Potential and Design for Head-Up Displays in Commercial Trucks

Exploring the Future of Head-Up Displays with Augmented Reality

Bachelor thesis in Industrial Design Engineering

LUKAS DAHLBERG
MÄRTA ERIKSSON
VIKTOR HJELMGREN
ALEXANDER LUNDH
EBBA WEYLER
HAMPUS SAHLIN WIKSTRÖM

DEPARTMENT OF INDUSTRIAL AND MATERIALS SCIENCE
CHALMERS UNIVERSITY OF TECHNOLOGY
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www.chalmers.se

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Department of Industrial and Materials Science

Division of Industrial Design Engineering

Chalmers University of Technology

SE-412 96 Gothenburg

Telephone +46 31 772 1000

Gothenburg, Sweden 2025

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We would like to extend our thanks to our supervisor from Chalmers, Oskar Rexfelt, who guided us through this project. We would also like to express our gratitude to our examiner Lars-Ola Bligård for his frequent visits and willingness to answer all our questions. Special thanks to our supervisors from Volvo GTT, Nina Theodorsson and Christian Larsson, whose support and guidance made this project possible. Finally, we would like to thank all the participants - commercial truck drivers, driver instructors and students - whose involvement through interviews and observations provided invaluable insights and input for the project.

Abstract

This thesis explores the potential with Augmented Reality Head-Up Displays (AR-HUDs) in commercial trucks, with a specific focus on the driver's perspective. Through research and interviews, the project investigates if and how AR-HUDs can be used to enhance safety, usability, and personalisation in the truck. The report describes the development process and presents the outcome: a conceptual interface of an AR-HUD featuring different modes for different driving situations.

Executive summary

This bachelor's thesis, commissioned by Volvo GTT, explores the integration of Augmented Reality Head-Up Displays (AR-HUDs) in commercial trucks. The purpose of the project was to investigate the potential benefits with AR-HUDs from a driver's perspective, and if the technology was desirable, to develop a conceptual design tailored for commercial truck driving.

The process began with a research and data collection phase, consisting of interviews, field observations, benchmarking, and literature review. Among the key insights from this phase is the understanding that drivers value clear and customisable information. Concerns about cognitive overload and technological complexity were common, highlighting the importance of minimalism and user control in the interface.

Based on the insights from the first phase, interface concepts were ideated, developed and later iteratively evaluated with users. The final concept features a flexible HUD system with three adaptive driving modes: Country Road, Highway and City. Each of the modes are automatically triggered based on driving context. The system supports customisation, allowing drivers to select which elements appear for all three modes.

Throughout the project, principles of usability and interaction design were applied. Nielsen's heuristics and Jordan's usability characteristics guided the design process and the evaluation in the right direction. The final concept was positively received by users, particularly for its flexibility and the ability to customise the interface.

This report presents the full development process, key insights, and provides conclusions and reflections on the relevance of augmented reality head-up displays (AR-HUDs) in the current and future context of the commercial truck industry.

Figure 1: Final concept

Sammanfattning på svenska

Detta kandidatarbete, utfört på uppdrag av Volvo GTT, undersöker potentialen hos Augmented Reality Head-Up Displays (AR-HUDs) i lastbilar. Målet har varit att ta reda på hur tekniken mottas bland förare, och hur ett eventuellt gränssnitt bör utformas för att vara användarvänligt, säkert och uppskattat.

Arbetet inleddes med insamling av data genom intervjuer, observationer och litteraturstudier. Resultaten visade att lastbilsförare värdesätter kontroll, tydlighet och framför allt möjligheten att anpassa information efter egna behov. Oro kring kognitiv överbelastning och brist på användarinflytande var vanliga orosmoment och därmed återkommande teman.

Utifrån fynden utvecklades flera koncept som utvärderades tillsammans med användare. Det slutgiltiga förslaget är ett HUD-system med tre anpassade körlägen: stad, landsväg och motorväg. Körlägena växlas automatiskt beroende på kontext, och föraren kan själv välja vilka element som ska visas i respektive körläge.

Designprocessen har vägletts med hjälp av teorier om användbarhet, främst Nielsens heuristik och Jordans användbarhetsaspekter. Resultatet är ett koncept som slutligen upplevdes positivt av testanvändarna, mycket för sin tydlighet och den flexibilitet som ju tydligt efterfrågades. Denna rapport presenterar arbetets gång, insikter, resultat och diskussion kring framtid och vidareutveckling.

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1. Introduction

Commercial truck drivers are required to process a substantial amount of information while driving, such as surrounding traffic, pedestrians, navigation and vehicle status. The amount of information in trucks is growing along with the technical evolution and the functional growth. The method and placement of information presentation are critical for maintaining safety and minimising distractions.

Today, most information in commercial trucks is displayed on screens or through diodes adjacent controls or buttons. With new technology, information can be presented in different ways than before, for example in the forward field of view. This can be done by projecting information on the windshield using what's called a Head-Up Display. A Head-Up Display, or HUD for short, projects information on the windshield, allowing the driver to access information without diverting attention from the road. HUDs serve as a technical alternative to traditional displays and can support the driver's focus and situation awareness.

According to the Swedish Transport Administration (Trafikverket, 2023), crashes involving heavy goods vehicles often result in severe consequences for other road users due to the vehicles' considerable mass. In 2022, 53 people were killed in such incidents, representing 23 percent of all road traffic fatalities in Sweden. This is the main reason to develop a safer way to present information in commercial trucks.

Head Up Displays have been used in military aircraft for decades (Korentsides et al. 2022) but have as of recently been implemented in both commercial planes and in personal vehicles as well. Since the information is projected in the forward field of view, the elements in the display can interact with the environment in the real world, which is known as Augmented Reality Head-Up Display, or AR-HUD for short. Head Up Displays using this technology exist in certain cars on the current market, but the potential of using AR-HUDs in commercial trucks remains a relatively unexplored area.

1.1 Purpose

The aim of the project is to determine requirements for information in commercial trucks according to the drivers, as well as developing a conceptual interface for a HUD that addresses the formulated needs. The study will also investigate the potential application of AR technology within the HUD to improve driver experience and efficiency of information delivery.

1.2 Research Questions

Based on the purpose the following questions are to be addressed:

- What information in a commercial truck is suitable for a HUD?
- What demands do commercial truck drivers have for a potential HUD?
- What potential do Head-Up Displays have in commercial trucks, and what opportunities do Augmented Reality bring to them?
- How can the questions above be addressed in a HUD interface with AR features?

1.3 Limitations

Alongside the task of evaluating the technology, including its acceptance and potential, the main objective of the project is to develop a user interface design for the HUD. In addition to the HUD itself, Interface designs of the secondary display (field no. 2 in fig. 1) that specifically relate to the HUD are included, while other screens, such as the instrument panel and other additions (field 1 and 3, respectively) fall outside the scope of this project.

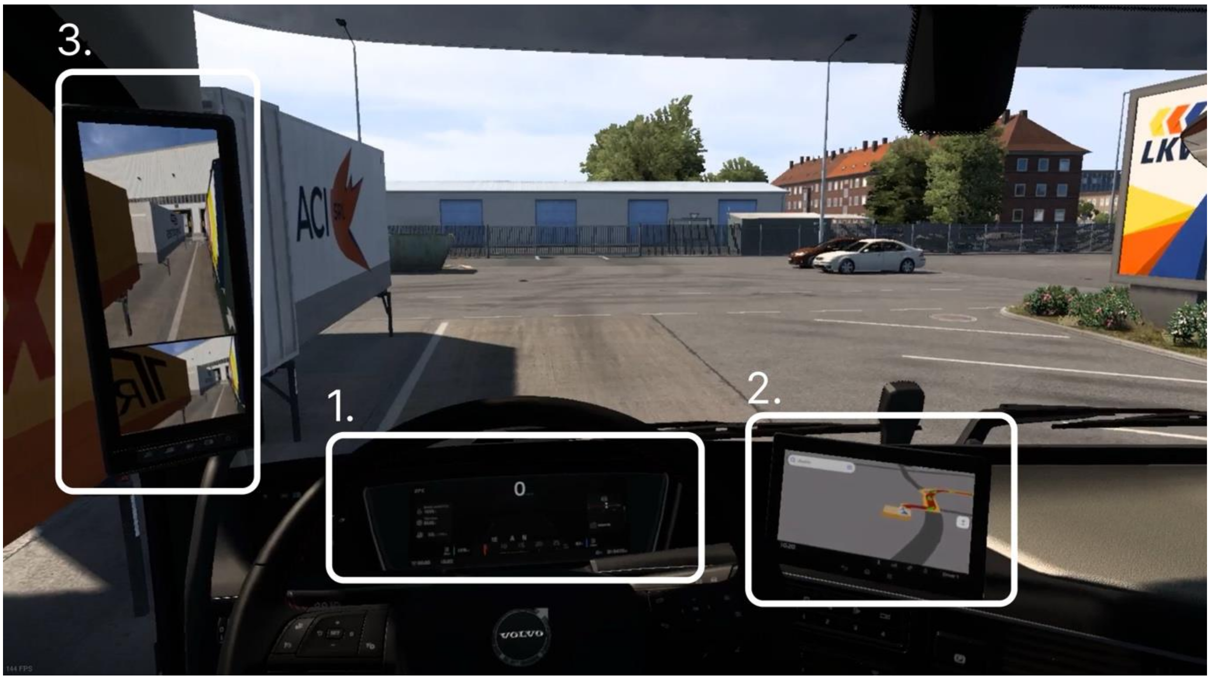

Figure 2. Different displays in the cabin. Reprinted with permission.

This is an explorative study, and any technical aspects of implementation for a HUD will be overlooked for the concepts and ideas in the concepts.

The baseline vehicle for the project is a commercial truck of the model Volvo FH16.

Due to budget and time constraints, there is no possibility of constructing a realistic prototype. This in turn prevents accurate real-world testing that could yield comparable results to an actual finished and implemented solution. This means that certain ergonomical aspects cannot be studied, neither cognitive nor physical. An example of this is refocusing of the eye which could be an important aspect for evaluating the efficiency of HUDs.

1.4 Societal and Ethical Aspects

The societal and ethical aspects to consider in this project include whether the outcome benefits or harms society. For truck driving, safety for people and goods is especially important since mistakes could lead to accidents. Because of this, cognitive overload is an important aspect to take into consideration when presenting information in a vehicle.

Another ethical aspect to consider is whether the outcome restricts driver autonomy and driver's perceived user control, that is, the driver's sense of control when interacting with the interface. Highly autonomous features might not be appreciated by drivers and could lead to inattentiveness or dissatisfaction. The aim is to develop a solution that supports drivers, not one that removes their independence and ability.

It is also important to note that a common application of HUDs is within the military industry (Korentsides et al. 2022). As the project partly explores the possibilities of AR-HUDs, it is important to consider the risk of improving tools that might also be used in military applications.

This project involves data collection and evaluation in the form of interviews and observations of truck drivers. Therefore, it is important to follow the General Data Protection Regulation (GDPR) to ensure that all participants have given their consent to participate are provided with privacy.

2. Final Results

This project resulted in the concept *HUD for commercial trucks: Three Adaptive and Customisable Modes*. An adaptable HUD with different driving modes that automatically activates depending on which type of road the truck is on. A HUD interface using AR-features to support commercial truck drivers. Figure 3 illustrates an example of the final concept with an AR-element activated. In the top left is a zoom in on the base-HUD.

Figure 3. Final Concept of HUD interface with AR-feature. Reprinted with permission.

The elements that don’t involve AR are placed in what is called the base-HUD. This consist of both constant and temporary elements. Figure 4 illustrates a base-HUD where all the elements are activated.

Figure 4. Base-HUD with all elements activated.

2.1 Three Modes: Country Road, Highway and City

The HUD has three driving modes: *Country Road*, *Highway* and *City* that are adapted to each driving situation with the same name. The modes automatically shift when moving from one type of road to another which is determined by the GPS in the truck.

2.1.1 Default Settings and Customisation

Each driving mode comes with a default setting where a selection of elements is activated. The user can also activate and deactivate elements themselves, for each mode. Table 1 below lists all the possible elements to display in the HUD, and which elements are selected in the default settings for each mode.

Table 1. Elements for the HUD and default selections for all modes.

	Country Road	**Highway**	**City**
BASE-HUD			
Constant			
Speedometer	☑	☑	☑
Speed limit	☑	☑	☑
Driving and rest time	☑	☑	☐
Outside temperature	☐	☐	☐
Clock	☐	☐	☐
Navigation			
3D map	☑	☐	☑
Upcoming turns/actions	☑	☑	☑
ETA (Estimated Time of Arrival)	☑	☑	☑
Temporary			
Cruise Control	☑	☑	☐
Adaptive Cruise Control	☑	☑	☐
Pilot Assist	☑	☑	☐
Critical vehicle status warnings	☑	☑	☑
Nearby pedestrian warning	☑	☐	☑
Incoming calls	☑	☑	☑
Slippery road conditions	☑	☑	☑
Short distance warning	☑	☑	☑
Road signs			
Priority road	☐	☐	☑
Prohibitory signs	☑	☐	☑
Warning signs	☑	☑	☑
AR-HUD			
Navigation			
Turns/Exits	☑	☑	☑
Navigation arrow on the road	☑	☑	☑
Highlight no entry roads:	☐	☐	☑
Height lim.	☐	☐	☑
Weight lim.	☐	☐	☑
Surroundings			
Highlight pedestrians	☑	☐	☑
Highlight cyclists	☑	☐	☑
Highlight slow-moving / stationary vehicles	☑	☑	☐
Highlight wildlife	☑	☐	☐
Other			
Adaptive Cruise Control	☑	☑	☐

2.2 User Response on Final Concept

This section presents a summary of the results of the evaluation, that was conducted through five interviews with truck drivers. The final concept has been refined according to the users' responses.

2.2.1 General Feedback

The general feedback from the truck drivers that evaluated the concept were positive. They were content with the three modes and positive to the automatic switching between modes. The elements that can be shown on the HUD were developed in collaboration with users and positively received. All participants were very positive to the ability to personally customise their HUD and said they would use the ability to customise it if they had a HUD in their truck. They were generally positive to using the HUD as long as they had the ability to customise which elements would be shown.

2.2.2 Key Concerns

The key concern from the user response was the risk of cognitive overload. This concern is mainly addressed through the customisation in the final concept.

3. Head-Up Displays

This chapter explains the technology of head-up displays and some of the technical aspects of implementing head-up displays in commercial trucks. It also explains the concept of augmented reality and how this could be used in head-up displays. Even though the project does not focus on technical implementation, it is still essential to understand the underlying technology and how it works in order to fully grasp the context of the project, what possibilities exist, and to build an accurate and relevant overall understanding of the field.

3.1 Head-Up Displays in Trucks

A head-up display denotes a transparent interface that conveys information without requiring the user to divert their gaze from their forward field of view. HUDs typically consist of three core components, a video generation computer, a projector unit and a combiner (fig. 4). The combiner refers to the transparent interface onto which information reflected. In the context of this project, the combiner would be the windshield of the truck. The projector unit as well as the video generation computer are both components that would be built into the truck.

The head-up display technology has been widely developed already and can be found in many cars on the market today. However, similar advancements have not been realised within the trucking industry in the same scope. One reason for this is the fundamental geometric and structural differences between cars and trucks. Regular passenger vehicles typically feature an angled windshield that allows projection and reflection of information directly into the driver’s line of sight from a projector unit mounted behind the dashboard. Commercial trucks usually employ a near-vertical windshield, and this configuration presents challenges for conventional HUD systems. It is a challenge to achieve the required reflection angle without altering the angle of the windshield. This would likely require positioning the projector unit closer to the driver, which complicates both design and implementation.

As per guidelines provided by Volvo GTT, the technological feasibility of implementing a HUD in a commercial truck fall outside the scope of this project. However, understanding the underlying technology remains relevant, an effort has therefore been put into exploring how HUD systems function in modern cars.

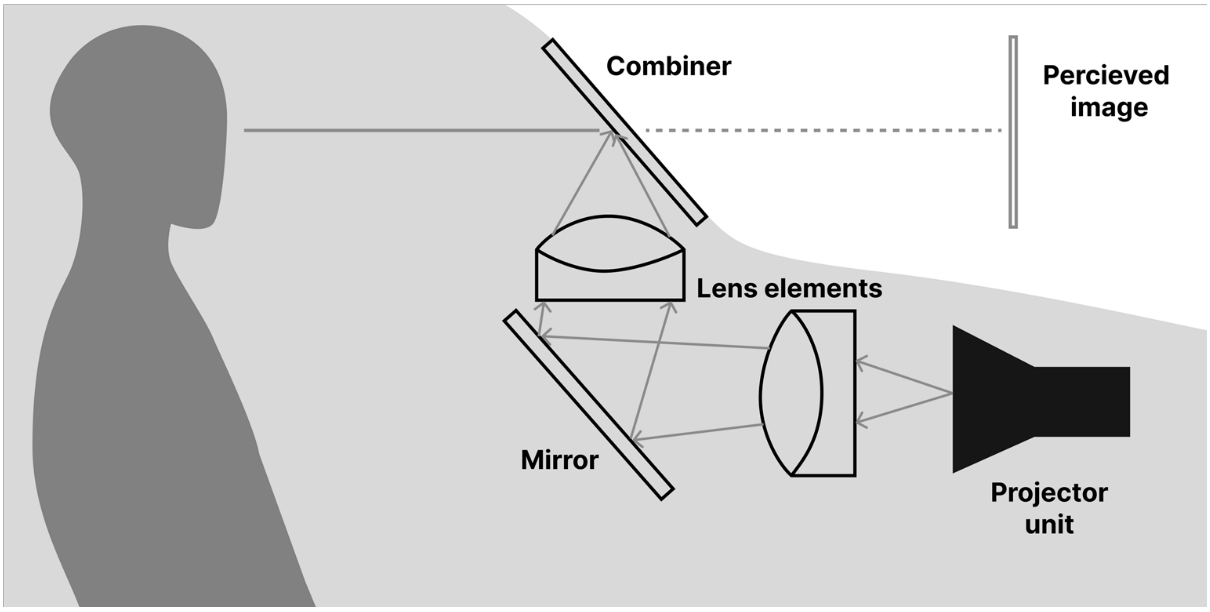

Figure 5. Simplified HUD illustration.

Since the head-up technology used in vehicles works by reflecting information onto the combiner, the image perceived by the driver can appear farther away than the windshield. The virtual distance between the windshield and the image can be extended several meters ahead of the vehicle. This functionality has cognitive ergonomic advantages, both because it allows the driver to take in information without having to refocus their eyes too much, and because the HUD reflection doesn't emit blue light in the same way a screen would. Both factors contribute to heightened awareness on the road as well as lessened fatigue in the drivers (Park, Im, 2020).

The distance between the combiner and the perceived image can also be dynamically adjusted, depending on how the image is reflected between the combiner and projector unit. If the HUD utilises mirrors and fixed lenses, then the images projected stay at a certain depth while active, but recent technological advancements such as liquid lenses and non-fixed lenses allow images to move in depth and focus (Kun, 2020).

3.2 Augmented Reality in Head-Up Displays

A recent development for Head-up display technology integrates Augmented Reality (AR). Augmented Reality refers to the interactive experience that overlays images and elements onto reality creating a feeling of immersion. Relevant examples for this project are physical elements outside the vehicle, such as pedestrians crossing, or having the navigation directions displayed on the road in real time.

The AR-HUD works through sensors and cameras mounted on the body of the vehicle, and the data from these sensors is processed by two main computers in the car. Calculations are made by these computers to get an accurate placement of the data in the display, as well as how the elements should adjust as the surroundings change.

4. Theoretical Background and Methodology

This chapter describes theory regarding design that has been used when making decisions throughout the project, and the specific methods that have been applied to advance the design process.

4.1 Usability

Usability plays a central role in interaction design, especially in systems within a safety-critical context such as driving. In this project, two well-established theoretical frameworks have been used to evaluate and make design choices: Jakob Nielsen's Ten Usability Heuristics and Jordan's Five Usability Characteristics. These two theories work as guidelines in creating and evaluating the quality of the interfaces' interactions.

4.1.1 Nielsen's Ten Usability Heuristics

One of the most widely recognised theories for evaluating usability is Jakob Nielsen's Ten Usability Heuristics**.** These heuristics provide general principles for user interface design and are often used to assess the quality of user interaction (Nielsen, 1995). Each principle highlights a critical aspect of how systems should be designed to ensure efficient and satisfying user experiences. The ten heuristics are:

Table 2. Nielsen's Ten Usability Heuristics.

Visibility and feedback	It is of great importance to keep the user informed about what is happening at any given time, using appropriate feedback.
Match between system and the real world	The interface should align with the user's mental models by using the right fitting language, symbols, and real-world conventions.
User Control	The interface needs to have the right amount of freedom. The user has to feel in control, being able to undo and redo actions without frustration.
Consistency	The design should maintain internal consistency and follow the own platform conventions. Having the same design through the whole interaction helps the user to learn and feel comfortable within the interface.

Error Prevention	The design should prevent problems before they occur, through clear instructions and constraints.
Recognition Rather Than Recall	Users should not have to remember. Actions and options should be visible and easily accessible at the relevant step.
Flexibility and Efficiency of Use	The interface should fit both novice and experienced users. For instance, by offering shortcuts and customisability.
Aesthetic and minimalist design	The design should avoid unnecessary information and maintain a clear and well-structured layout. Every element should serve a purpose.
Error recovery	Error messages should be clear, explain the issue, and suggest an easy-to-understand solution.
Help and documentation	While ideally unnecessary, help and documentation should be easy to get, and being focused on the user's task and needs.

(Nielsen, 1995).

4.1.2 Jordan’s Five Usability Characteristics

While covering a great part of what is important to keep in mind while designing, Jordan’s Five Usability Characteristics provide a picture of how the interaction with interface holds up over time. These aspects therefore have a stronger presence in the later stages of the project, particularly during the evaluation of the developed system:

Table 3. Jordan's five usability characteristics.

Guessability	How well a new user can operate and navigate through the system on the first attempt, without prior instruction.
Learnability	How quickly a user improves performance after the initial use. This is most accurately measured by how the user performs when interacting with the system for the second time.
Experienced User Performance	The efficiency with which an experienced user can complete tasks. Often using shortcuts or special strategies.
System Potential	The theoretical optimal performance that could be achieved with the system, assuming perfect use.
Re-usability	How well users can remember how to use the system after a certain time period of non-use.

(Jordan, 1998).

4.2 Work Structure

This chapter describes the methods used to structure the process of the project.

4.2.1 Design Thinking

Design thinking is both looking for new ideas, as well as discarding ideas that do not fit at the time. Using this approach in a continuous discussion about what is best for the user is a fundamental principle of design thinking. For designers, this is a natural way of looking at the process of product development (Wikberg-Nilsson et al., 2021).

4.2.2 ACD3-Method

ACD^3 is a method for structurally dividing the process of product development into phases, where each phase focuses on a different level of design. The different phases included in the method are user need identification, design for use, general design, detailed design, construction, production and commissioning. For each of these phases certain design activities are included, which are data collection, analysis, idea generation, synthesis and evaluation. As seen in figure 6 below, an important aspect of the method is to iterate throughout the entire process. For this project the phases for production and commissioning are overlooked (Bligård, 2015).

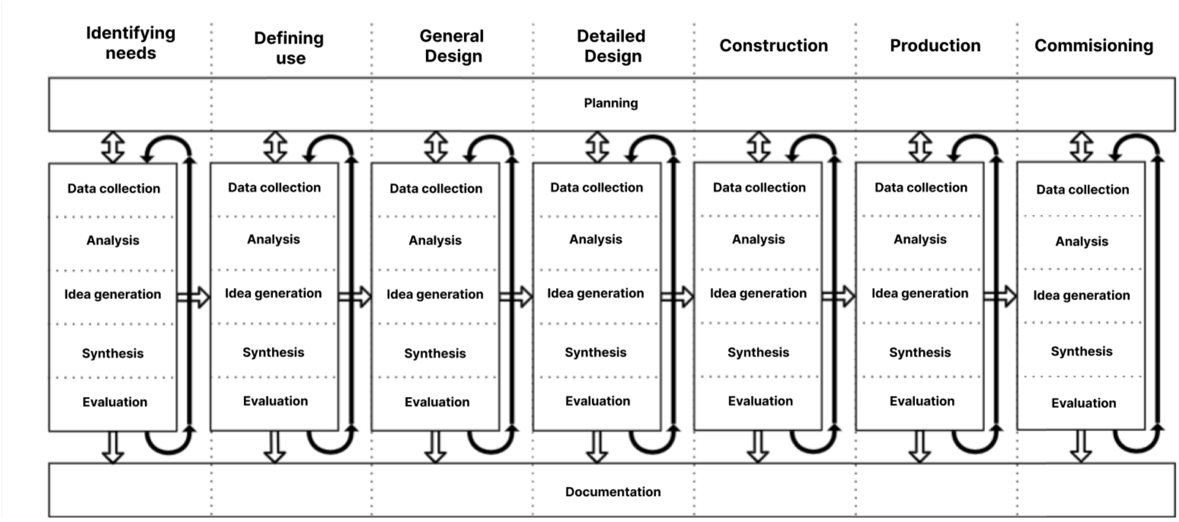

Figure 6. Translated illustration of ACD3-method.

4.2.3 Figma

Figma is a digital design tool that offers the ability to let parties work together with several documents at the same time. It can also be used for presenting and evaluating concepts, since it provides the ability to get an overview, and because it is easy to work on several documents at the same time.

4.3 Data Collection

This chapter describes the methods for empirical data collection used throughout the project.

4.3.1 Benchmarking

Benchmarking is the process of exploring the market of solutions for problems similar to the one at hand. Useful results from performing this method include furthering the understanding of the problem and the goals of the project (Eijlertsson et al., 2009).

4.3.2 State of the Art Review

The purpose of a state-of-the-art review is to specifically look for solutions or matters which are at the very edge of development, to understand what areas to focus on in the project (Grant et al., 2009).

4.3.3 Studies of Relevant Scientific Studies

Gathering information and knowledge from earlier projects and other scientific relevant studies is done to deepen the knowledge about the subjects related to the project (Bligård, 2015).

4.3.4 Interviews

Interviewing people in a target group is a useful method for gathering credible data. Depending on whether qualitative or quantitative data is desired, the type of questions in the interview will vary. If quantitative data is desired, closed-ended questions from a strict interview template are better, and this is known as a structured interview. If qualitative data is desired, open-ended questions are favourable since it leaves room to develop a dialogue and to expand on certain points. This is often referred to as an unstructured interview, and when combining both types of questions one can conduct a semi-structured interview. By utilising probing questions to home in on certain topics, the interview follows what is called a funnel structure which means starting with broad questions and narrowing down (Bligård, 2015).

Interviews can be formative or summative. For formative interviews the feedback from the users is used to develop a concept further. A summative interview is used to confirm the results (Wikberg-Nilsson et al., 2021).

4.3.5 Observations

Observations are useful to gain an understanding of the user context. An observation can be open or hidden, referring to the user’s knowledge of the observation taking place. Observations can be structured, semi-structured, or non-structured. A structured observation aims to study specific actions and requires a certain amount of preparation. A non-structured observation does not require the same amount of preparation but rather seeks to gain a general understanding of the user context (Rexfelt, 2023).

4.3.6 Sampling

When extracting a sample of users, it is important to draw from a group of relevant subjects. There is always going to be some level of convenience sampling due to constraints related to time and costs (Wienclaw, 2024).

4.4 Analysis and Synthesis

This chapter describes the methods used to analyse and synthesise used throughout the project.

4.4.1 KJ-Analysis

This method is named after its creator Kawakita Jiro and the primary purpose is to form categories from collected data, and to prioritise the most important problems areas. Comments and observations from the data collection are written down on post-its, and are then grouped without prior categorisation. Discussion during the analysis is limited to making the groupings as natural as possible. When the groups have been created, they are named appropriately. The categories with the most post its are likely representing areas that should be prioritised (Spool, 2022).

4.4.2 Scenario

There are different ways to look at and build scenarios. By building scenarios from a situational perspective, problematic aspects of that situation can be concretised (Filippidou, 1998).

4.4.3 List of Functions

Creating a list of functions is a way to structurally list what a product should do, rather than how it solves problems. A correctly formulated function should follow the form of verb + subject. By creating a list of functions, the participants are allowed to think in terms of function rather than solution (Landquist, 2001).

4.5 Ideation and Concept Development

This chapter describes the methods used for ideation and concept development throughout the project.

4.5.1 Brain Drawing

This method focuses on sketching to stimulate new ideas. The participants each sketch on their own paper or a whiteboard, and after a short period of time, the sketches are rotated to the next person, allowing them to build on the ideas of the previous person. This is repeated until each participant has had the opportunity to draw on each sketch, or until the activity is concluded. By utilising this visual type of idea generation, some new perspectives may arise that would be missed in writing or talking. Guidelines for brain drawing includes aiming for bizarre ideas and to not criticise during the exercise. After the exercise the results are discussed (Wikberg-Nilsson et al., 2021).

4.5.2 Brainstorming

The purpose of brainstorming is to create many ideas. The topic is defined and formulated as a question, and all answers form the participants are written down. Important aspects of this method are not to criticise ideas before the session is over, to aim for wild ideas, and to produce ideas in quantity before quality. The results are discussed after the exercise (Wikberg-Nilsson et al., 2021).

4.5.3 Scamper

Scamper is a method used for further developing existing ideas. Each idea is put up against a series of questions and actions listed below (Wikberg-Nilsson et al., 2021):

Substitute?

- Substitute materials to enhance the idea.
- Try different processes.
- Try substituting earlier needs.
- Try the potential for another field of use.

Combine?

- Combine different ideas to create something entirely different.
- Could you maximise the user experience by combining two or more ideas?
- Could you combine different resources to create a new combination?
- Could the purpose and result be combined?

Adapt?

- Adapt an idea to explore a new area of usage.
- Could you adapt the idea to make it similar to something else?
- Is there another context that would be suitable for the idea?
- Could you explore the current context and adapt the idea to better fit in?

Modify?

- Could you modify the expression of the idea, trough shape and or visualisation?
- Could new components be added to modify the idea?
- Could you remove components to modify the idea?
- Could you enhance something within the idea?

Put to other use?

- Could the idea be put to another use?
- Could the idea be better suited to another context?
- Is the idea better suited to another user?
- Could you create something new by utilising different parts of the idea?

Eliminate?

- Could the idea be enhanced by removing certain parts?
- How does the idea look in its simplest form?
- Explore what happens when certain parts are toned down or muted.

Reverse?

- Explore what would happen if the idea were “flipped on its head” and used in the opposite way of the intended usage.

- Change the idea by rearranging the order of parts and overall shape.

4.5.4 Idea Evaluation

This method focuses on presenting each idea in a similar way. Each participant gets a certain number of points to mark which ideas they prefer. If there are many ideas presented, only one type of point is needed. If there is a smaller number of ideas presented, the exercise can include positive as well as negative and neutral points (Wikberg-Nilsson et al., 2021).

5. Project Process

This is an overview of the activities performed throughout the process of the project. With inspiration from the ACD[3]-method and the idea of iteration, the process was adapted to suit the specific demands of this project. The project workflow was divided into five phases. These phases and their respective goals, actions and results are presented in figure 7. Figure 8 shows an overview of the phases.

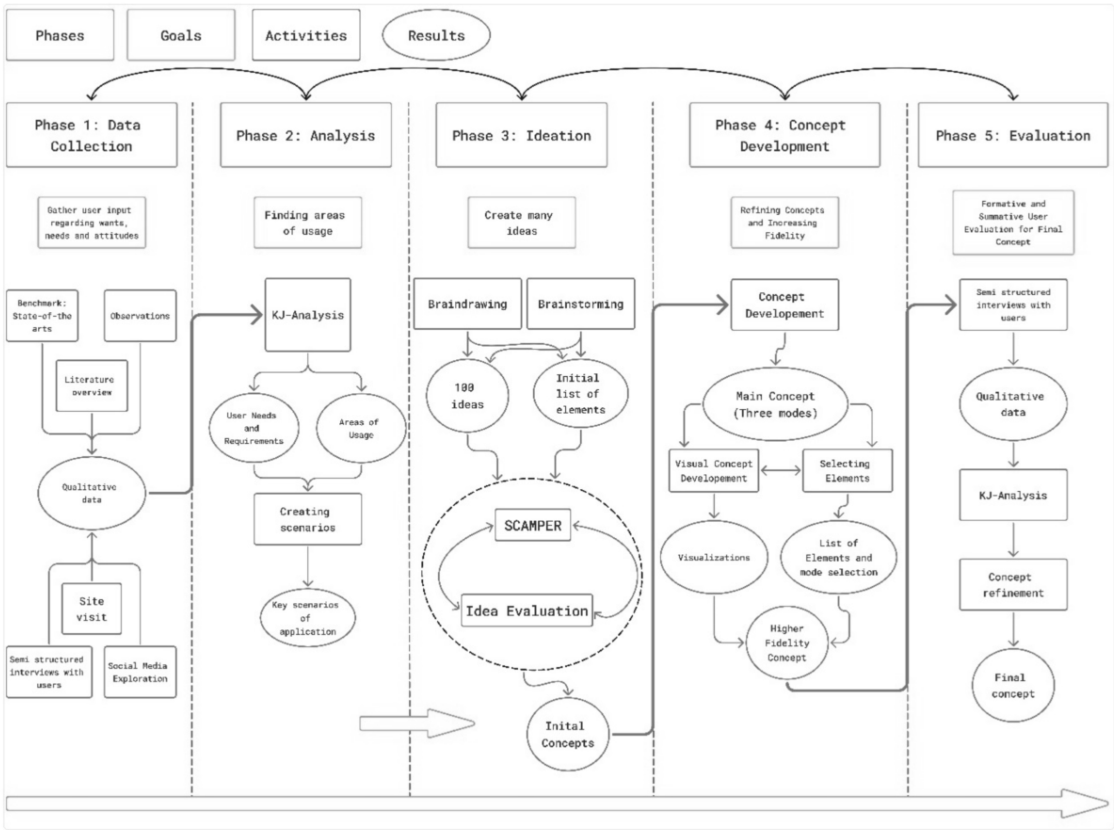

Figure 7. Detailed process.

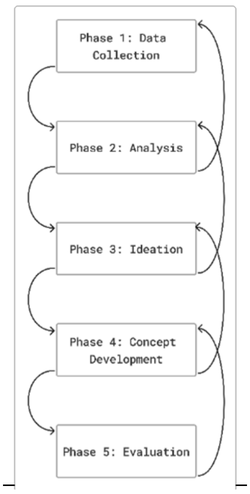

Figure 8. Process overview.

5.1 Phase 1: Data Collection

The data collected in this phase included information from current technologies and research, as well as data concerning user needs of truck drivers. From this phase, much qualitative data was collected in the form of quotes and observations.

Truck driving companies were contacted for interviews and observations with the drivers. The outreach led to interviews with five different truck drivers and a few observations. The interviews were conducted at Chalmers or in the truck driver's vehicle. One site visit was at a truck driving school. Spontaneous interviews were also conducted, which was made possible due to a loading dock where trucks regularly stopped being located near the regular workplace for the project.

All participants had experience as truck drivers; some were currently active, while others had driven in the past. To complement the information gathered from direct contact with people, an online forum for truckers was used, where questions were asked and the group had interactions with a variety of people.

5.1.1 Technology Benchmarking and Literature Review

To gain inspiration and knowledge of Head up displays and Augmented Reality in HUDs, a benchmark of state of the arts technology was performed. This was done on the internet, including the Chalmers library search portal for academic articles.

Volvo provided group members with the opportunity to test drive two cars with different types of HUDs. One of the cars was a top-of-the-line car with an AR-HUD, which depth of view was set at approximately ten meters from the driver. The HUD in the other car was without AR functionality, and with a depth set approximately two meters from the driver. This provided the group with some personal insight into the differences between two HUDs with different amounts of information and graphics, as well as different depths of view.

Articles and studies that evaluate HUDs in cars were overviewed to gather information about how HUDs should be designed for maximum positive effect.

5.1.2 Empirical Data Collection

Empirical data collection was partly done through interviews and observations and table 4 shows an overview of the participants. All participants were truck drivers, either currently active or in the past.

Table 4. Overview of participants in interviews, phase 1.

Participant	**Interview Phase 1**	**Interview Format**	**Observation**
P1	x	At Chalmers	Separate Ride-Along
P2	x	Group interview with P3, inside a truck	Still standing
P3	x	Group interview with P2, inside a truck	Still standing
P4	x	At Chalmers	
P5	x	Interview during Ride-Along	Ride-Along
P6	x	Short & informal	Short, still standing
P7	x	Short & informal	Short, still standing

Semi Structured Interviews with Users

Five truck drivers were interviewed in longer semi structured interviews. Three of them were currently employed as commercial truck drivers, while two of them were previously employed truck drivers that now work office jobs at a trucking company. These two participants were interviewed together in a group interview. The audio of all interviews was recorded, which allowed for further analysation afterwards.

The interviews were all semi structured, with an interview guide (see appendix A) that gave room for follow-up questions. A funnel structure was used, starting with broad questions and narrowing down on specific areas of interest. Questions about the person's job was asked at the start of the interviews, including what type of truck, distances, and cargo they drove, as well as at which hours of the day they worked. Then questions were asked about what information is presented in a truck. For example, which info is important to display and how they would like it presented. The interviews then moved on to address HUDs and AR more specifically, where example pictures, low fidelity sketches and video examples were used to explain what a HUD is, and how AR could be utilised. Lastly, questions were asked about what possibilities they saw in HUDs and what possibilities AR could bring to them.

Observations

Five observations were made with trucks. The observations were generally an opportunity to get a sense of how the drivers operate the vehicle and to see them in action. This also allowed for the opportunity to photograph and take videos of the truck inside for later use and inspiration.

A detailed look at a stationary Volvo truck was made in the beginning of the project. This was an opportunity given by the commissioner of the project, Volvo GTT, to gain an understanding of the driver's cabin and the locations of all the different displays. All group members took turns sitting in the driver's seat, playing around with different settings.

Observations in the form of a ride-along were conducted with two different drivers. This allowed for longer observation while the driver was working, along with the possibility to ask questions. The same interview template was used as with the other interviews. By following the interview template and showing videos of HUD and AR, this interview was conducted like the others.

One of the observations was conducted with two former truck drivers that now work an office job at a trucking company. They brought a truck as a mediating object where they could explain what they were talking about in real time, as well as show different functions of the truck they liked or disliked. This was recorded and treated like the other interviews, and the same interview template was used here as well. The different settings inside a truck made the interview less formal and more open-ended.

Two spontaneous observations were conducted at Chalmers, with truck drivers who were delivering things to campus. These observations were shorter than the others since the drivers were on the clock. However, they both had enough time for a quick 15–30-minute interview, and observations of their trucks could also be conducted. Questions about what they deemed important and what problem areas they could identify in their line of work were asked.

Site Visit

One site visit was conducted at a trucking school in Kungsbacka. First the group had a conversation with the teachers at the school about the project and showed them videos and examples of a HUD and an AR-HUD. The group was then allowed a visit to one of the school's classes of last year students. There were about 20 students of ages around 19 years old in the class. The students were showed videos of AR-HUDs and were asked to divide into breakout groups for discussion. After a while the group went around the classroom and asked to hear their thoughts on the subject. The students had varying opinions about everything, which gave the group a lot of new insights. Some were really inspired and started sketching to communicate their thoughts.

The site visit to a trucking school with younger students was conducted partly due to the age of the students. Since a lot of the people interviewed earlier in the process had some experience of the work and were of a different generation than that of the students this felt like an opportunity to get a different view of technology overall.

Social Media Exploration

Since it was hard in the beginning to get in contact with potential users, the internet was a big help. A post was made in an internet forum (r/Sweden, 2025), this was done to reach a larger audience. The post (Reddit – the Heart of the Internet, 2025) that was made contained some information about the project and some questions regarding information in trucks. Some of the answers that were given by users of the forum were interacted with, follow up questions were asked to understand them better.

5.2 Phase 2: Analysis

In phase 2: Analysis, the qualitive data from the data collection was analysed to gain a better understanding of different needs, requirements, and problem areas which later concepts would be based on.

5.2.1 KJ-Analysis

The information gathered in the previous phase from interviews, observations, literature and site visits, was then analysed using a KJ-analysis to identify problem areas (see Appendix B). All the interviews and observations were transcribed manually to be examined. The transcripts were read through in search of useful information such as user needs and requirements as well as areas of usage. Quotes regarding these topics were extracted and noted on digital post its in the program Figma, which were then sorted after relevant context. Categories and relationships took shape as the analysis progressed, and this laid the foundation for creating scenarios based on that information. The categories were overviewed by the group and names representing the consistent theme were given to them based on the information and context of the quotes.

The KJ-analysis method was chosen as the primary tool for analysing all the qualitative data collected because it’s ability to break down large quantities of data into understandable parts. This was fitting for this project as there were five long interviews with data to analyse. The goal was to identify areas of usage, especially where HUDs and AR-HUDs show promise.

5.2.2 Creating Scenarios

Based on the categories extracted from the KJ-analysis, different scenarios of user context could be created by further categorising of the information inside the already created categories.

The team divided into groups of three and described different scenarios. The purpose of this was to put the information gathered back into context to gain a sense of how the HUD should work to support the driver in different situations. The scenarios were based on the results from interviews and observations, and they provided a foundation for generating ideas.

5.3 Phase 3: Ideation

Based on the analysis and the categories from the previous phase, ideation could begin. The goal was to produce a large quantity of ideas, so that the group could later weed the ideas that were unfavourable. Since the project focuses on a digital user interface, it was necessary to produce ideas in the form of symbols or images of scenarios with the interface. This made braindrawing and brainstorming the primary methods for producing ideas.

5.3.1 Braindrawing

All six members of the project group sat together and started sketching on a A4 paper, while a timer of three minutes was activated. When the timer rang, the papers were moved in a clockwise manner to be continued. Someone else's idea was continued and evolved into something as the process continued. This was done until each of the papers had been around the table. This generated a lot of different ideas, which was the reason braindrawing was used.

5.3.2 Brainstorming

Brainstorming sessions were conducted on several occasions, in both the large group and in smaller groups. A large focus was placed on letting all the members share their ideas without being criticising.

5.3.3 Idea Evaluation

All the sketches that were created through the method of braindrawing were placed on a large table. Each of the members in the project group were handed differently coloured adhesive stickers with different value based on the colour, red = dislike, yellow = maybe, and green = like. These were then placed onto the different elements and ideas from earlier idea generation. When all the stickers had been stuck to a sketch, each sketch that had a sticker was discussed and evaluated further by the group.

The sketches were later shared with Volvo and our supervisor, where there were open conversations about which ideas could work and which could not.

5.3.4 Scamper

To further develop the ideas, the SCAMPER method was used. This method was used to explore the possibilities of ideas and create new ideas and concepts. The group picked relevant questions from the SCAMPER method to do this.

5.3.5 Nielsen's Ten

During this phase, the work was partly based on a few of Nielsen's Ten Usability Heuristics to shape the ideas and their design according to the most suitable interaction.

The ideas were grounded in trying to create a layout that was as stripped-down as possible, in line with what Nielsen refers to as Aesthetic and Minimalist Design (Nielsen, 1995). The ideas that progressed beyond this stage had thereby, already in their early stages, undergone a form of selection based on minimalism.

Another key consideration during the ideation phase was the driver's perceived User Control (Nielsen, 1995) of the interface, as this surfaced as a top priority during the interviews. The more negative attitudes that emerged during the conversations often revolved around a form of resistance to technology, seemingly rooted in a fear of not being able to control what was shown and how.

This also ties into the third and last important aspects of the core design values which framed our approach throughout the ideation process: what Nielsen describes as Flexibility and Efficiency of Use. That is, being able to personalize the interface.

Based on these three core pillars drawn from some of Nielsen's usability heuristics, the foundation was laid for the concepts that eventually moved on to the next phase of the project.

5.4 Phase 4: Concept Development

The purpose of this phase was to create a digital concept of a HUD interface that meets user needs and requirements. To design the HUD, the program Figma was used.

5.4.1 Digitalisation

The last phase ended with a lot of sketches that were digitalised, since this project aspired to develop a digital concept of an interface. Hand drawn sketches were translated into digital ones, and a traced image of the inside of a truck was created. This worked as a wireframe for idea sketches. The wireframe could also be paired with different drawings of different surroundings, which created opportunities to draw ideas onto different contexts. Elements and symbols were sketched onto printed versions of the traced wireframes.

Later, all the different elements, symbols and scenarios that had been sketched on paper were sketched in low fidelity on the computer using Figma. Then these were put onto similar backgrounds as before and in context with each other, which gave the interface a higher level of fidelity than before.

5.4.2 Three Main Modes

At this time a concept took form through discussion and continued idea evaluation. Three main modes for different types of driving were determined. These modes laid the ground for the main concept.

5.4.3 Customisable Base-HUD and AR-HUD

The HUD was separated into a Base-HUD and an AR-HUD, which was done because some information was deemed unsuitable for the AR-HUD. The separation of the Base-HUD and

AR-HUD made it possible to continue the concept development on two different fronts so that the work could be divided.

5.4.4 High Fidelity Concept

To increase the level of fidelity even more, detailed designs of the elements were created that resembled the already existing Volvo HUD for personal cars. To separate different types of information a colour scheme was decided for the elements. Red elements are important warnings that indicate immediate danger. Yellow elements indicate warnings that you should be aware of. White elements are general settings. Blue has been used for navigation. Green is used for cruise control.

To have some environment to place these in, a youtuber (*TruckersEyeView*, n.d.) that drives a truck and films it to put on YouTube was contacted. The question was asked if his videos could be used as background for the interface in the project. This made it possible to place the digital designs in many different and real scenarios.

While the images that were extracted from these videos were helpful during the designprocess, some situations were still missing. For this reason, the game Euro Truck Simulator 2 developed by SCS Software s.r.o. was purchased and downloaded by one of the group members. The game provided the ability to create specific scenarios presented itself. The same treatment as with the video screenshots were applied to screenshots from the game. Digital designs were placed over the screenshots to create a realistic looking HUD in a truck.

5.5 Phase 5: Evaluation

It was decided that the concepts would be best evaluated by the users themselves and that the evaluation would be of both formative and summative character. Some of the information gathered helped guide in further adjustments of the final concept, while some the information confirmed that certain aspects of the concept were good. The evaluations were conducted through interviews since the format made it possible to explain the concept and allowed the participants to ask questions.

In total, five users were contacted to evaluate what they had helped develop. Three of the users from the initial interviews participated again in the evaluation of the High-Fidelity Concept, while two were new contacts (see table 5). It was important to include these new users in the evaluation to further validate the concept, since they had not been part of influencing the development of the concepts beforehand.

There were a lot of things to evaluate and for the users to look at and the focus of the evaluation was foremost the information, secondly the functionality and lastly the appearance. The information was considered the most important to evaluate since that was the primary concept developed, while the functionality and appearance could be changed easier.

Table 55. Overview of participants in evaluation interviews.

Participant	Reoccurring from Phase 1	Evaluation
P2	X	X
P3	X	X
P4	X	X
P8		X
P9		X

5.5.1 Semi Structured Interviews with Users

An interview template was designed to be semi structured and funnel like to let the users speak freely but also to have the opportunity to dig deep if necessary. Because there were many images of ideas this free evaluation format was suitable. To better evaluate aspects such as guessability (Jordan, 1998), the interviewee was not always explicitly told what each part or symbol represented. This was done intentionally to better observe how they would interpret the elements on their own. Alongside the verbal material (i.e., interview questions), a visual presentation was provided showed the different scenarios and the concept itself.

Evaluation with the users was conducted both in person and virtually over Microsoft Teams. The users were shown different environments with the layouts made earlier and they were both interviewed about it and were allowed to talk freely about the different scenarios.

5.5.2 KJ-Analysis

After semi structured interviews with the users, there were a lot of new qualitative data to be analysed. Again, since it needed to be broken down in understandable parts, a KJ-analysis was done. This analysis was based on the transcripts of the evaluation interviews and was supposed to help refine the concept. Quotes from the transcripts were extracted and noted on virtual post its in Figma and was placed in context with the others. Categories took form as different aims of feedback by the users. The categories were summarised, and the concept could be adjusted.

5.5.3 Concept Refinement

The concept was refined using the input from the users in the evaluation. This refinement meant confirming all the elements to be displayed on the HUD and making the final touches for the graphical interface visualisations.

6. Results

This chapter presents the results of this project. Firstly, the user needs and requirements which laid the ground for the rest of the project are presented. Thereafter, a set of key scenarios of application are presented to describe the variation of needs and demands in different situations. Areas of usage where HUDs provides possibilities in improving the driving situation, as well as an initial list of elements for the HUD, is also presented.

Concepts and ideas are presented with sketches and descriptions. At the end of the results chapter is the final concept: *HUD for commercial trucks: Three Adaptive and Customisable Modes*. The result is presented with the main aspects of the concept, a list of all the included elements, visualisations and features of the final concept. The results from the user evaluation of the final concept are included in the result of the final concept.

6.1 Results – User Needs and Requirements

This section regards user needs and requirements. These results mainly derive from the interviews, observations, site visits and social media exploration that were conducted in Phase 1: Data Collection. The user needs were also further explored and analysed in Phase 2: Analysis, through the making of a KJ-analysis (see Appendix B) and creating scenarios. These scenarios are also presented in this section.

To understand the users, it was important to understand their attitudes toward technology in general and specifically HUD technology. From the interviews and the site visit it was clear that these attitudes varied a lot between different participants.

For some, it was a general lack of trust in technology, based on previous experiences:

> *"I've had major issues with cars where it flickers, lags, and doesn't quite keep up. The biggest request is to scale back the technology a bit."*
>
> Interview quote from a commercial truck driver

> *"That's just how technology is these days; all of a sudden, it can go haywire, and there's nothing more annoying than something that keeps blinking. So, a button to turn it off and to activate it [would be great]."*
>
> Interview quote from a commercial truck driver

Almost all participants mentioned the desire to be able to turn off the HUD. This became a requirement for all further concepts since it was essential for getting the users to agree to use a HUD.

> *"I want to be able to control what is displayed myself and easily turn it off."*
>
> Interview quote from a commercial truck driver

These aspects all connected to the drivers' sense of control. Perceived user control became another requirement for concepts to be accepted by users. User control includes the ability to turn the HUD off but also extends to the ability to customise the HUD in further detail and specifically choose what is shown on the HUD. Several of the participants wanted to be able to customise the interface to their personal preferences, but there was also a belief that older truck drivers didn't share the same need and interest in changing the interface themselves.

Another important user need was the need to not be overwhelmed with information which was expressed as:

> *"Show me what's important in the moment."*
>
> Interview quote from a commercial truck driver

> *"Show me as little as possible."*
>
> Interview quote from a commercial truck driver

The importance of not being overwhelmed was supported by research concerning the level of distraction caused by AR-HUDs (Sun et al., 2015). And even though the drivers were keen on not being overwhelmed there was a general interest in the possibility of HUDs keeping eyes on the road. Most of the participants were generally positive about using HUDs if it did not become too distracting.

> *"The fact that it's a head-up display is definitely a good thing – it keeps your eyes on the road the whole time, and that's not bad at all. Honestly, it should be standard."*
>
> Interview quote from a commercial truck driver

However, a minority was strongly against HUDs, and this was clearly demonstrated by one of the drivers from the social media exploration:

"MAYBE you find it hard to look down, so we'll just put the information right IN FRONT of you – so you can't ignore it and must get it shoved in your face, while paying less attention to the road. I mean, you're only driving sixty-four tons. Oh, and by the way, the car in front of you just braked – but anyway you're exiting in two hundred meters."

From post in Reddit forum

Lastly it was mentioned by several drivers that the risk of accidents was a huge risk in their profession:

"Over the past three years, I've seen far too much. Accidents and incidents that happened because someone lost focus on the road. It really makes you stop and think."

Interview quote from a commercial truck driver

"When you glance down at the instrument panel, those few seconds can be crucial."

Interview quote from a commercial truck driver

Because of this, keeping the driver focused and keeping eyes on the road were essential requirements that laid the ground for all further concepts, and something that was considered throughout the concept development.

6.1.1 Key Scenarios of Application

From the interviews it was clear that different truck drivers have varying working situations. For example, it can be differences in the cargo they are transporting, the distances they drive, in which traffic setting they operate and what time of day it is. Through the KJ analysis in phase 2 these aspects were further analysed to establish the user's needs and requirements. From the KJ analysis a few key areas of usage were also identified (see Appendix B). These are explored later in the results chapter. From the user needs and areas of usage three key scenarios of applications were created. These scenarios illustrate the various contexts a truck driver operates in.

Scenario 1: Long-Haul Driving Through the Night

Johan Andersson drives a heavy-duty truck with a total weight of approximately sixty tons. He covers long distances, often spending several consecutive days on the road. Many of the hours are driven in darkness at night, during which he is usually alone on the road. His routes primarily consist of long stretches on highways.

Scenario 2: Urban Logistics Between Port and City

Jonna Johansson operates a heavy-duty truck in the Gothenburg area, primarily between the port and Gamlestaden. She loads and unloads multiple times per day and adjusts her driving *to suit the port environment, expressways, and urban traffic. When driving in the city, it is crucial that she does not end up on the wrong street. However, since she drives the same route back and forth, the risk of wrong turns is relatively low. That said, Gothenburg is known for frequent construction, road closures, and traffic diversions.*

Scenario 3: Cross-Country Driving During the Day

Jesper Lindbergh drives a heavy-duty truck across Europe. He primarily drives during the daytime on both highways and country roads. Traffic levels vary, but he is rarely completely alone on the road. Jesper enjoys looking out over the landscape as he drives. While on the road, he talks on the phone with colleagues and listens to the radio.

6.1.2 Order of Relevance for Information, Functionality and Appearance

An order of relevance was established for the various aspects of the solutions. This is based on what the participants in all the interviews, both in the data collection phase and the evaluation phase, expressed as most important. They all agreed that the most important factor was which information would be displayed on the HUD. This was followed by its functionality, meaning how it works to support the driver’s needs and adapts in different situations. The appearance of the HUD was considered the least important aspects among the participants, meaning the visual design of elements and the overall layout of the interface. This hierarchy is presented in figure 9.

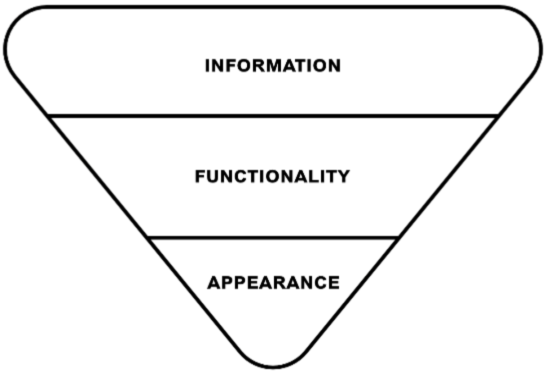

Figure 9. Order of relevance.

6.2 Results – Areas of Usage for Head Up Displays

This section presents the potential areas of use for HUDs. These results are based on the KJ analysis that was performed during Phase 2: Analysis.

6.2.1 Six Categories of Usage

The KJ analysis resulted in six categories of usage (see Appendix B), that later worked as categories for elements in the HUD. These six areas were:

- Driving times and rest periods
- Vehicle status
- Media, calls and notifications
- Warnings
- Surroundings
- Navigation

The last two categories, surroundings and navigation, were identified as the categories best suited for AR elements since AR provides the possibility to target objects in the surroundings in their actual position and for placing navigational directions directly on the road.

Driving Times and Rest Periods

One problem area that was identified through the KJ analysis was driving and rest times. All participants in the interviews mentioned that a reoccurring problem in their work was to ensure that their driving times and rest periods were within the regulation limits. This was especially difficult during long-haul driving through Europe where it is hard to find places to stop, since the truck stops very often are full. Because driving times and rest periods was seen as a problem by all interview participants, it was regarded as a potential area of usage for a HUD.

Vehicle Status

Information regarding vehicle status was important for all drivers that were interviewed. Examples of vehicle status include current speed, payload, axle load and power meter. For some, the information regarding load was mainly relevant during loading and unloading of cargo, and for others who drove very heavy cargo it was important throughout the driving.

Media, Calls and Notifications

During the interviews the drivers were asked about what information they frequently looked at and many of them answered that media was something they often had on their secondary display. This was partly because they needed to display the radio to change song or station. But when they were asked if they also used the display to see which song was playing, to which many of them answered yes. Therefore, media was also considered an important category of information for the users.

Another type of information that made the drivers look away from the road was to see who was calling if the phone rang. One participant even mentioned that they sometimes checked their phone for notifications.

Warnings

Warnings was an area of information that was discussed in the interviews and seemed important from the analysis. The “warnings”-category consists of warning signs and warnings for vehicle issues. It was requested by the interview participants that warnings are yellow, orange or red depending on the severance of the warning.

This category somewhat overlaps with the following category “surroundings” since there are some warnings that regard surroundings.

Surroundings

“Surroundings” focuses on the surrounding traffic environment. The category includes priority, and instruction road signs. Warning road signs are not included. Surroundings also include all traffic participants – meaning other vehicles, pedestrians, cyclists and animals such as wildlife.

Navigation

Navigation was deemed one of the most important types of information for the drivers to have on display in the truck. Most of the drivers used the secondary display to see a GPS map. This meant that navigation was something causing them to take their eyes off the road because they looked down on the secondary display. Navigation was also described as incredibly important since driving onto a road with weight or height limitations can have terrible consequences. The following quote illustrates the importance of getting correct road directions:

> *"If I were to take a wrong turn, it would be a bit of a disaster! There's nowhere to turn around."*
>
> Interview quote from a commercial truck driver

6.2.2 Initial List of Elements

The HUD was divided into a base-HUD and an AR-HUD to gain a sense of the different areas where elements could go. The base-HUD was defined as the HUD that sits in a constant position with both constant and temporary elements. The AR-HUD includes all elements that are connected to real life surroundings.

An initial list of elements (table 6) was made using the categories and the division between the base- and AR-HUD. These are elements to be selected and displayed on the HUD. The initial list of elements is quite extensive since there was a variety of wanted functions among different users. The elements that are crossed off were eliminated in the final concept but remain here to demonstrate the development.

Table 6. Initial list of elements

BASE-HUD	AR-HUD
Constant	**Navigation**
Speedometer	Turns/Exits
Speed limit	Navigation arrow in the road
Driving and rest times	Highlight no entry roads:
Navigation	Height lim.
3D map	Weight lim.
Upcoming turns/actions	**Surroundings**
ETA (Estimated Time of Arrival)	Highlight pedestrians
Outside temperature	Highlight cyclists
Current time	Highlight slow moving vehicles
	Highlight wildlife
Temporary	Highlight road signs
Road signs	**Other**
Priority road	Adaptive Cruise Control
Prohibitory signs	
Warning signs	
~~Instructions signs~~	
Cruise Control	
Adaptive Cruise Control	
Pilot Assist	
Critical vehicle status warnings	
~~Vehical status notifications~~	
~~Break status~~	
~~Air pressure system~~	
~~Battery~~	
~~Broken light~~	
Nearby pedestrian warning	
~~Blind spot warning~~	
~~Media / music~~	
Incoming calls	
~~Phone notifications~~	
Road condition warning	
Short distance warning	
~~Parking break~~	
~~Open door~~	
~~Show avaliability at truck stops~~	
~~Show facilities at truck stops~~	

Elements that did not actively support the driving situation were eliminated. Elements that required a lot of text were also eliminated because it posed a risk of demanding to much focus to read. Elements with complex symbols were eliminated because the transparency of the HUD threatened the visual clarity. Examples of this is vehicle status notifications. This was also a type of information that the users were satisfied with in the current information clusters, and therefore it was seen as unnecessarily complicated to move it to the HUD. Blind spot warnings were eliminated due to a law legislation (Blind Spot Information System for the Detection of Bicycles, 2020), that states that blind spot warnings must be displayed at an angle greater than 30° from an axis going through the drivers ocular reference point.

6.3 Results – Ideas and Concepts

This section presents the interfaces developed during the project. The interfaces span a range of fidelity levels, from early-stage ideas to more refined concepts, all of which contributed to the formulation of the final concept.

6.3.1 Visualisations of Ideas

This section presents visualisations of ideas to give and understanding of how the development of the concept evolved throughout the process.

Idea Sketches

The idea sketches (fig. 10-13) present ideas from phase 3: ideation. There were around a hundred ideas so these sketches are mainly chosen to give an overall understanding.

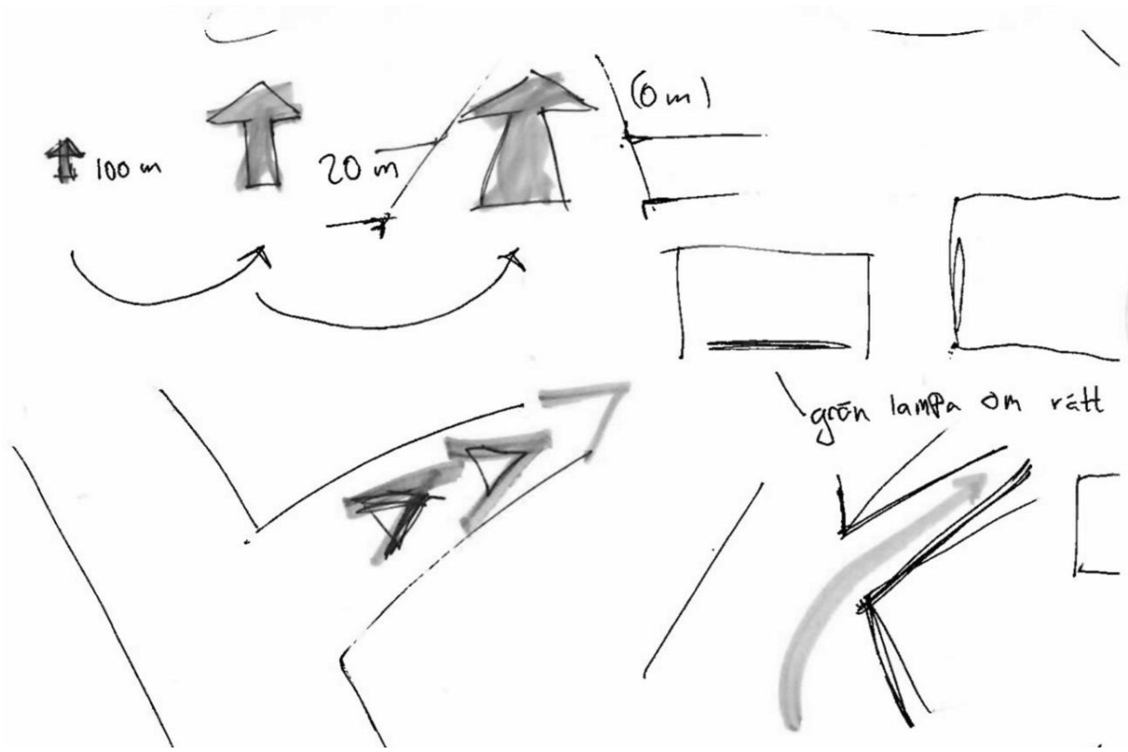

Figure 10. Early-stage ideas for navigation.

Figure 11. Early-stage ideas for road signs.

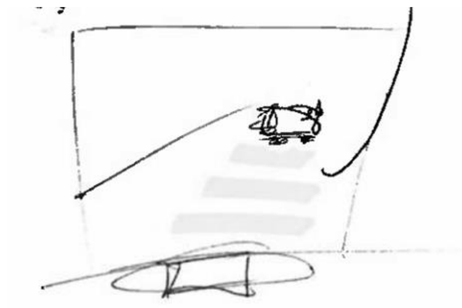

Figure 12. Early-stage idea for Adaptive Cruise Control

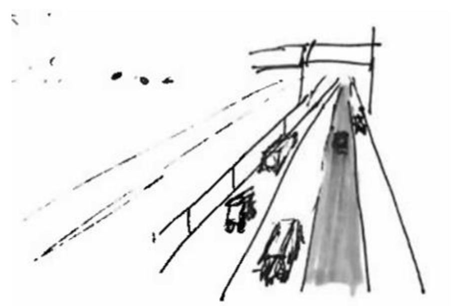

Figure 13. Early-stage idea for marking the correct field.

Low Fidelity Concepts

In the final stages of ideation and the beginning of concept development ideas were sketched in higher fidelity. These concepts are shown in figure 14 and 15.

Figure 14. Low fidelity concept highlighting surrounding cars and pedestrians.

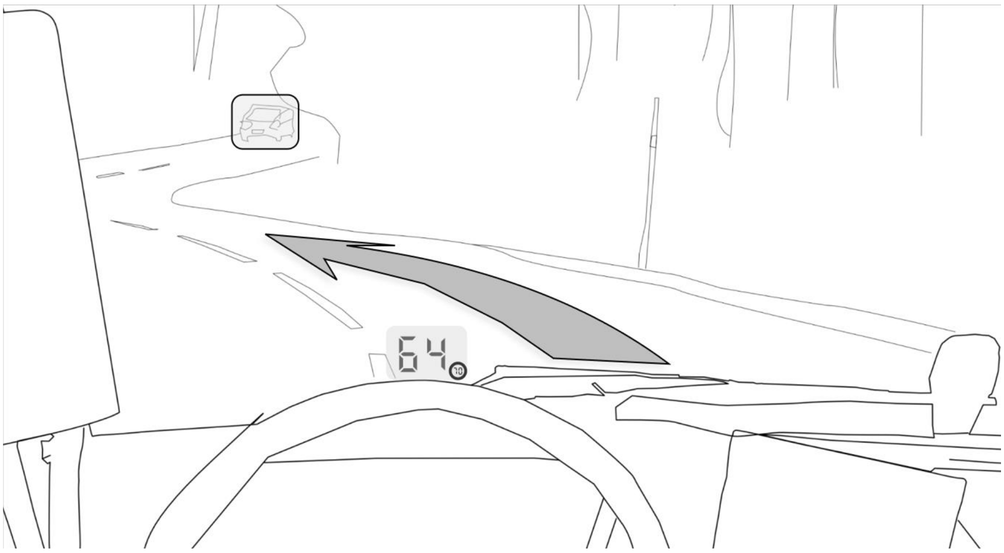

Figure 15. Low fidelity concept of navigation arrow on the road.

Increased Fidelity Concepts

The fidelity was further increased by placing digital sketches onto real-life images to give them more context. These concepts are shown in figure 16 and 17, and later they evolved into the final concept.

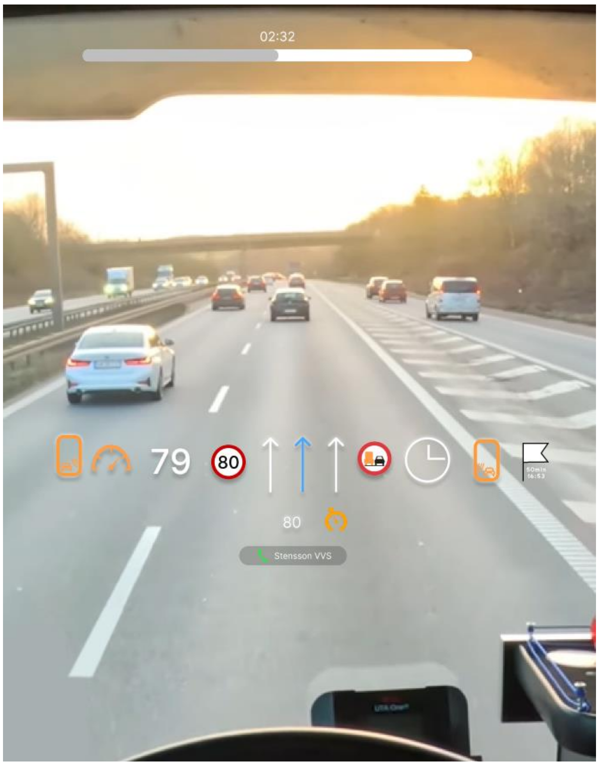

Figure 16. Concept with a wide base-HUD and driving and rest time displayed as a bar in the top of the windshield. Reprinted with permission.

Figure 17. A stripped down base-HUD. Reprinted with permission

Ideas for Augmented Reality

Below in figure 18-20 are three examples of how to display AR-elements for navigation. These ideas were incorporated in the final concept.

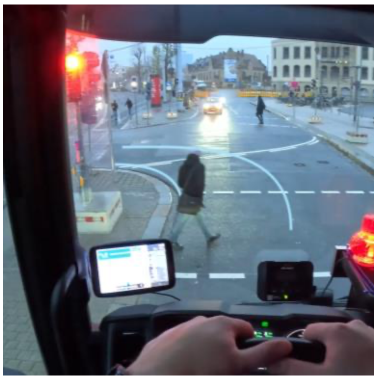

Figure 18. AR-navigation with thin lines. Reprinted with permission.

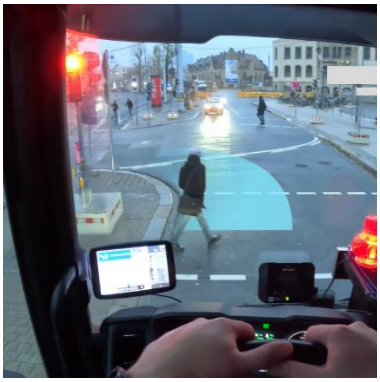

Figure 19. AR-navigation with swooping curve. Reprinted with permission.

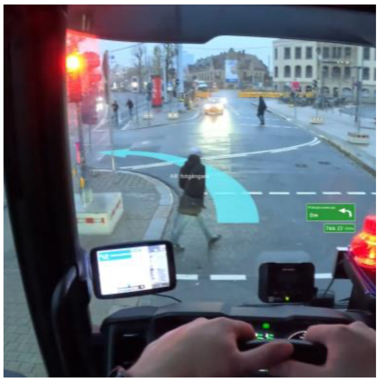

Figure 20. AR-navigation with arrow on the road. Reprinted with permission.

6.3.2 Developing the modes

The modes were developed based on the different types of driving and scenarios that were discovered through data collection and analysis. The different demands in different scenarios were dependent on the context and traffic situation rather than for example speed. This was the reasoning behind the decision to make the modes switch based on GPS.

In the early stages of the concept a night mode and a queue mode were included, since these were driving situations that had been addressed by the participants in the data collection phase. When these modes were further developed it became apparent that the specific elements that should be displayed on the HUD does not necessarily change during night or when queuing. Instead, night mode is more connected to the brightness of the HUD – and because of this night mode became a setting instead of a mode. Queue mode was discarded since it was not perceived as a major issue in the KJ analysis from phase 2.

6.3.3 Different Versions of Functionalities

During the ideation, different ideas of how the HUD should function were developed. One idea was to have a static base-HUD with a set selection of information, that is always displayed. Another idea was to have a downscale base-HUD that automatically adapts to the surrounding environment and only shows what is essential in that specific situation. This type of HUD would be very minimal by removing all elements deemed redundant at the given moment and only show information if something changes, or if the driver needs to be alerted about some information.

There were also different ideas of how the base-HUD and AR-HUD should interact. They could either be kept separate and seen as complements to each other or they could be intertwined – meaning the base-HUD elements turn into AR-elements when close to the situation, for example a turn arrow becomes AR when the turn is about to happen.

6.3.4 Outlier Ideas

This section presents some outlier ideas that were later discarded. This was because they were deemed to lie outside the scope of developing a HUD that improves the safety while driving.

One idea was to have a standby mode for when the drivers are on their break. This could for example be a big clock to show the remaining break time when lying in the bed in the driver's cab.

Another idea came from the reoccurring issue of finding places to stop at truck stops, mainly during long-haul drives through Europe. A solution to this could be a HUD-element that showed how many available spots there were at a truck stop, similar to the signs outside parking garages. Another idea was to show which facilities were available at truck stops, for example if there were showers or a restaurant.

6.4 Results – Final Concept

This section presents the final concept which was the result of the concept development and evaluation phase. A few final adjustments were made after the evaluation to reach the final solution.

The final concept of this project is *HUD for commercial trucks: Three Adaptive and Customisable Modes*. An adaptable HUD with different driving modes that automatically activates depending on which type of road the truck is on. A concept developed to suit the varying demands for driving a truck and the various needs among different drivers. The depth of view for the HUD is set at approximately 10 meters from the driver, based on the personal experience of test-driving cars with HUDs set on different distances.

6.4.1 Three Modes: Country Road, Highway and City

Below is a definition of each of these driving situations.

Country Road

The mode *Country Road* refers to roads in rural or less populated areas with speed limits around 70-90 km/h. Usually narrower than highways with possible curves and sometimes low visibility. Risk for wildlife accidents and occurrences of slow-moving vehicles such as tractors.

Highway

Highway refers to highways and also expressways. These are roads designed for high-speed and long-distance driving. Highways usually have multiple wide lanes and barriers separating the different directions.

City

City refers to urban roads in populated areas. These roads generally have lots of traffic and they have a large variety with different speed limits and designs.

Personal Customisation

Each driving mode comes with a default setting where a selection of elements is activated. The user can also activate and deactivate elements themselves, for each mode. Table 5 below lists all the possible elements that can be displayed in the HUD as well as which elements are selected in the default settings for each mode.

Table 57. List of Elements and mode selection.

	Country Road	**Highway**	**City**
BASE-HUD			
Constant			
Speedometer	☑	☑	☑
Speed limit	☑	☑	☑
Driving and rest time	☑	☑	☐
Outside temperature	☐	☐	☐
Clock	☐	☐	☐
Navigation			
3D map	☑	☐	☑
Upcoming turns/actions	☑	☑	☑
ETA (Estimated Time of Arrival)	☑	☑	☑
Temporary			
Cruise Control	☑	☑	☐
Adaptive Cruise Control	☑	☑	☐
Pilot Assist	☑	☑	☐
Critical vehicle status warnings	☑	☑	☑
Nearby pedestrian warning	☑	☐	☑
Incoming calls	☑	☑	☑
Slippery road conditions	☑	☑	☑
Short distance warning	☑	☑	☑
Road signs			
Priority road	☐	☐	☑
Prohibitory signs	☑	☐	☑
Warning signs	☑	☑	☑
AR-HUD			
Navigation			
Turns/Exits	☑	☑	☑
Navigation arrow on the road	☑	☑	☑
Highlight no entry roads:	☐	☐	☑
Height lim.	☐	☐	☑
Weight lim.	☐	☐	☑
Surroundings			
Highlight pedestrians	☑	☐	☑
Highlight cyclists	☑	☐	☑
Highlight slow-moving / stationary vehicles	☑	☑	☐
Highlight wildlife	☑	☐	☐
Other			
Adaptive Cruise Control	☑	☑	☐

This selection is done with a list of toggle switches on the secondary display, as shown in figure 21. The picture shows two different closeups of the HUD-settings on the secondary display. To the left in each closeup is a preview of the selected settings. This allows the user to understand what they have selected and where it will be presented when activated. The settings made on the secondary display can be saved to the driver card.

Figure 21. HUD setting on the secondary display. Two versions with different selections. Reprinted with permission.

6.4.2 Visualisations of the Final Concept

This section presents visualisations of the final concept. These were created in Figma using background images from Euro truck simulator 2. These visualisations have been evaluated and updated according to the users' response.

Base-HUD

Starting off are three images of the base-HUD, one for each mode (see fig. 22-24).

Figure 22. Country mode with constant base-HUD elements. Reprinted with permission.

Figure 23. City mode with constant base-HUD elements. Reprinted with permission.

Figure 24. Highway mode base-HUD with constant elements and two temporary elements (road sign and adaptive cruise control). Reprinted with permission.

AR-HUD

Below in figure 25-30 are visual representations of AR-elements in the HUD. All the AR-elements are temporary and situational. Figure 25 and 26 shows *Highlight slow moving / stationary vehicles*. Figure 25 has a red indication behind the slowed down vehicle because it presents an immediate danger, and the driver is required to slow down. Figure 26 has a yellow indication because the vehicle in front is only marginally slower – it does not require immediate action, but the driver should still be alerted. If the car with the yellow marking would slow down further and the distance closes in, the AR-element would turn red. Figure 27 shows a *Navigation arrow in the road*. Figure 28 displays the AR-element for *Adaptive Cruise Control*. This element is only displayed when the Adaptive Cruise Control is activated to give the driver a better sense of the set distance. Figure 29 shows another example of a *Navigation arrow in the road*, this time in a roundabout. Fig 30 shows an example of how pedestrians can be highlighted with AR.

Figure 25. Highlight slow moving / stationary vehicles. Reprinted with permission.

Figure 26. Highlight slow moving / stationary vehicles. Reprinted with permission.

Figure 27. Navigation arrow in the road. Reprinted with permission

Figure 28. Adaptive Cruise Control. Reprinted with permission.

Figure 29. Navigation arrow in the road. Reprinted with permission.

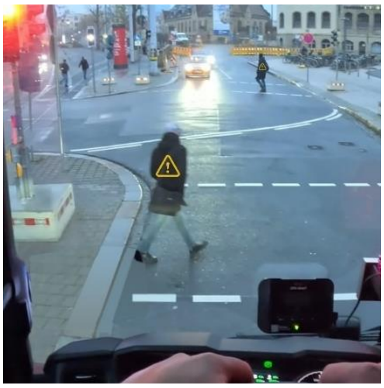

Figure 30. Highlight pedestrians. Reprinted with permission.

Different Versions of HUDs

The figures 31-36 show a few different versions of HUD with different modes and settings activated.

Figure 31. Country road one. Reprinted with permission.

Figure 32. Country road two. Reprinted with permission.

Figure 33. Highway one. Reprinted with permission.

Figure 34. Highway two. Reprinted with permission.

Figure 35. City one. Reprinted with permission.

Figure 36. Highway three. Reprinted with permission.

Figure 37. Base-HUD with short distance warning. reprinted with permission.

In figure 37 the short distance warning is activated, seen as the red light at the bottom of the windshield. The nearby pedestrian warning is also activated in the base-HUD. As seen in the picture the short distance warning differentiates from the other elements on the HUD because it is a light bar rather than a symbol on the HUD. This is to quickly attract the driver's attention to avoid collisions.

6.4.3 Design Choices: Colours, Symbols and Layout

The following section presents the resulting design choices and reasoning behind them.

Colours

The HUD uses different colours for information with different levels of priority. Red is used for critical warnings and for prohibitory and warning road signs. Yellow is used for second level warnings such as "Nearby Pedestrian Warning" (see fig. 37). This is a warning to be cautious, but it does not necessarily mean they should stop immediately. White is used for basic information, blue for navigation and green for cruise control.

Symbols

The symbols in figure 38 are elements on the base-HUD. They are developed to match the real world in alignment with Nielsen's ten usability heuristics.

Figure 38. Elements in the base-HUD.

Layout

Figure 39-42 show four examples of base-HUDs with different selections and different amounts of temporary elements displayed.

Figure 39. Base-HUD all activated.

Figure 40. Base-HUD variation.

Figure 41. Base-HUD variation.

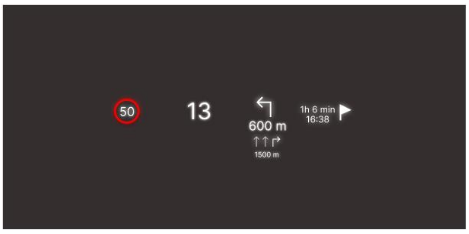

Figure 42. Minimal base-HUD.

Figure 39 is an example of a HUD where all the elements in the base-HUD are activated at the same time. This is unlikely to happen but still a possibility that had to be taken into consideration. Figure 39 also shows the positions for elements when all of them are activated. These are the starting positions for the elements in the base-HUD. This is based on a hierarchy of priority. The most desired information by the users (navigation and speed) is currently placed close to the center in the upper field.

The base-HUD has a grid to create visual clarity when many elements are activated. The grid can be turned off if desired by the user, for example if they only have a few elements on their HUD.

Temporary elements are placed in the lower row. Exceptions are the driving and rest time and the upcoming turns / actions symbol. Elements that are connected are placed close to each other. Elements move towards the centre when other elements are turned off. Elements do not switch sides in the interface, to avoid confusion. If the visual centre of gravity of the HUD significantly changes, the entire HUD auto adjusts to become more centred in the field of view (see figure 43).

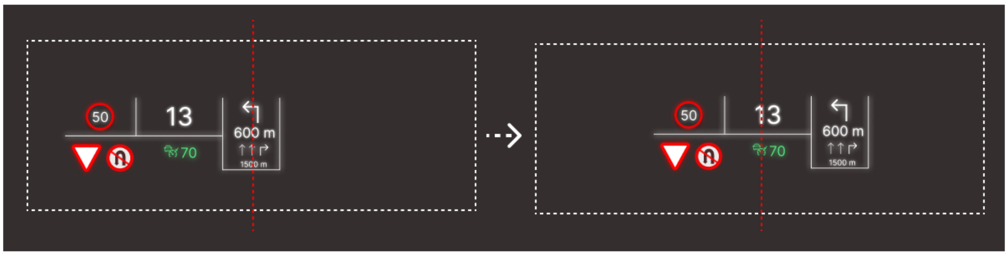

Figure 43. Auto adjustment to the centre.

6.4.4 Extra Features

This section consists of extra features that are included in the final concept. These features were approved by users in the evaluation but are not as developed as other aspects of the final concept.

Speed Limit Indication

The speed limit sign will blink to attract attention when the driver is more than 5 km/h above the speed limit. The threshold was set to 5 km above the limit to avoid irritation while still supporting the drivers and ensuring safety.

Night Driving

When driving at night the brightness of the HUD will automatically adjust to lower, to prevent eye fatigue.

Consistency Across Modes and Vehicles

With the press of a button there is a setting to make all three modes the same, without changing them all manually. This setting is used if the driver wants a consistent HUD where all modes are the same – meaning there is no switching between modes in different situations. The idea is to include a button on the secondary display that makes all modes the same. There is also a button that resets modes to their default.

It will also be possible to save HUD settings on the driver card for the tachograph system - in the same way that radio channel settings can be saved today. The tachograph is the system that keeps track and driving and rest times.

6.4.5 User Response on Final Concept

This section presents the results of the evaluation that was conducted through five interviews with truck drivers. The final concept has been refined according to the users' responses.

Modes

Using different modes depending on the driving situation was well received by the users – both the categorisation of country-, highway- and city driving, as well as the automatic switching between these. All five participants thought that the three modes were applicable to all different types of driving situations they could think of and when asked if they wanted other or different modes, they all said no. This cemented the three modes in the final concept. The automatic switching was also confirmed due to the positive feedback from all participants.

Customisation

All participants agreed that it was good to be able to choose which elements are displayed on the HUD. Some of the participants also wanted to be able to change the layout of elements – however this was saved for future development. All participants said that they would not mind going into the settings and adjust the HUD to their personal preferences if they had the *HUD for commercial trucks: Three Adaptive and Customisable Modes* in their own vehicle.

Debated Features

The participants were asked about some of the debated features in the project. Media was the main debate topic and opinions varied among users. Some wanted songs to appear on the HUD when it changed because they felt it was information making them divert their gaze while driving. Others believed it was unsuitable for the HUD.

> "I feel that phone notifications and music are unnecessary. I don't really think they belong there."
>
> User response from evaluation

Highlighting surroundings was another feature that was discussed in the evaluations. The users expressed some concerns to whether it would be feasible to highlight other road users without it becoming overwhelming. They all agreed that surrounding people such as pedestrians, cyclists and electric scooter users are a big risk while driving and therefore they were generally positive toward having AR-features that highlighted these surrounding objects, if it reduced these risks.

Most participants also supported the idea to highlight wildlife on country roads. Nonetheless, this was followed with some concerns of the systems reliability of whether the HUD would be capable of detecting wild animals in time and only highlight animals that posed a risk of collision.

Negative Feedback

The main concern from the user response was cognitive overload. This concern is mainly addressed through the customisation in the final concept.

> “I might be the wrong generation for this. I think it should be kept minimal.”
>
> User response from evaluation

> “I would definitely remove the call feature”
>
> User response from evaluation

> “It shouldn't be too much, because it also takes away focus from driving. You're already busy looking at other things, and if you must spend too much time looking at these features, you end up losing focus on the rest of the traffic and everything else.”
>
> User response from evaluation

Another concern was that drivers would become too reliant on the functions of the HUD and experience a false sense of security. For example, if the driver were to rely solely on the HUD to detect surrounding traffic or to detect slippery road conditions.

Important User Input

One key point that derived from the evaluation was the importance of not causing annoyance. An example of this is when speed limit starts to blink when it is exceeded. All participants agreed that it was important to remain within the speed limit, but excessive warnings seemed to have a counteractive effect, with the drivers saying they would simply turn it off.

The idea of using the driver card for the tachograph system to save settings came from two of our drivers in the interviews and this became a great solution for simplifying the customisation.

As previously mentioned, the users were invested in choosing which elements would appear themselves and the list of elements was developed in consultation with the users. They specified a desire for the ability to choose elements on a detailed level, which then was integrated into the final concept.

7. Discussion

This chapter reflects on challenges encountered during the process, the final concept and its evaluation, ethical considerations, and possible future development.

7.1 Process

This section assesses how well the process supported the completion of the project. It mainly focuses on the challenges that came with performing this project.

7.1.1 Development Challenges and Key Insights

During the project the group faced several difficulties which either limited or redirected the development- and evaluation processes in the project.

Limitations in Testing Efficiently

One of the biggest limitations that the group faced was the inability to conduct realistic testing that would yield comparable results to real-life testing, as mentioned above in the *Limitations*-section.

The group was made aware of this limitation very early, following a meeting with the client representatives at Volvo GTT, where the possibility of constructing a prototype was discussed. Since the company's internal policies around confidentiality and limited resources did not allow access to their prototyping tools, the group was unable to develop a realistic prototype. Creating one independently would most likely have been time-consuming, expensive, and unlikely to meet the standards needed for meaningful testing. As a result, the decision was made to forgo building a functional prototype during the project.

This meant that factors such as the concepts ability to decrease reaction time, lowers drivers' fatigue, or increase eyes-on-road time, were unable to be formally evaluated. It was difficult to approximate the scale of the HUD due to the lack of access to simulations to determine appropriate and readable sizes for the interface and its elements. The final design therefore reflects the group's informed assumptions based on observations, existing knowledge in usability and ergonomics, as well as direct input from the drivers regarding what they considered helpful.

Establishing design priorities

One challenge during the project was establishing the design priorities. It was important to create visualisations both to have mediating objects for interviews, and to further develop the concept. This led to a tendency of focusing on the visual and aesthetics aspects of the HUD, despite the actual information in the interface being more important. Because of this the group had to iteratively redirect focus back on the needs and expectations of commercial truck drivers, ensuring that the end concept would be perceived as a useful support tool rather than an intrusive technological addition.

General attitude and issues following convenience sampling

A noteworthy challenge during the initial phase of data collection was the recruitment of commercial truck drivers for interviews. A form of convenience sampling was used, in which participants tended to be those who were already familiar with the concept of Head-Up Displays and often held clear, outspoken opinions about the technology. In particular, those who were eager to contribute were primarily those who were positive toward the technology.

While this provided valuable insights into what aspects of the concept were appreciated, it became difficult to achieve deeper discussions about limitations and potential improvement. Ideally, the sample would have included a broader range of perspectives and levels of familiarity with the technology, which was later achieved after considerable effort. Also, it might have given a broader base if our sample had included greater variation in terms of age, gender, experience with technology, the types of driving the participants typically engaged in, and a wider range of truck brands. This may have affected the direction and efficiency of the project.

The premise of working navigational technology

A noteworthy aspect regarding the final concept is that a large part of it is based on the fact that the navigational software in the truck is working as intended. As mentioned, the different modes and the seamless switching between them is based on data received from the navigation software. I.e. the software tells the HUD when the vehicle drives out onto a different type of road and alters the information on the HUD to the corresponding mode. This prerequisite was given to the group from the company contacts at Volvo, who established that the group could assume all technology in the truck works as intended, meaning that technical aspects of how the HUD works could be overlooked.

7.2 Final Results

This section discusses and evaluates the final concept, its details and valuable points for future development.

7.2.1 Reflections on the Fulfilment of the Research Aim

Throughout the course of the project the group evaluated the research questions, aiming to explore the potential of HUDs in commercial trucks.

What information in a commercial truck is suitable for a HUD?

Through interviews, observations and site visits, the group identified several key pieces of information that were suitable to be displayed on a HUD. These categories included speed, navigation, road signs, outside conditions, tachograph information and highlights of the surroundings. These categories were then prioritised based on their relevance to the driver and the information users would need without drawing attention away from the current driving situation. Following this, the group was able to clearly define what information would be most suitable for a HUD, meeting the overarching goal of improving intuitive information delivery.

However, this list of information is based on a small number of users. A larger data pool and testing in real life situations could change which information is deemed suitable. The priority for information should also be further tested. It is possible that the participants in the interviews noted their “nice to have” as needs which means that there might be too much available information to choose from. It is also possible that we missed elements that are deemed essential to other users, for example drivers who drive different other types of trucks than the participants in this study. Something all users seemed to agree on was the importance of navigation. But exactly how they will use it will first be apparent when the concept is implemented. Once the concept is implemented, Volvo will be able to gather data from all the active users and study their selections across all modes. This will allow Volvo to change the presets in each mode and easily sort through the most used elements and use this information to create an overarching hierarchy for the concept.

What demands do commercial truck drivers have for a potential HUD?

Interviewees put emphasis on the HUD needing to be clear and non-intrusive, expressing concern about cognitive overload and highlighting the demand for high customizability. These insights influenced the final concept greatly, particularly the implementation of user-controlled customizability through the secondary display. By considering these concerns in the final concept, the group fulfilled the aim of this research question and ensured the concept was based on inputs from drivers directly.

What potential do Head-Up Displays have in commercial trucks, and what opportunities does Augmented Reality bring to them?

During the data collection phase, the technology benchmarking and literary review indicated that HUDs in general have significant potential to increase driver awareness and reduce eyes-off-road time, so long as the interface remains cognitively manageable. Through interviews it was also revealed that drivers saw potential in Augmented Reality functions involving navigation and hazard detection, but expressed caution regarding the potential cognitive overload too many highlights or elements could bring. By combining and comparing this data, the group successfully identified both the promise and limitations of HUD and AR technologies, incorporating it into the final concept design to properly support drivers without introducing unnecessary complexity.

How can the questions above be addressed in a HUD interface with AR features?

The final concept balances functionality, clarity and adaptability through a streamlined base interface, and by integrating AR in a focused way to not cognitively overload the driver during potentially risky driving scenarios. The solution also offers user-controlled customisability for different modes to fit any driver regardless of the driving situation. The solution therefore addresses both drivers' needs while also exploring the practical benefits of AR integration.

Insights beyond the research

This project has given the group a lot of insight into the world of commercial trucks and Head-Up displays thanks to all the participants' willingness to contribute. However, it is the group's belief that there is still a lot to figure out about this technology and the great diversity of opinions regarding it. Even though all the drivers that were interviewed for the project have expressed their satisfaction with the final concept, a lot of them still expressed some concern regarding the HUD being too overwhelming. It is the group's view that this issue has been solved by integrating customisability, letting users select what elements to include in their HUD and stripping it of all elements they themselves regard as nonessentials. However, the availability of this option raises the question of how widely the solution will be adopted in practice.

7.2.2 Details of the Concept

During the study, there were several interesting discussions and evaluations regarding information categories and if these were suitable for the HUD as well as how certain information was to be represented and the overall visual interface of the HUD.

Media Integration and Driver Distraction

The implementation of media functions into the HUD has been a recurring topic throughout the project, especially during the analysis and ideation phases. When the drivers were questioned about what factors lead to them diverting their gaze, all of them mentioned media as one of the major distractions. Some examples were when they change the current song or radio station or check the identity of an incoming caller. These answers led the group to consider adding such features to the HUD, but without a proper way to assess whether it would distract the drivers further, the idea was met with caution. Eventually the group decided to implement incoming caller onto the HUD but leave the rest of the media functionality for the secondary display.

The incoming caller notification was implemented into the HUD so drivers can identify the caller without having to avert their gaze from the road, whereas the media functionality was deliberately discarded from the HUD to avoid introducing unnecessary cognitive load to the user. Media-related tasks were, according to the group, better suited for interaction through either the secondary screen or through the controls on the steering wheel.

That said, the group was also made aware of the fact that some drivers routinely interact with their phone while driving. This presented a significant design challenge when balancing cognitive overload against the potential of reducing visual distraction. On one hand, integrating media functions into the HUD could potentially discourage drivers from interacting with their phone as much. On the other hand, it could also lead to cognitive overload by introducing too many points of interest, especially in critical driving situations.

Placement of navigational icons

During the ideation and concept development phase, the design and visual presentation of navigational functions were one of the categories that was deemed of high importance due to many users expressing a desire for this functionality in a potential HUD. The Base-HUD navigation element included both the primary action, as well as the following- or secondary action. A topic of debate during the project was what order the two should be displayed. This refers to whether the primary action should be at the top, or if it is more intuitive to place it below the secondary action. There are design principles that speak for both alternatives, and when evaluated in phase 5 the users were divided on which variant they preferred. The group eventually decided on the layout with the primary action placed at the top and the secondary action at the bottom. The prospect of making the order of the actions customisable was discussed in the group, but that option was ultimately rejected in favour of simplifying the customisation.

Infinite combinations

When providing many settings for the user to customise, the risk of accidentally switching to undesired settings became a factor to consider in the design process. When customising the interface for different modes on the secondary display, the user is instantly presented with an example layout showing both permanent and temporary elements activated on the secondary screen. This is to avoid the user encountering a situation where the HUD is suddenly overflowing with information. The absence of temporary elements could otherwise be something the user would assume constant, until a situation arises where everything activates at once.

The group deemed it necessary to incorporate the option for every mode to be reverted to a default setting easily. This prevents the user from being forced to search for the default settings manually, which could cause frustration.

Another problem that arose from the large number of available combinations is how the placement of the elements should relate to each when different combinations of elements are enabled. One option is that each element has a fixed place, and that deactivating an element in the middle of the HUD simply would leave extra space between the remaining elements. Another way to solve this is to define a hierarchy between the elements, and for these to strive for a certain placement. By approaching the problem like this, the HUD would feel more thoroughly implemented by adapting to the user's personal settings.

As mentioned in the results, some users expressed that they wanted freedom to customise the exact placement of the specific elements. The ability to do this stands somewhat in conflict with the previously mentioned concept of a placement hierarchy. It is of course possible to design a system that provides both functions, but the implementation would become much more complex, and the interface could risk becoming difficult to navigate. For these reasons the developed concept employs the placement hierarchy solution, even though the group considers the ability for customisation an interesting point for further development.

7.2.3 Evaluation of Final Concept in regard to Usability Aspects

The concept's development was grounded in established usability principles, particularly Nielsen's heuristics and Jordan's usability dimensions, which guided the design process and key decisions throughout the project.

Nielsen's 10 Heuristics for User Interface Design

When designing the parts of the interface that are interactive (in the sense that the driver provides actual input – in this case to customise which elements are visible in the HUD), it is relevant to consider *Consistency* and *Match between system and the real world*, also referred to as internal and external consistency, respectively. By using toggle switches derived from nearby, already existing interfaces, natural recognition is ensured. This became evident during the interviews, where all participants expressed general satisfaction and demonstrated a clear understanding of the interface structure.

The reason why some of Nielsen's other heuristics were not as central during the project can be attributed to the nature of the interface itself. It is relatively shallow and horizontally structured, which led us to focus on aspects deemed most relevant for the context. Factors such as *Error Prevention* and *Error Recovery*, for example, were considered less applicable simply because the interface does not include submenus or any navigational flows.

Jordan's Five Usability Dimensions

Guessability is an important aspect and appears to be relatively high in this case. This became evident during the evaluation, as the interviewees were not explicitly told what each part and symbol represented. This was a deliberate choice, to observe how the users interpreted the elements on their own. The participants primarily seemed to interpret the interface correctly, leading to the conclusion that its guessability is high.

Regarding *Experienced User Performance (EUP)* and *System Potential*, the material used during the evaluation were well suited to address these aspects. This is because many of the interview questions revolved around choices, customisability, personalisation, and the interviewee's attitudes towards the current way of configuring what is displayed and how.

However, it is also the case that both EUP and system potential might become somewhat less relevant in this context or at least are not given much opportunity to be either particularly strong or weak. This since the interface is quite shallow and limited, in terms of what is interactive in an action-based sense.

At the same time, one could argue that the system potential is, by definition, still high, simply because there is little within the interface that could hinder optimal use. EUP, to some extent also, is supported, albeit in a simple way, through efficient customisability.

7.3 Ethical Aspects

This section explores key ethical considerations encountered during the project, including safety, driver autonomy, potentially controversial applications, and the handling of personal data during interviews.

7.3.1 Safety

Perhaps the most important aspect that the group had to consider while developing the conceptual HUD was safety. The goal for the final concept was to increase the overarching traffic safety regarding commercial trucks, and in turn decrease roadway incidents involving trucks. This was especially important considering the mortality rates of traffic incidents involving trucks.

This aspect permeated the entire project, with cognitive overload as the number one risk factor to avoid during the development. Decisions on what information should be presented on the HUD and not were therefore heavily influenced by the safety aspect. The final concept reflects these safety considerations through its deliberately minimal design, prioritising clarity and reducing cognitive load to support safer driving conditions.

7.3.2 Driver Autonomy

Driver autonomy was a big aspect that the group considered heavily throughout the project, not only because of the societal and ethical aspects surrounding it but also because this was a factor that was brought up regularly in interviews and through other interactions with commercial truck drivers. It is considered by the group as one of the major ethical aspects that affect the development of the HUD.

Many of the interviewed drivers expressed concern about adding too many functions that would "simplify" the driving, not only because they saw it as distracting, but also because they felt it intervened with their autonomy as drivers. The reluctant interviewees did not necessarily express it clearly, but sentiments such as "I don't want the truck to drive for me", or "I prefer to take in the information myself, not from the HUD" came up, especially when interviewing drivers who initially saw negatively upon the prospect of adding a HUD, as well as during the on-site visit we did at the truck-driver school. This aspect was therefore considered heavily in the selection process regarding what information should be displayed on the HUD and was eventually one of the main factors that led to the concept being customisable.

7.3.3 Military Applications

One of the ethical aspects discussed previously in the report was the impact this project could potentially have on the military industry, given that Head-up displays originated from such applications. But, since the technical solution to how the product would be implemented is outside the scope of this project, the direct application of our solution to a product that could be useful for such industries seems very limited. However, there are a few results that could still potentially be of use for the development of further HUD-technologies in the military industry.

Since every member of the group has studied both usability and cognitive ergonomics, the results developed have been cultivated with this knowledge in mind. The results are therefore adapted in ways that simplify and streamline usability, which could be useful knowledge that other industries may take advantage of when designing and developing similar products for other applications. This is a factor that the project group has heavily considered, but due to still aiming to deliver a concept, the group concluded that this factor is hard to avoid without heavily impacting the result of the study. This risk has therefore been dismissed, though the group still believes it is necessary to mention, given the liability it poses.

7.3.4 Interviews and Data Collection

All interviewees were given a GDPR form to sign, as well as a run-down on how the group would handle their interview answers and personal data prior to their interviews starting. The interviewees signed two identical forms, one that they could keep for themselves and one that the group kept. The form was taken directly off Chalmers website and included contact details for the group in case the interviewee at any point wanted to withdraw their consent to participate.

Any data collected by the group during the interview, such as personal details about the drivers like names, ages and phone numbers as well as answers to interview questions were stored in the group's Microsoft Teams folder. This was stated in the form as well as verbally to the interviewee prior to the interview, along with a deadline for when the data was to be removed. The deadline was set to 2025-06-17, a couple weeks after the project's conclusion. The interviewees were informed that their answers may be published anonymously in the project's report, and thus the data was handled according to the General Data Protection Regulation.

7.4 Future Development

This final section outlines areas for potential future improvement of the concept, as well as a broader outlook on HUD technology in the context of commercial trucks.

7.4.1 Deferred Elements and Opportunities for Future Work

Upon reflection, the group identified several elements that could benefit the final concept, but that were deliberately left out due to being out of the scope of the project or deferred due to time or resource constraints.

Defining Visual Dimensions

As mentioned earlier in the report, due to limitations regarding testing resources, the final concept does not currently have any set dimensions. As a result, the interface lacks a validated scale ensuring proper readability and optimal placement in the driver's field of view.

A valuable improvement to the concept would therefore be to conduct user testing to determine appropriate sizes, placements and spacing for elements.

Auditive and Haptic Features

The current final concept employs entirely visual elements to present information to the users. This limitation arose from the project early on being deliberately restricted to the design of visual components, to ensure a manageable scope within the available time. The group, however, believes that adding other features such as haptic or auditive feedback could be a well-suited improvement for future development. That said, it would be essential to evaluate such additions through proper user testing, provided resources are available, to avoid cognitive overload because of multiple simultaneous stimuli.

Assumptions on Depth of Field

In the brief for this project there was an indication that HUDs with a depth of view further away are generally preferred. Throughout the project this assumption has been largely supported, based on the reasoning that placing information closer to the driver's focal point ahead on the road, minimises the amount of time and cognitive effort required to refocus the eye of the driver between the HUD and the driving environment.

A different perspective that provides a counterargument for this, is that when the line is blurred between the driving environment and the HUD, it is easy to unintentionally encourage the drivers prolonged attention on the HUD, rather than on external stimuli. By employing a shorter depth of view, the HUD can instead encourage driver focus on the driving environment during critical moments when needed, while still providing more convenient access to essential information than traditional dashboard clusters.

7.4.2 Outlook on HUD Technology and Commercial Trucks

Head-Up Displays are becoming increasingly available to consumers, as more major car manufacturing companies offer them as an add-on when purchasing a new car. However, more availability does not in itself confirm the value or quality of the safety solution. Instead, it is more likely that customers choose to add the HUD feature to their purchase out of convenience or interest in the high-tech solution, rather than because of its safety benefits.

In the future there might be autonomous vehicles which diminish the role of truck drivers and the potential need for a HUD. Windshields may even be eliminated entirely. However, this project is based on the driver's current role and the level of information and control this entails.

This future uncertainty was also discussed with an industry contact at Volvo, who outlined two prevailing perspectives. One suggests that autonomous cars will render HUDs obsolete, since no human driver will be required. The other maintains that due to the vehicle being autonomous, a HUD could play an even more important role in serving as a bridge between the automated system and the person inside the vehicle.

8. Conclusion

In conclusion, Head-Up Displays demonstrate great potential for improving the driving experience in commercial trucks, particularly by tailoring information to different driving contexts. The study shows how HUDs could improve driver experience and quality, but the exact effectiveness of these improvements should be further evaluated through effective testing using high fidelity prototypes.

The drivers had a general conservative attitude towards technology in general which greatly influenced the project. Throughout the project it was proven that attitudes could be swayed partially through giving the users a more in-depth understanding of how the technology worked, pointing towards how negative attitudes could stem from a lack of understanding of the HUDs technical properties and how it works in reality. The users' attitudes to Head-Up Display technology were also proved to be influenceable positively the more the concept was tailored to their specific needs.

The concept of an adaptable HUD with three driving modes was positively received by all participants in the user evaluation. However, to properly assess the HUDs impact on driving safety and performance, further studies in real-life traffic settings are necessary. The HUD featured separate modes for driving on country roads, highways and city roads which were determined by the group through user-studies to be a sufficient division of driving environments that featured different requirements for a HUD. Throughout the design and testing process, the group gained valuable insights regarding user-centred design and the challenges of balancing the efficiency of information retention with the risk of distraction.

The group regards the final concept to have great potential, considering the positive feedback it received from users. This feedback was mainly directed towards the concepts' customizability, its different and adaptable modes, the possibility of increasing eyes-on-road time as well as lowering the risk of accidents. Whether or not Augmented Reality is a necessity to accomplish these improvements is not yet determined. However, users still saw benefits in AR assisting the drivers in certain situations and the group sees great potential in developing such additions even further in the future using accurate testing. In conclusion, this project offers a solid foundation for future studies and exploration of HUD integration in commercial trucks.

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Appendices

8.1 Appendix A – Semi-Structured Interview Guide for Phase 1

Kom ihåg: Mycket probing!

Introduktion

Hej! Tack för att du vill delta i vårt arbete!
Innan vi börjar:

- Fika
- GDPR - du kan närsomhelst ta tillbaka
- Går det bra att vi spelar in ljud?

Vi jobbar med att visa information i lastbilar på ett säkert och bekvämt sätt. Därför undersöker vi just nu potentialen i att använda Head-Up Displayer i lastbilar, där Augmented Reality kan användas för att koppla det som visas till verkligheten. Därför är vi intresserade av vilken information som kan visas och hur/var informationen bäst visas.

Frågor

- Vad heter du och hur länge har du arbetat som lastbilschaufför (eller något annat)?
- Vad för sorts fordon kör du just nu?
  - Märke, modell, årgång,
- Vilken typ av körning och hur ser din rutt ut i nuläget? (Och hur såg den ut förr/kommer se ut i framtiden)
- Vilken information tycker du är viktigt att se?
  - Och vilken ytterligare information hade du velat ha? Skiljer det sig beroende på vilken kontext? Hur då?
    - Stadsmiljö
    - Landsväg
    - Motorväg
    - Vid parkering/manövrering
    - Utomlands/inrikes
- Hur hade du velat få informationen presenterad?
  - På något särskilt ställe, eller särskilt sätt?
- Om du föreställer dig de skärmar som finns idag och informationen som visas på dem - finns det något du stör dig på idag? Gällande den information som visas, och hur den visas.
- Har du några särskilda inställningar på dina skärmar som du ställt in själv?

HUD

- Hur bekant är du med Head-Up Display?

- **När behöver du titta bort från vindrutan?**
  - Hur långt?

- Hur länge?
- Hur ofta?
- Känns det farligt?
- Har du någonsin varit med om en olycka?
  - Tror du att bilen hade kunnat hjälpa dig att undvika olyckan genom att visa information eller ge varning på vindrutan?

Augmented Reality

- Med AR-HUD öppnas möjligheten att displayen interagerar med verkligheten.

Vad skulle du helst se att displayen interagerade med?

Navigering och körning

- Rutt, körtid, (pauser)

Fordonsstatus

- Bränsle, bromsar, tryck, tyngd etc.

Omgivning

- Trafiksituationer, cyklister, djur

- Vad vill du se hela tiden? Vad vill du se ibland? När vill du se det? Notiser?
- Visa video + Vad ser du för fördelar/risker med det?

I slutet av intervjun:

- Tack så mycket!
- Har du några kompisar som också vill ställa upp?
- Tack igen!

8.2 Appendix B – KJ Analysis from Phase 2

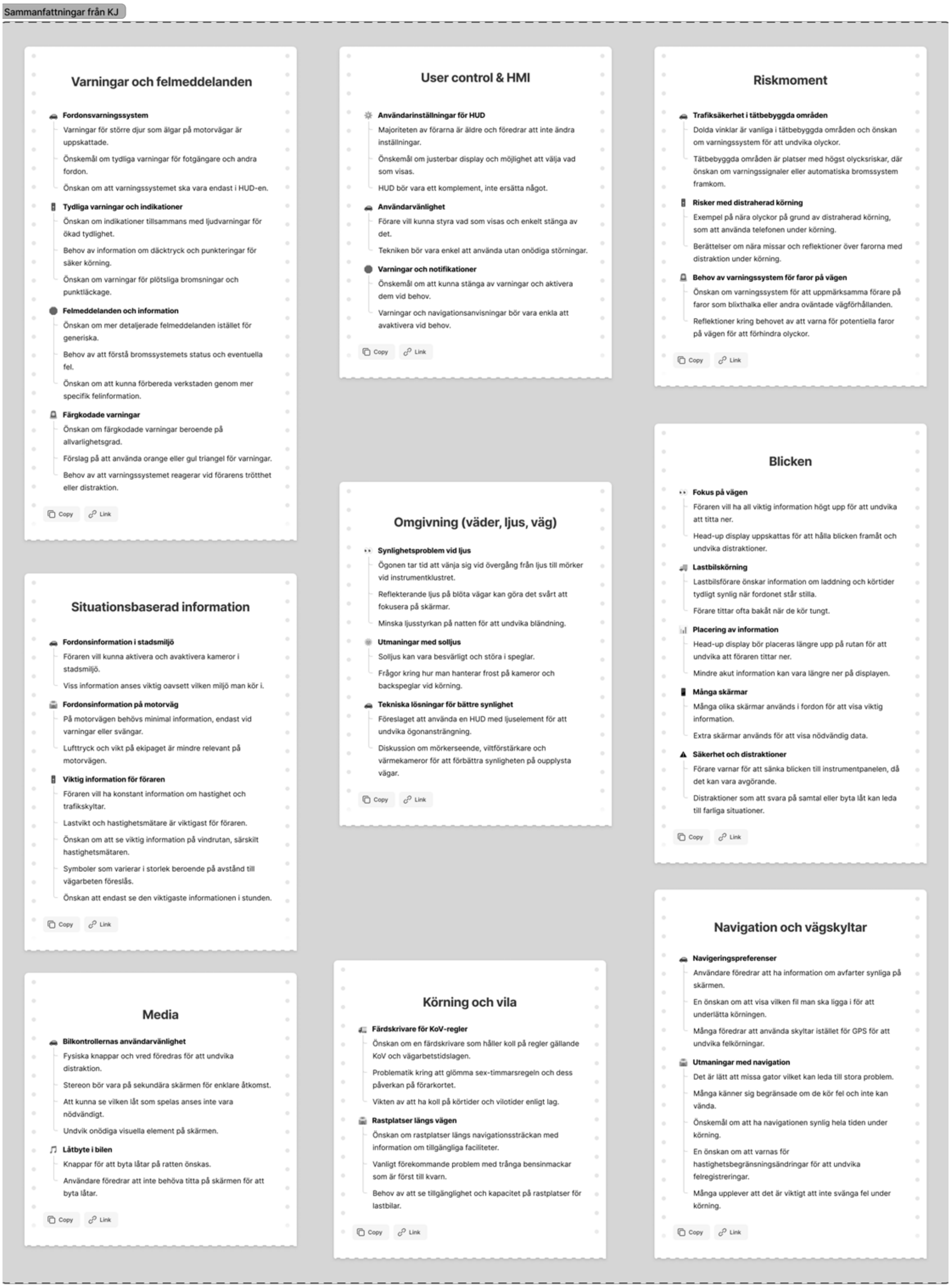

Figure B. 1. Summary of KJ-analysis.

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