluated as an important factor in comfortable transitioning from traditional dashboards. In order to validate our findings on this topic, additional studies specifically targeting the value of redundant gauges in transitional design should be conducted.

12

Conclusion

In this chapter, we present the conclusions that we can draw from conducting our project. First, we present our research question, along with the set of considerations that answers it. Since we performed a generative design process, we were able to produce nine different conceptual designs for the digital dashboard interface in an electric terminal tractor, from which we will present some additional conclusions. Our research question is the following:

> *"What are the considerations when designing a digital dashboard in a user-centred approach, to achieve a comfortable transition from a traditional to an electric terminal tractor?*

By investigating the design actions we performed during our process, we establish a set of considerations that summarise the knowledge we produced from conducting a Research through Design project. The following are our considerations:

- In order to further integrate terminal tractor operators in the design process, each stakeholder should be involved in the user-centred approach.

- Performing social media ethnography without establishing contact with users is only an effective approach to gain a basic understanding of the user. However, it can not substitute establishing contact with them.

- Legacy bias can be effectively used in the design process to create a comfortable transition.

- Certain information in a vehicle dashboard is more effectively visualised by either excluding the numerical or visual counterpart.

- In transitions from analogue to digital interfaces, redundant gauges can alleviate the burden of adapting to the new design if their analogue component is reminiscent of the traditional gauge.

- Adopting the icons proposed by standardisation organisations is useful in most situations, but in some cases, alternative icons could prove more efficient or interpretable.

Additionally, we produced a set of designs for an electric terminal tractor digital dashboard interface: one final concept and eight additional concepts from the process iterations.

The final concept is our proposal for a new dashboard interface for the client company's new electric terminal tractor. In general, the final concept was received well by both the operator and stakeholders that we interviewed. The concept was praised both for how intuitive it is and for the introduction of several additional features that are not present in traditional dashboards. The colour palette was appreciated, especially the orange accent, which embodied the company. However, the red colour which is used to indicate criticality must be tested for visibility, as using the display in bright sunlight can prove troublesome. Furthermore, transitioning from a traditional dashboard interface was deemed to be straightforward and switching between an electric and traditional tractor would be easy. We are proud of how the final concept turned out, and believe it to be a successful result. Additionally, per the feedback from the final evaluation, we also proposed some minor revisions to be made before the product is finalised.

The eight first concepts, five from Iteration I and three from Iteration II, clearly show the divergence between our prototypes and the design. If contact with additional operators can be established in the future, these eight concepts will be valuable to revisit to investigate and validate the findings of this project.

By using legacy bias as a technique in divergent prototyping, we managed to effectively investigate how different design choices would contribute to a comfortable transition. We presented a gradient of design choices for a specific element in multiple concepts to an operator, which allowed us to evaluate which 'level' is most suitable for the new terminal tractor dashboard. This gradient often stretched between the design that has traditionally been used, to what is used in modern, electric, vehicles. The most comfortable transition would be to simply retain the design of a traditional dashboard. But it became obvious in early conversations with an operator that traditional interfaces could be frustrating to use, and they would prefer if large parts of the user experience were reworked. Designing elements for the sake of improving the user experience as well as creating a comfortable transition proved to be a difficult balancing act. We found that heavy use of redundant gauges, combining analogue dials with digital numbers, both improved the usability of the display, as well as made adapting to the new interface much easier. Furthermore, the addition of several features, such as a clock, ambient temperature indicator, and a tell-tale dialogue box, proved to be highly appreciated in our evaluations, essentially being plain upgrades to the utility of traditional dashboards.

Performing a user-centred design approach as inexperienced students in a commercial project that has no structure in place for involving users in the design process presented many difficult challenges. We found that involving stakeholders taking part in the user-centred practice, such as inviting them to participate in discussions with users, is an effective strategy to convince them of the inherent value of user-centred design, and in return, encourage them to support the process.

The low availability of users made the process of creating and evaluating the designs challenging. We were only able to interview one terminal tractor operator, whom we first got in contact with after having created five concepts. To understand the end-users of the product before then, we resorted to social media ethnography, analysing the content that operators post on social platforms online. We found that performing this method, without establishing contact with users, provides ample insights to start generating initial ideas. However, we argue that directly communicating with users is a much more effective approach

In this project, we have conducted a user-centred design approach within a challenging project, championing the perspective and opinion of users that find themselves in an intimidating transition. The methods and tools used in the project have supported the process well and produced the desired results. We argue that performing a user-centred design approach, in this case, is the most ethical approach, as it would be impossible for anyone else but the user to determine what constitutes a comfortable transition. We have shown how we are able, through various design choices, to both improve the user experience of a terminal tractor dashboard, as well as create an interface that operators can comfortably adapt to, in the transition to an electric terminal tractor. We also provide a set of considerations that can be used in similar projects to build upon the knowledge that we created through our design actions. We would even go as far as to speculate that, if given the choice, operators would prefer to use the design that we have developed over a traditional dashboard interface. Our final design may very well contribute to better standards for the future of terminal tractor interfaces, and empower the operators.

Bibliography

Adobe. (2022). *Adobe homepage*. Retrieved May 31, 2022, from https://adobe.com/

Android Studio. (2022). *Android studio homepage*. Retrieved May 31, 2022, from https://developer.android.com/studio

Ball, J. (2019). The double diamond: A universally accepted depiction of the design process. Retrieved June 8, 2022, from https://www.designcouncil.org.uk/our-work/news-opinion/double-diamond-universally-accepted-depiction-design-process/

Brewer, J. (2000). *Ethnography*. McGraw-Hill Education (UK).

Brown, M. (n.d.). Research methods: The value of quick and dirty prototypes. Retrieved June 8, 2022, from https://nightingaledesignresearch.com/insights/research-methods-the-value-of-quick-and-dirty-prototypes/

Budiu, R. (2017). Quantitative vs. qualitative usability testing. Retrieved February 1, 2022, from https://www.nngroup.com/articles/quant-vs-qual/

Carroll, J. M., & Kellogg, W. A. (1989). Artifact as theory-nexus: Hermeneutics meets theory-based design. *Proceedings of the SIGCHI conference on Human factors in computing systems*, 7–14.

Chang, C.-C., Huang, P.-C., & Tu, J.-S. (2019). Life cycle assessment of yard tractors using hydrogen fuel at the port of kaohsiung, taiwan. *Energy*, *189*, 116222.

Clarke, V., & Braun, V. (2013). Teaching thematic analysis: Overcoming challenges and developing strategies for effective learning. *The Psychologist*, *26*, 120–123.

Coppola, R., & Morisio, M. (2016). Connected car: Technologies, issues, future trends. *ACM Comput. Surv.*, *49*(3). https://doi.org/10.1145/2971482

Dam, R., & Siang, T. (2018). What is design thinking and why is it so popular. *Interaction Design Foundation*.

Di Ilio, G., Di Giorgio, P., Tribioli, L., Bella, G., & Jannelli, E. (2021). Preliminary design of a fuel cell/battery hybrid powertrain for a heavy-duty yard truck for port logistics. *Energy Conversion and Management*, *243*, 114423. https://doi.org/https://doi.org/10.1016/j.enconman.2021.114423

Don Norman, J. N. (n.d.). *The definition of user experience (ux)*. Retrieved June 15, 2022, from https://www.nngroup.com/articles/definition-user-experience/

d.school. (2018). Bootcamp bootleg. *Hasso Plattner Institute of Design at Stanford University*. Retrieved January 28, 2022, from https://dschool.stanford.edu/resources/design-thinking-bootleg

Elizarova, O., & Dowd, K. (2017). Participatory design in practice. *UX Magazine.* Retrieved June 8, 2022, from https://uxmag.com/articles/participatory-design-in-practice

Fank, J., Knies, C., & Diermeyer, F. (2021). After you! design and evaluation of a human machine interface for cooperative truck overtaking maneuvers on freeways. *13th international conference on automotive user interfaces and interactive vehicular applications* (pp. 90–98). Association for Computing Machinery. https://doi.org/10.1145/3409118.3475139

Francois, M., Crave, P., Osiurak, F., Fort, A., & Navarro, J. (2017). Digital, analogue, or redundant speedometers for truck driving: impact on visual distraction and usability. *Applied Ergonomics*, *65*, pp. 12–22. https://doi.org/10.1016/j.apergo.2017.05.013

François, M., Fort, A., Crave, P., Osiurak, F., & Navarro, J. (2019). Gauges design for a digital instrument cluster: Efficiency, visual capture, and satisfaction assessment for truck driving. *International Journal of Industrial Ergonomics*, *72*, 290–297. https://doi.org/https://doi.org/10.1016/j.ergon.2019.06.004

Frayling, C. (1994). Research in art and design (royal college of art research papers, vol 1, no 1, 1993/4).

Freitag, S. (2019). UX research methods (part III): When to use quantitative data to justify product improvement decisions. *Openfield.* Retrieved February 2, 2022, from https://openfieldx.com/ux-research-methods-quantitative-data-strengths/

Gaver, W. (2012). What should we expect from research through design? *Proceedings of the SIGCHI conference on human factors in computing systems*, 937–946.

Georgieff, A., & Milanez, A. (2021). What happened to jobs at high risk of automation?

Gittleman, M., & Monaco, K. (2020). Truck-driving jobs: Are they headed for rapid elimination? *ILR Review*, *73*(1), 3–24. https://doi.org/10.1177/0019793919858079

Goddard, W., & Cercos, R. (2015). Playful hacking within research-through-design. *Proceedings of the Annual Meeting of the Australian Special Interest Group for Computer Human Interaction.*

Google Design Sprints. (n.d.). *Crazy 8's.* Retrieved May 30, 2022, from https://designsprintkit.withgoogle.com/methodology/phase3-sketch/crazy-8s

Guerra, V. (2020). *How to enhance ux design with mood boards: Adobe xd ideas.* Retrieved May 30, 2022, from https://xd.adobe.com/ideas/process/ui-design/how-to-enhance-ux-design-with-mood-boards/

Hambeukers, D. (2019). The new double diamond design process is here. Retrieved June 8, 2022, from https://medium.com/design-leadership-notebook/the-new-double-diamond-design-process-7c8f12d7945e

Hawley, M. (2009). Laddering: A research interview technique for uncovering core values. *UX Matters*, *38.*

Interaction Design Foundation. (n.d.-a). *User experience (ux) design.* Retrieved June 15, 2022, from https://www.interaction-design.org/literature/topics/ux-design

Interaction Design Foundation. (n.d.-b). *What is user centered design?* Retrieved June 15, 2022, from https://www.interaction-design.org/literature/topics/user-centered-design

Interaction Design Foundation. (2021). *Affinity diagram, learn how to cluster and bundle ideas and facts*. Retrieved May 19, 2022, from https://www.interaction-design.org/literature/article/affinity-diagrams-learn-how-to-cluster-and-bundle-ideas-and-facts

ISO. (2022). *International organization for standardization*. Retrieved May 19, 2022, from https://www.iso.org/home.html

ISO. (2021). *Road vehicles — Symbols for controls, indicators and tell-tales* (9th ed., Standard). International Organization for Standardization. Geneva, CH.

ISO. (2019). *Graphical symbols for use on equipment — Registered symbols* (6th ed., Standard). International Organization for Standardization. Geneva, CH.

SAE. (2010). *Road Vehicles—Symbols for Controls, Indicators, and Tell-tales* (Standard). SAE International. Warrendale, PA, USA.

Kalmar. (2022). *Kalmar smartport process automation*. Retrieved May 15, 2022, from https://www.kalmarglobal.com/automation/kalmarone/kalmar-smartport/

Konecranes. (2022). *Automated terminal tractor*. Retrieved May 15, 2022, from https://www.konecranes.com/equipment/container-handling-equipment/automated-terminal-tractor

Köpsel, A., & Bubalo, N. (2015). Benefiting from legacy bias. *Interactions*, *22*(5). https://doi.org/10.1145/2803169

Lavrakas, P. J. (2008). *Encyclopedia of survey research methods*. Sage publications.

Lundström, A. (2014). Differentiated driving range: Exploring a solution to the problems with the "guess-o-meter" in electric cars. *Proceedings of the 6th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, 1–8. https://doi.org/10.1145/2667317.2667347

Lundström, A., & Bogdan, C. (2014). Having a lead foot? exploring how to visualize energy consumption and driving in electric cars. *Adjunct Proceedings of the 6th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, 1–4. https://doi.org/10.1145/2667239.2667303

Lundström, A., & Hellström, F. (2015). Getting to know electric cars through an app. *Proceedings of the 7th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, 289–296. https://doi.org/10.1145/2799250.2799272

Martínez-Moya, J., Vazquez-Paja, B., & Gimenez Maldonado, J. A. (2019). Energy efficiency and co2 emissions of port container terminal equipment: Evidence from the port of valencia. *Energy Policy*, *131*, 312–319. https://doi.org/https://doi.org/10.1016/j.enpol.2019.04.044

Miro. (2022). *Homepage miro*. Retrieved May 31, 2022, from https://miro.com/

Morris, M. R., Danielescu, A., Drucker, S., Fisher, D., Lee, B., schraefel m. c., m. c., & Wobbrock, J. O. (2014). Reducing legacy bias in gesture elicitation studies. *Interactions*, *21*(3), 40–45. https://doi.org/10.1145/2591689

Muller, M. J. (2007). *Participatory design: The third space in hci*. CRC press.

Nielsen, J. (2012a). Thinking aloud: The #1 usability tool. *Nielsen Norman Group*. Retrieved February 2, 2022, from https://www.nngroup.com/articles/thinking-aloud-the-1-usability-tool/?lm=why-you-only-need-to-test-with-5-users&pt=article

Nielsen, J. (2012b). Usability 101: Introduction to usability. *Nielsen Norman Group*. Retrieved February 1, 2022, from https://www.nngroup.com/articles/usability-101-introduction-to-usability/

Ordóñez, A. S., Lema, C. G., Puga, M. F. M., Lema, C., & Vega, F. (2017). Design thinking as a methodology for solving problems: Contributions from academia to society. *Global Partnerships for Development and Engineering Education: Proceedings of the 15th LACCEI International Multi-Conference for Engineering, Education and Technology*, 19–21.

Orii, L., Tosca, D., Kun, A. L., & Shaer, O. (2021). Perceptions of trucking automation: Insights from the r/truckers community. *13th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, 137–146. https://doi.org/10.1145/3409118.3475154

Osborn, A. F. (1963). *Applied imagination; principles and procedures of creative problem-solving: Principles and procedures of creative problem-solving*. Scribner.

Rahmati, A., & Zhong, L. (2009). Human–battery interaction on mobile phones. *Pervasive and Mobile Computing*, *5*(5), 465–477. https://doi.org/https://doi.org/10.1016/j.pmcj.2008.08.003

Rittel, H. W., & Webber, M. M. (1973). Dilemmas in a general theory of planning. *Policy sciences*, *4*(2), 155–169.

SAE. (2022). *Sae international*. Retrieved May 19, 2022, from https://www.sae.org/

Shuhalii, A. (2020). What is the difference between low and high fidelity prototypes? Retrieved June 8, 2020, from https://bootcamp.uxdesign.cc/what-is-the-difference-between-low-and-high-fidelity-prototypes-b1f3612f85f7

Sihombing, D. M. (2021). *Ux case study: Retail company shopping app (ikea indonesia)*. Retrieved June 15, 2022, from https://bootcamp.uxdesign.cc/ux-case-study-retail-company-shopping-app-ikea-indonesia-f8cc552b12b8

Starcrest. (2021). *Port of los angeles inventory of air emissions - 2020* (tech. rep.). Retrieved June 5, 2022, from https://www.portoflosangeles.org/environment/air-quality/air-emissions-inventory

Strömberg, H., Andersson, P., Almgren, S., Ericsson, J., Karlsson, M., & Nåbo, A. (2011). Driver interfaces for electric vehicles. *Proceedings of the 3rd International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, 177–184. https://doi.org/10.1145/2381416.2381445

Terberg. (2022). *Live tests of autonomous terminal tractor in busy container terminal*. Retrieved May 15, 2022, from https://www.terbergspecialvehicles.com/en/news/live-tests-of-autonomous-terminal-tractor-in-busy-container-terminal/

Wang, D., & Liu, S. (2021). Doing ethnography on social media: A methodological reflection on the study of online groups in china. *Qualitative Inquiry*, *27*(8-9), 977–987. https://doi.org/10.1177/10778004211014610

Wensveen, S., & Matthews, B. (2015). Prototypes and prototyping in design research. *The Routledge Companion to Design Research. Taylor & Francis.*

Yu, H., Ge, Y.-E., Chen, J., Luo, L., Tan, C., & Liu, D. (2017). Co2 emission evaluation of yard tractors during loading at container terminals. *Transportation Research Part D: Transport and Environment*, *53*, 17–36. https://doi.org/https://doi.org/10.1016/j.trd.2017.03.014

Zimmerman, J., & Forlizzi, J. (2014). Research through design in hci. In J. S. Olson & W. A. Kellogg (Eds.), *Ways of knowing in hci* (pp. 167–189). Springer New York. https://doi.org/10.1007/978-1-4939-0378-8_8

A

Appendix 1

This appendix presents the semi-structured interview script which was used in the final evaluation.

Show interface

User experience
How do you feel about the concept? What are your thoughts and impressions?

Do you think the interface has all the necessary features it needs?
    Is there anything in the interface that can be misinterpreted?

Do you think the information in the interface can be interpreted efficiently?

What do you think it would feel like to drive a terminal tractor with this interface every day?

Comfortable transition
As an experienced driver, that has driven different varieties, how do you consider the experience of transition to driving with this interface?

Do you find it difficult to adapt to the new interface?

How would it feel like to use this interface for a driver that has only driven diesel-driven?
    Yes or no?
    What makes it feel easy/hard?
    Anything specific in the interface?

Say a port were to only buy a couple of these new electric tractors, and a driver would have to switch between using an electric and a diesel-driven tractor. How comfortable would that switch be for the driver?

Do you think the think the interface would either help or be a problem for a driver when they switch tractors?

FEELING

Does the interface make you feel safe when driving?
- In control

A tough question. What feelings would this interface evoke when driving?

Features
Is the warnings clear?
Is it clear when it is on?

B

Appendix 2

This appendix presents the questionnaire from the evaluations in the first iteration of the create process-phase. Note that the client name is exchanged for "[Client Company]"

[Client Company] Advanced GUI

Hi,
Thank you for answering our survey.

In this questionnaire you will be asked questions regarding the design of the advanced Graphical User Interface (GUI) for the new [Client Company] Terminal Tractor. Each question is completely optional to answer except your role at [Client Company], since that affects how your data will be analyzed. [Client Company] will not be named in the report, nor will the logo be shown.

Feel free to contact us at filip.andreasson@cpacsystems.se or christoffer.boman@cpacsystems.se if you have any questions regarding the questionnaire or how your data is treated.

---

* Required

1. What is your name? (optional)

____

2. What is your role at [Client Company]? *

____

3. By answering this questionnaire I allow Filip and Christoffer to store, analyze and anonymously present my data in the final report of their project. I understand that I do not have to respond to any question that I do not feel comfortable with answering. My data will be stored until the end of August 2022, after which it will be deleted. *

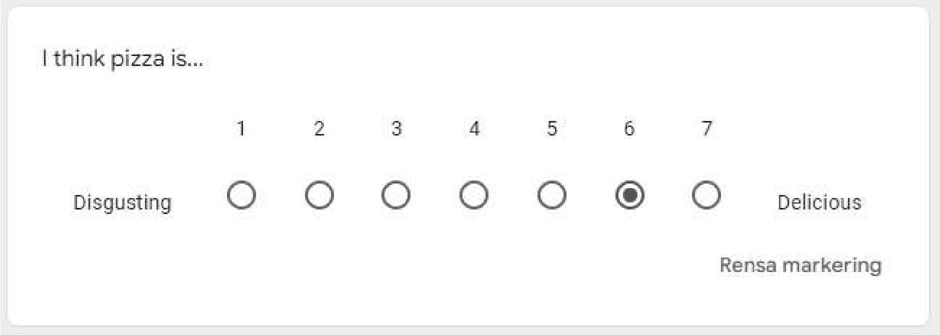
Mark only one oval.

○ I agree

Semantic questions

In the next two sections, you will be presented with unfinished statements with a scale. Finish each statement by specifying where on the scale you believe the GUI should be.

For example, for the following question. If you do like pizza, you would choose an answer closer to 'Delicious' on the right side of the scale.



I think pizza is...

	1	2	3	4	5	6	7	
Disgusting	○	○	○	○	○	●	○	Delicious

Semantic questions

In the this section, you will be presented with questions regarding the general style of the GUI. Answer on the scale what attributes you feel is the most appropriate for the GUI to express. If there is any question that you do not understand, please skip it and move on the next.

4. Would you prefer if the interface was more...

Mark only one oval.

	1	2	3	4	5	6	7	
Serious	○	○	○	○	○	○	○	Fun

5. Would you prefer if the interface was more...

Mark only one oval.

	1	2	3	4	5	6	7	
Traditional	○	○	○	○	○	○	○	Innovative

6. Would you prefer if the interface was more...

Mark only one oval.

	1	2	3	4	5	6	7	
Minimalistic	○	○	○	○	○	○	○	Detailed

7. Would you prefer if the interface was more...

Mark only one oval.

	1	2	3	4	5	6	7	
Relaxed	○	○	○	○	○	○	○	Energetic

8. Would you prefer if the interface was more...

Mark only one oval.

	1	2	3	4	5	6	7	
Generic	○	○	○	○	○	○	○	Unique

9. Would you prefer if the interface was more...

Mark only one oval.

	1	2	3	4	5	6	7	
Simple	○	○	○	○	○	○	○	Feature-rich

10. Would you prefer if the interface was more...

Mark only one oval.

	1	2	3	4	5	6	7	
Informal	○	○	○	○	○	○	○	Formal

11. Would you prefer if the interface was more...

Mark only one oval.

	1	2	3	4	5	6	7	
Static	○	○	○	○	○	○	○	Dynamic

12. Would you prefer if the interface was more...

Mark only one oval.

	1	2	3	4	5	6	7	
Muted	○	○	○	○	○	○	○	Vibrant

13. Would you prefer if the interface was more...

Mark only one oval.

	1	2	3	4	5	6	7	
Safe	○	○	○	○	○	○	○	Brave

14. Would you prefer if the interface was more...

Mark only one oval.

	1	2	3	4	5	6	7	
Intuitive	○	○	○	○	○	○	○	Advanced

15. Would you prefer if the interface was more...

Mark only one oval.

	1	2	3	4	5	6	7	
Humble	○	○	○	○	○	○	○	Confident

Importance of elements

In this section you will be presented with a question regarding the importance of various element that could be included in the GUI. We want to understand what elements are more or less important to understand how to prioritize elements.

16. During operation, how important do you think it is to see the ...?

Mark only one oval per row.

	Unnecessary			Moderately Important			Extremly Important
Pressure Gauges	○	○	○	○	○	○	○
Speedometer	○	○	○	○	○	○	○
Battery Level	○	○	○	○	○	○	○
ESS Temperature (battery)	○	○	○	○	○	○	○
Engine Temperature	○	○	○	○	○	○	○
Energy Consumption	○	○	○	○	○	○	○
Avg. Energy Consumption	○	○	○	○	○	○	○
Total Energy Consumption	○	○	○	○	○	○	○
Clock	○	○	○	○	○	○	○
Runtime since start	○	○	○	○	○	○	○
Logotype	○	○	○	○	○	○	○
Odometer (total dist.)	○	○	○	○	○	○	○
Active Gear	○	○	○	○	○	○	○
Parking Brake	○	○	○	○	○	○	○
System Voltage	○	○	○	○	○	○	○
Retarder Level (motor-breaking)	○	○	○	○	○	○	○
Seat Belt Warning	○	○	○	○	○	○	○
Turn Signals	○	○	○	○	○	○	○

17. Is there something not listed you find particularly relevant to show in the display?

18. Did you think of something else you want to tell us?