Interface Development for Semi-Autonomous Trucks

Visual and Auditory Feedback

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Abstract

Vehicles are becoming increasingly autonomous, as automotive industries are investing in innovative technology. Therefore the technology becomes more available and affordable, making it possible for Toyota Material Handling Europe (TMHE) to introduce automated features in their trucks. Vehicles that have a forward collision warning system, and thus are partly autonomous, are involved in less accidents than those without. In manufacturing industries there is currently a problem with truck collisions and an automated solution might be a suitable way to prevent these. When implementing an automation device, human machine interaction and user-friendliness are aspects to keep in mind during the development.

The thesis concerns how autonomous features can assist the truck driver, and how to provide the driver with intuitive feedback. The purpose was to ensure the drivers’ and surrounding personnel’s safety as well as increase the productivity. Research was performed regarding in what situation an assisting device is needed and how to communicate information in an intuitive manner to help the driver in this situation. A conceptual interface was developed that allows communication between the driver and a future all-knowing system, that tracks all objects and personnel in a warehouse.

The drivers have had a central role in the process. The observations were performed in the TMHE warehouse to identify situations. The most perilous and frequent situation was when drivers need to focus both in the fork and drive wheel directions simultaneously. This either puts the surroundings or the driver in danger. A conceptual interface was developed to help the driver in this situation. This resulted in a concept implementable in both current and future trucks, to harmonise the solution and ensure a safe warehouse environment. A lo-fi prototype was constructed and evaluated iteratively with drivers to ensure the quality and usability of the concept.

The resulting feedback solution consists of sounds from speakers mounted in the headrest and a display interface with warning symbols. The sounds are directional to notify the driver if the danger is to the left or right behind his back. If the danger is only semi-close, the driver receives a warning, but if it is very close, the truck is stopped autonomously. The symbols appear on the display simultaneously as the sounds are heard, to provide further feedback. Additionally, an Autonomous Positioning feature has been developed, that consists of symbols and buttons on the display interface, as well as an alert sound from the display to indicate the system’s activation and deactivation. Safety is enhanced since neither personnel nor trucks are in risk of collision when implementing the concept. As the concept helps the driver position the truck effortlessly towards the pallet the productivity is also improved.
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Dictionary

Words, abbreviations and definitions used in the thesis are listed here, as well as explanatory images of expressions.

List of Words

**Autonomous vehicle** - A self-driving vehicle that moves from A to B with or without human passengers

**BTP** - BT Products

**Display interface** - The layout of text and icons seen on a display screen, that is used to communicate information between the driver and truck

**FCP** - Function Concept Paper

**FFE** - Fuzzy Front End of product development

**Interface** - The boundary across which interaction and communication between a human and a machine occurs. May include displays and controls such as buttons

**LOA** - Levels of automation

**Lorry** - A heavy road vehicle used to transport cargo

**Pallet** - A EUR-pallet; a wooden four-way pallet with the standardised measurements 1200x800x144 mm, which is used throughout Europe. For more information, see Explanatory Images below

**Pallet tunnels** - Where to position the truck’s forks in order to lift the pallet. For more information, see Explanatory Images below

**Prototype** - In this thesis, prototype is used to mean a 3D representation of a concept design
Reach trucks - Designed for work in narrow aisles in warehouses, the name refers to how the fork carriage can reach out past the stabilising legs to collect a pallet and then move it back within the wheelbase. One wheel is positioned on each stabilising legs and the drive wheel is below the driver. For more information, see Explanatory Images below.

Reference group - A group of employees at BTP with experience from development of truck features and interior

Semi-autonomous vehicle - A vehicle that, to a degree, operates without human input

TMHE - Toyota Material Handling Europe

Truck - A forklift truck used to move EUR-pallets in a warehouse or production facility

Explanatory Images

The master thesis focuses on reach trucks. An example of a reach truck can be seen below [1]:

![Reach Truck Example](image-url)
A reach truck can drive in two directions: the fork direction or the drive wheel direction. The driver is positioned facing to the right in the drive wheel direction. Most often, reach trucks travel in the drive wheel direction, thus left and right are named after this direction, see below:

A pallet has so called pallet tunnels in which the forks are inserted when collecting the pallet. An illustration of a EUR-pallet can be seen below [2]:

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[2]: Refer to page 2 for details on the EUR-pallet.
Chapter 1

Introduction

The background, purpose and objective is presented below, together with the formulation of questions for the thesis.

1.1 Background

More and more vehicles are becoming autonomous. In Germany, modifications of Autobahn infrastructure for autonomous cars has already begun [3]. Modern technologies enable a shift in the relationship between driver and vehicle [4]. As the level of automation rises, the role of the driver is shifted [4]. In 2012, Volvo Trucks launched a safety system for lorries to avoid collisions for velocities up to 70 km/h [5]. Additionally, last year Volvo Trucks presented a feature that, using sensors, radar and cameras, can scan 360 degrees around the vehicle and identify pedestrians and cyclists [6]. A warning message is sent to the driver, and if the driver does not respond the system can take control and reduce the speed [6]. Scania has developed a similar system for their lorries, that take over the monotonous driving in traffic congestion [7]. The technology gives the driver possibility to relax and the risk that the driver becomes upset or irritated at other drivers, caused by the traffic congestion, decreases [7].

1.1.1 Toyota Material Handling Europe

Since 2006 Toyota Material Handling Europe (TMHE) is managing the BT and Toyota materials handling business in Europe. TMHE provides forklift trucks and warehouse equipment for both the Toyota and BT brands and offers supporting service and customer adapted solutions. TMHE is the European part of the organisation Toyota Material Handling Group, which in turn is part of the world leading organisation in materials handling Toyota Industries Corporation. [8]

BT Products (BTP) is the part of TMHE that develops indoor trucks [9]. BTP delivers the trucks to TMHE which is the sales organisation [9]. Sales of the company’s products are based on customer orders, which BTP then strive to meet [10]. This results in a large variance with many unique combinations,
however, the company endeavours a harmonised product range [10]. TMHE’s core values are safety, productivity, which are used in the product development process [11]. In order to keep a leading market position, there is a need of continuously improve efficiency of the product and to predict future customer needs. One way to increase the efficiency and safety could be to introduce trucks with a higher degree of automation.

Currently BTP is developing driver-less, autonomous trucks on a smaller scale but believes it is an up and coming area [10]. TMHE is only using a few autonomous trucks in their own production because of the difficulty to program unpredictable scenarios caused by shifting inventories [12]. The technologies that are used for existing autonomous trucks are based on predicted situations that the system can handle, which makes it difficult to implement the trucks in areas where there are manually driven trucks as well [12].

1.1.2 All-knowing System

The technology for autonomous vehicles is becoming increasingly available. A future, All-knowing System (see Figure 1.1) could optimise the flow of goods to increase both safety and productivity, by allowing the trucks to be aware of their surroundings, including other trucks, EUR-pallets and people moving around. This calls for an intuitive interface between driver and system: what information is needed and how should it be transferred to the truck driver. The All-knowing System is currently under development at BTP, and as required technology for the system such as sensors and cameras are becoming less expensive, the possibility to implement semi-autonomous trucks is increasing. [10]

![Figure 1.1: An All-knowing System communicates information to the truck driver.](image-url)
1.2 Purpose

1.1.3 Driver Assist

As technology is becoming increasingly affordable, more truck functions will become autonomous. Since drastic changes do not appear from one day to another, there will be a period where trucks with autonomous features interact with manually driven trucks. In the semi-autonomous trucks some interaction between the driver and the system is needed, to inform the driver of the actions of the autonomous system. [10]

It is essential to explore in which situations the system could ease the truck driver’s work. It is also important to study how the driver should be notified that a system is taking control. To be of assistance for the driver, this interaction requires feedback which is intuitive and useful for the driver. The type of task that is automated and the extent of the automation is important to consider, as the driver assist should help the drivers to perform their duties. The risk with taking over too many tasks from the drivers is that they will not get stimulated enough [4]. This might lead to less motivated personnel and an unsafe situation when it is crucial for the drivers to be attentive.

Since TMHE want their products to be harmonised, in order to facilitate for the customers and drivers, the feedback solution should be possible to implement in both existing as well as future trucks [10]. Thus, the driver assist concept require two designs, one which can be integrated on future offerings and a modified one which can be a retrofitted to the existing trucks.

1.2 Purpose

The purpose of the thesis is to identify ways to assist the driver as trucks are becoming more autonomous, thus enhancing the safety of the driver and surrounding personnel as well as increasing the productivity of Toyota trucks. The driver assist is a first step in gaining customer acceptance of increasingly autonomous trucks, through implementing a feedback device that helps truck drivers perform in critical situations.

1.3 Objective

The objective is to develop a conceptual interface that allows communication between the driver and the All-knowing System, by providing intuitive feedback to the driver.

The concept is made in two designs:

- *Add-on*, which can be implemented in trucks currently in production, and
- *Innovation*, which can be integrated in a next generation market offering.

The concept is made according to the design representation level Operational Model defined in 4.5.1 ID Cards.
1.4 Formulation of Questions

The following questions are studied in the thesis:

Q1 In which situation is a driver assist appropriate to implement?
Q2 What type of information should be communicated to the driver?
Q3 In what manner is it suitable that the system and driver interact?
Q4 To what extent should the driver be able to choose if a system is in control or not?
Q5 How should the concept be designed to suit both an existing and a future truck type, respectively?

1.5 Demarcation

The technology involved in the All-knowing System is currently under development at the BTP department of new, immature technology and is therefore not included in this thesis. The thesis is focusing on the interaction between the future All-knowing System and the truck driver, and it is assumed in the thesis that the All-knowing System will exist in the future. Thus, the system technology is not a limiting factor for the resulting concept.

No Augmented Reality concepts, where computer-generated sensory input supplement elements of the real-world environment, are considered due to a parallel project at TMHE.

Reach trucks with four-way steering are not considered in the thesis as they are driven differently, thus these trucks are used in other environments. The focus is on situations that occur indoors, rather than outside, as user studies and observations takes place in the TMHE production and warehouse.

The concept’s Add-on design is developed to function primarily on the reach trucks currently in production, however it is seen as a success if it also functions for much older reach trucks that have been out in warehouses for many years.

The Add-on design is developed primarily for reach trucks without cold store cabin, as the driver environment in a truck with cabin is different due to the isolation from the surroundings.
Chapter 2

Prerequisites

This chapter describes the starting position of the master’s thesis, based on the prerequisites resulting from the development process and routines at BT Products. It holds a description of the currently produced reach trucks, the work process as it has been described to the thesis authors and as it stands in internal documentation, as well as a more in-depth mission statement explanation.

2.1 Compatibility

As described in 1.3 Objective, the concept is made available in both an Add-on and an Innovation design. The reason for this is that to be able to provide a harmonised offering to the customers, new functions must be available for many different types of trucks. A customer may already be in possession of an older truck, and as truck drivers often alter between trucks at a site, it would be confusing if one of the trucks has a certain system and the others do not. Additionally, if the customer in the future wants to purchase more trucks, these should also harmonise with the current truck fleet. The figure shows examples of Toyota Material Handling trucks (see Figure 2.1) [13].

Figure 2.1: Example of trucks that a customer’s truck fleet may contain [13].
The core values of TMHE are safety and productivity. If an innovative safety system is developed for new trucks, but not added onto the existing trucks, the result could be that drivers believe a safety system exist in these as well even though it does not. This would counteract the core values and put the drivers, as well as TMHE’s reputation, at risk. To avoid this the company has to take the entire range of trucks into account when developing new systems; a first step in this direction is this thesis focusing on reach trucks. To ensure a consistent product offering and backward compatibility, the *Innovation* design is developed to be included in all future reach trucks, whereas the *Add-on* is intended to be retrofitted onto the trucks currently sold from TMHE. The thesis focuses on the driver-truck interface, because currently when new systems are implemented the drivers are given no feedback as to why the system performs an action.

### 2.1.1 Description of Reach Trucks

The reach truck is a common truck type (holding approximately 10% of current TMHE sales) as it has a high level of flexibility: it can lift pallets that are heavy, high up, and reach further (thus its name) [10]. The frame that enables the forks to go up and down, can in reach trucks be extended towards the storage rack, which enables the driver to collect pallets where the supports legs cannot fit under the storage rack.

In the reach truck’s driver environment, there are naturally many different parts and functions to consider. In certain reach trucks, depending on how the customer wants it, there are rear-view mirrors placed near the roof of the truck, next to a radio and a display that is showing the weight on the forks and their height (see Figure 2.2) [14]. In all reach trucks there are three pedals: one safety pedal to ensure that the driver has the left foot within the truck to prevent accident, if the foot is not on this pedal the truck cannot be moved. The other two pedals are, similar to in a car, the brake and accelerator.

![Figure 2.2: Rear-view mirror, interior overlay, and the three pedals (safety pedal, brake and accelerator)](image)

The reach truck is manoeuvred using a steering wheel with a knob, which the driver rotates with his/her left hand. In front of the driver is a horizontal e-bar, on which different devices such as laptops can be fastened (see Figure 2.3). The driver is positioned sideways in the travelling direction, as can be seen by the position of the chair. On the right hand module, there is a small display currently used when
2.1 Compatibility

starting the truck. A code is used when starting, to which personalised settings can be registered.

![Steering wheel, horizontal e-bar, interior overlay and the right hand module](image)

Figure 2.3: Steering wheel, horizontal e-bar, interior overlay and the right hand module [14].

There are two types of seats (see Figure 2.4), as BTP has two different suppliers. One seat is more basic: cheaper and without a headrest. The other seat comes either with or without headrest, and seat-belt is optional. The two chairs are mounted differently in the truck. Thus, the backrest of the basic chair cannot be interchanged for the backrest of the other.

![The optional features include one of two chair types, of which the right one exists with or without a headrest](image)

Figure 2.4: The optional features include one of two chair types, of which the right one exists with or without a headrest [1].

Below the display are four finger levers used to rise or lower the forks when collecting pallets, move the frame towards the racking shelves and back, as well as controlling tilt and sideshift of the forks (see Figure 2.5). By the thumb, there is a switch used to control the truck’s travelling direction. Over the display there are small LED-light symbols to indicate: the travelling direction, if the parking brake is engaged, active warnings or a stop-sign if the truck has stopped due to critical errors [1], as well as if the battery is low (see Figure 2.5). The clock, battery and active speed limitations are shown on the display, as well as if the driver has forgot to engage the left foot safety pedal. There are warning symbols for high
temperature or if the truck needs service. There are also symbols indicating the vertical position and tilt of the forks. When the truck is in driving mode, the display shows a large icon of the reach truck from above, visualising if the position of the forks’ frame is reached in or out.

Figure 2.5: The right hand module, with display, finger levers and switch to control travelling direction [1].

There is a great variance of the reach trucks currently in production. The trucks are equipped with different functions, due to adaptations where the customer may choose between options or whether or not to include certain functions. These are the currently produced reach trucks that the Add-on design will be implemented on (see Figure 2.6), as presented to the customers.
Figure 2.6: BT Reflex - the current range of reach trucks from Toyota Material Handling [14].
Among the different optional features are sideshift and tilting forks, height indicator, horizontal e-bar (standard feature in the R-, E-, N- and O-series), vertical e-bar and adjustable seat with safety belt. The e-bars can be seen in Figure 2.7.

Understandably, the driver has one perspective of what features are needed, and the warehouse manager another. It is not the truck drivers that purchase the trucks, which is something that needs to be taken into consideration.

### 2.2 BTP Development Process

The development process at BTP is divided into four different flows, as can be seen in Figure 2.8. The yellow arrow, Core Technology Development, handles early development of new or immature technology. Green, Product Development Projects, develop new trucks, whereas red, Product Optimisation, work with cost improvements and problem solving on existing trucks. The forth arrow, Special Products, handles special client orders.

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**Figure 2.7**: Optional features include the vertical e-bar (the pillar seen to the left) and the horizontal e-bar (on which the computer is mounted).

**Figure 2.8**: TMHE Product Development flows.
Work is still ongoing to define the project model for Core Technology Development. It can, however, be seen as a pre-phase for Product Development Projects. For Product Development Projects the process is divided into a Development and a Final Verification and Industrialisation phase, see Figure 2.9. During the development phase, Tollgates Reviews (TG) are held with the project steering committee. Similarly, during the Final Verification and Industrialisation phase, Design Reviews (DR) are held with members of the company management (either TMHE or Toyota Material Handling Group depending on the size of the project). Unlike DR:s, TG:s are internal within BTP.

However, decisions are already made at mid management level before these meetings take place, as all work and discussions are already completed. The TG:s and DR:s are about one hour long, and are conducted as a formal approval from the higher management of the decisions. The technology discussions and conflicts are managed in the daily work and finalised at Quality Gates (marked by green triangles in Figure 2.9), that precede the TG:s and DR:s.

### 2.2.1 Impact on the Thesis Process

The master thesis is located under the yellow arrow, Core Technology Development. This is due to the futuristic aspect of the thesis dealing with immature technology and the All-knowing System, and as the resulting concept is not ready for market. The thesis is also strongly related to Product Development Projects, as it involves Driver Environment, an area belonging to Product Development Projects.

The Product Development Project process cannot be implemented as it stands on the thesis work. What is used is the way of thinking and the decision making process. All work and discussions are held between the authors, with input during weekly one-hour meetings with the BTP supervisor. Decisions are formally approved during Reference Group meetings. A Reference Group meeting is held approximately every two weeks.
For Reference Group meetings, general meetings, and requests of participants for workshops, booking at least a week in advance is needed as most participants are heavily scheduled. Regarding requests of drivers for interviews and the two prototype evaluations with truck drivers, a decision time of minimum two weeks is recommended from TMHE.

2.3 Kansei Engineering at BTP

Kansei Engineering is a method of interest at BTP. The methodology department recommends this method to be used when developing products at BTP, as it fits their development needs seen from a method perspective. An implication is that Kansei Engineering now is beginning to be introduced, but establishing working approaches is still undergoing. In the thesis, Kansei Engineering is used to select a problematic situation to develop a solution for, as a request from BTP. At the methodology department works a developer who is an expert at Kansei Engineering, and who’s assistance is available during the thesis work.

2.4 Function Concept Paper

Function Concept Paper (FCP) is a standardised working tool at TMHE, developed to clarify requirements and facilitate decision making in concept selection. The benefits with the tool is that the traceability of rejected concepts and the decisions in a concept development process is clarified. The possibilities to analyse consequences caused by changed scope increases. It is also a way to involve stakeholders early in the concept development phase. The document is a supporting tool when selecting concept, consisting of requirements, aims, strategies and checklists. Since it is a standardised document, others at TMHE can easily follow the process.

2.5 Reference Group

Meetings are held with the reference group to verify the decisions made in the thesis, similarly to the generic decision process at BTP. For the thesis, these meetings take place after each major decision and development phase, thus roughly every other week. The reference group meetings are a way to connect the thesis work to the organisation, and achieve a higher understanding and acceptance of the new ideas introduced. The reference group consists of four employees, all from the development department (see Table 2.1).
### Table 2.1: BTP Reference Group.

<table>
<thead>
<tr>
<th>Person 1: Male, 47 years old</th>
<th>Person 2: Male, 47 years old</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manager Technology Solutions</td>
<td>Core Technology Developer</td>
</tr>
<tr>
<td>Been at BTP 19 years</td>
<td>Been at BTP 5 years</td>
</tr>
<tr>
<td>Has truck driving licence but rarely drives</td>
<td>Has truck driving licence, drives once a month</td>
</tr>
<tr>
<td>Responsible for the department that works with innovation, pre-development and future technology linked to the truck industry and products</td>
<td>Works with development of products using new or innovative technology</td>
</tr>
<tr>
<td>Has worked with product development, both as a design engineer but mainly in management positions. Has experience of various applications and how the products are used by the customers. Also has good insight of how the products function and are constructed technically</td>
<td>Has worked in product development over 25 years of which 10 as a consultant, mainly in the automotive and aerospace industries in Europe, with information processing systems and production technology. Is the thesis’ supervisor at BTP</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Person 3: Male, 40 years old</th>
<th>Person 4: Male, 30 years old</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manager Driver Environment</td>
<td>Design Engineer</td>
</tr>
<tr>
<td>Been at BTP 15 years</td>
<td>Been at BTP 3 years</td>
</tr>
<tr>
<td>Has truck driving licence, drives a few times a week</td>
<td>Has truck driving licence, drives once a week</td>
</tr>
<tr>
<td>Responsible for ergonomics, driver interface and the ”driving feel”</td>
<td>Works with ”driving feel”, including specification of software and electrical components, new development and improvement of existing products. Conducts driver evaluations on occasion</td>
</tr>
<tr>
<td>Has worked with ergonomics, human machine interaction and ”driving feel” since 2000, and has worked with driver evaluations.</td>
<td>Has worked as a truck driver, has MSc Industrial Design Engineering, and 5 years experience of product development</td>
</tr>
</tbody>
</table>
18 Prerequisites
Chapter 3

Theoretical Framework

The theories that are used in the thesis are presented and described in this chapter. Theories regarding automation is presented first and follows by a larger section about Human Machine Interaction.

3.1 Automation

Having automated vehicles has several benefits, primarily in safety and cost savings [4]. A study made by the Insurance Institute for Highway safety shows that vehicles that are partly autonomous are involved in less crashes [15]. This includes vehicles that have a forward collision warning system, that either brakes automatically or warns the driver of a potential collision [15]. Incidents and collisions with trucks occur most frequently in manufacturing industries [16].

The three most common truck accidents are crashes between trucks, collisions and pinching, according to Prevent [16]. Both the personnel driving the trucks and the personnel that frequent the facility are in need of a safety training of how to behave in truck areas, since poor education seems to be the main reason for the truck accidents [16].

It is also important with a high degree of user-friendliness of the technology in order to achieve an interaction which is safe [17]. Since the industrial revolution the perspective of automation has been focusing on the function or process that shall be controlled, without or with little concern of the people that are involved in the automation [18]. As the complexity of the automation increased, and required a larger focus on the people involved in the automation, the approach towards automation long continued without regards to the behavioural sciences [18].

Today, automation is present everywhere and is continuously increasing. However the same approach still exists to an extent, as it has changed less rapidly than the technology. The consequences of this is that automation problems has increased, showing themselves as daily disturbances which sometimes results in dramatic accidents. A solution to these accidents has often been to establish even more automation in order to reduce the human performance which has been seen as the unreliable factor that causes the problem. [18]
3.1.1 Levels of Automation

Sheridan [19] describes two possibilities of human interaction with a system: it is either the human who invokes the changes, called adaptable automation, or they occur by the automation itself, called adaptive automation. Adaptive automation means that a conjunction between the human and the automation is required. Another way to define adaptive automation is what role the levels of automation (LOA) has when performing a task. There are four types of stages: The first one is to gather the required information that is needed to be able to perform the task. The second is analysing that information. The third step it is about making decisions of what action is needed, and the last step includes execution of that action. [19]

The LOA often refers to if it is the machine or the human that performs the earlier mentioned tasks. If the human performs the task, the control is limited to the human. If instead the computer is the controller, the actions are limited to the specific control functions which it has been programmed with. Sheridan [19] also mentions that automation is limited, because a system can only take control over tasks based on criteria that it has been pre-programmed with. The different levels of automation, from human controlled to fully autonomous, can be seen in the list below. [19]

1. No assistance is offered by the computer, hence all decisions must be made by the human.

2. A complete set of action or decision alternatives is offered by the computer, or

3. the computer reduces the selection to a few alternatives, or

4. one alternative is suggested;

5. if the human approves it, the computer executes the suggestion, or

6. the human is allowed to veto for a restricted time before automatic execution, or

7. execution is made automatically, then if necessary the human is informed, and

8. the human is only informed if asked, or

9. the human is only informed if the computer decides to.

10. The computer make all decisions and acts autonomously, hence ignoring the human.

Hollnagel and Woods [18] present a picture of the stages of human-machine dependency. The dependency consists of three stages (see Figure 3.1): Manual, Supervisory and Fully automatic control. The manual control does not impinge on the operator’s ability to control since it solely consists of operations that the
3.1 Automation

operator was ill fitted at performing. In supervisory control, which is the next stage, the automation gradually removes the operator’s direct control of the process, since the automation progressively takes over functions that had previously been controlled by people. In the third step, control is fully automatic, and the operator can now only follow what is going on; the possibilities for intervention is few. [18]

![Diagram showing human machine dependency levels]

Figure 3.1: Human machine dependency consists of three levels: Manual, Supervisory and Fully automatic control [18].

3.1.2 Automation Effects on the Driver Environment

As new automation systems take control of the driving, the drivers’ alertness will be reduced. A result of this is increased reaction times that could compromise the safety. A way of handling this is while the vehicles still have a steering wheel and brake (and a driver is needed as they are not entirely autonomous), the driver needs to maintain some sort of driving function to remain alert. [4]

There are three levels of vehicle control: operational, tactical and strategic. Operational control include actions that occur within 0.5-5 seconds, such as braking and accelerating. Tactical level includes behaviours happening within 5-60 seconds, for example changing lanes or making a turn. The strategic level include activities that involve planning; activities that take place over minutes ahead. [20] Current technology development focuses on the operational and tactical levels [4].

The MODAS project, a collaboration between Scania CV AB, Interactive Institute Swedish ICT as well as Uppsala and Luleå Universities, is developing a future driver environment that assists the driver. Operational and tactical decisions will be controlled by a system - the lorry is autonomous in these situations, while providing feedback to the driver as to what is going on. The driver will take on a supervising role, monitoring the systems and the environment and take corrective actions as needed. The driver will remain in control of strategic decisions. [4]

As the vehicle controls more operational and tactical actions in many situations,
its interface needs to help the drivers in making strategic decisions as well as enable them to override the automation when necessary. Drivers must be made aware not only of the current state and future intentions, but also of events or conditions in the surroundings that are relevant for decision-making.[4]

Google are also developing autonomous vehicles, however these cars are now developed to be fully autonomous [21]. Google spent four years developing an semi-autonomous car which partly involved driver control but after a study that involved hundreds of persons they gave up semi-autonomous driving and focused on fully autonomous instead [22]. The cars will not require any human intervention and does therefore not provide steering wheel, brake or accelerator pedal [21].

In the MODAS project, the resulting prototype is a simulator with both auditory and visual displays, that support safety, efficiency and driver pleasure when controlling a highly autonomous vehicle [4]. The auditory display consists of a surround rig that can direct the sound from different positions in the lorry to effectively guide the driver’s attention [23]. Furthermore the visual display is projected on the cab’s windscreen, showing information like surrounding traffic, fuel level and system questions, and is linked to a touch pad that the driver uses to answer the questions from the system. Sound is used in addition to the visual feedback to help the user navigate the interface and prioritise information (a heads up on what is ahead or a warning to stop right now) [23]. The driver’s role is supervising the system and handling strategic decisions like re-planning routes or deliveries [23].

Automation technologies will change the role of the driver, which will result in new driver behaviours and errors. Difficulties lie in predicting the effects of such a large technology shift. Factors that need to be considered are drivers’ situation awareness, fatigue and mental workload, as well as the drivers’ trust in the new technology and interface. [4]

3.1.3 System Development Challenges

A complex system is composed of multiple interacting parts, and will increase in complexity as functions and modifications are added. A growing system complexity puts added complexity onto the driver of the vehicle. While driving, drivers receive information about the subsystems through a speed display, a gear display, and the sound of the engine. The main difference from previous, older subsystems, is that information used to be presented regarding the vehicles mechanical subsystems, whereas with future systems drivers will require feedback of the vehicle’s “cognitive” system - why an automated vehicle act in a certain manner in a particular situation. [4]

To develop a future system, it is important to consider the user needs in the system context. However, common user-centred methods are often based on the current system and it is improved by analysing either how the users perform the task (descriptive) or how they ought to perform the task (normative) [4]. The new automation technologies brings the opportunity to create a new type of driver environment instead of fitting new technology into legacy systems [4]. This brings the challenge of developing a unique system in the absence of a current, where
3.2 Human Machine Interaction

A human machine system consists of humans and technology that interact in a certain context [25]. The interface is the meeting point at which an interaction occurs between two or more systems or processes [26]. The human receives information through the interface, and processes the information in order to perform actions [25]. The actions are translated into functions by the machine, that then displays it to the human (see Figure 3.2) [25]. The aim of a human machine system is to create a functioning cooperation between machine and human, thus to prevent human limitations while the human ability to operate the system can be utilised [25].

![Human Machine Interaction Diagram](image)

Figure 3.2: Human Machine Interaction is communication between man and system, which occurs through an interface. Translated from [25].

3.2.1 Cognitive Systems

A cognitive system is a system that can modify behaviour on the basis of experience so as to achieve specific anti-entropic ends. Anti-entropic means to maintain order when disruptive incidents occur, and control what the system does. [18]

Factors that affect complexity in cognitive systems are insufficient training and experience, insufficient time and knowledge or a deficient interface design. The third category is associated to the complexity of the interface (which provides both information of the incident and the means to react to it). If the interface is unintuitive, the users’ actions may be late or faulty. To solve this, the designer can rely on established standards. [18]
A joint cognitive system takes into account both its human and its mechanical parts, and how these function together as a system. Any joint cognitive system can also be seen as part of an overarching joint cognitive system. Thus, the simplest joint cognitive system consist of either two cognitive systems, such as two people working together, or one cognitive system and an artefact, for example a person using a tool. On a higher level, a joint cognitive system could exist between a car and its driver, or between the car, its driver and the roads, or it could include traffic infrastructure and even topography and weather (see Figure 3.3). It is definitely important to consider the ergonomics of the car to know how the driver is affected, however the driver-car system must be seen within its context for correct assumptions to be drawn. [18]

**Figure 3.3: Example of joint cognitive systems [18].**

### 3.2.2 Semantics

Product semantics is applied in the design process to help the user to interpret the product correctly [27]. Semantics is about understanding a product and knowing how to use it [26]. The understanding is influenced by the product’s shape, colour and surface texture [26]. It should also be noted that people will implement previous experience on new and unfamiliar products [26]. For example, if an object has a rigid, smooth, flat surface in the same level as the human knee, it invites to be sat on [27]. An upward shape and bright colours give the impression that the product is light [26].

The general semantic approach consists of three steps: determining the nature of the product, selecting relevant attributes and exploring the visual expression of these attributes. Metaphors or icons help to clarify the product’s meaning. For example, an existing symbol or shape from another object can be used to relate the product function to the function of this object. [27]

In semantics, there are signals to caution or encourage the user to react in a specific way. Examples of this are the traffic lights’ green man that glows when
3.2 Human Machine Interaction

it is allowed to walk across the street and the ring tone that alerts you to answer the telephone. It can also be an order on a display or a flashing light on a control panel. It is important that the instructions are clear, since a person’s actions are highly influenced by the signal. For example, the picture of the airplane has such a strong effect that it can counteract the direction of the arrow (see Figure 3.4).

![Figure 3.4: The arrow is counteracted by a non-semantic icon](image)

When people are stressed or anxious, they are more focused on a specific task and thus more likely to miss additional information. Where this is the case, the information required to perform the task must be visible, with clear and unambiguous feedback about the operations that the device is preforming. Products that are intended to be used in stressful situations require attention to detail.

For control panels to be easily legible, abbreviations should be avoided, the font should be easy to read and icons should be used to facilitate for the user. To clarify the current state of a lever or button, text can be used, but to show its function well-known symbols or textural patterns are preferable. The brain recognises the images and icons much faster than text can be read, thus they are advantageous to convey functions. Images can also allow the user to remember associated information.

**Semiotics**

Whereas semantics is the study of the messages of signs, and thereby what the sign refers to, semiotics is the study of the signs themselves. A sign is something that has meaning: a phenomenon which has significance that is independent to its material form. The product sign is used to communicate a message of how the product is used, how it functions, and who the intended user is. This is communicated to the buyers, that form their own interpretation of the message.

There are different types of signs. Visual signs are divided into the categories icon, index and symbol. The difference of these is how the message is connected to the sign. An icon is a sign that bears physical resemblance to what it symbolises. An example is the airplane icon in (Figure 3.4), or the little button with printer on it, that is used to print something from a computer. An index is when there is a link between the sign and an object, such as tracks in the snow that indicate
where cars have driven or the form of the corkscrew indicating its use. A symbol is a sign which by a convention represents something else, through an unexpressed practice or by an agreement. An example is the steam engine that is the symbol for railways, even though trains have long had electrical locomotives. [26]

Other signs are auditory. Hearing sounds of the surroundings is vital for humans’ well-being as well as ability to orient room-wise. Some noise is good because it notifies of warns of important occurrences, whereas other sounds are undesirable noise. When we hear sounds we impart meaning to them as we interpret them - this is what makes them auditory signs. Audio signs must correspond with visual signs, for example so that a product that expresses quality does not make clattering sounds. [26]

Warning signals are important, both visual and auditory. The rhythmic clicking sound of pedestrian crossings is a well-known sound. Here, the rhythm changes when time is running out to cross. Two visual signs that are commonly used to warn the user can be seen in Figure 3.5. The glass is an icon used to warn about the fragility of an object. The skull is a symbol that warns of death through poisonous material. [26]

![Figure 3.5: Icon that warns of fragility and symbol that warns of danger [26].](image)

A display’s usability is highly dependent on the design of the available icons on the screen [30]. The usability is significantly reduced if the icons are small and located near the edge of the display. Semantic quality shows that users prefer to see icons in combination with text [30]. The icons should not be too close together, as the screen in this case is perceived as cluttered and complex, which can lead to nervousness and stress for the user [31]. Large icons may contain more details while small icons must be simple and easy to understand [31]. To use symbols (or icons) in a user interface is beneficial compared to text, as they often function international, but the symbol must be familiar and the interpretation of it unambiguous [25]. Symbols can have various levels of abstraction: it can be graphical symbols that represent reality or abstract symbols referring to perceptions [25].

**Use of Colour**

Colour can advantageously be used to detect status changes on the screen [30]. However, it can vary when different colours are considered appropriate because people have different connotations to them. Red can, for instance, be attractive or signal danger [30]. An example of what associations different colours impose, can be seen in Figure 3.6. Colour quality is an important factor for inexperienced users, while more experienced users stresses the importance of getting feedback when pressing the icons [30]. If the display should have a high usability it must
be taken into account that about four percent of all people have red-green colour blindness [32]. The colours that best suit the majority of the population poses problems for these users - instead a monochromatic colour scheme can be used [32]. It is of great importance to use colours sparingly [25]. In a display interface, not more than four colours should be used [25].

![Figure 3.6: Example of the meaning of colours. Translated from [25].](image)

**Gestalt laws**

Gestalt can be defined as several parts that appears and functions as a whole that is more than the sum of its parts, and thus is important to consider in achieving good semantics [26]. The basic idea behind the gestalt laws of psychology is to find the simplest and most direct interpretation of incomplete visual information [29]. Some of the most important gestalt factors are proximity, similarity and symmetry [26].

In a display interface design, the laws of proximity and similarity should be taken into account [29]. Proximity is to do with the placement: objects that are closer together than to other objects are perceived as a group [33]. This makes it possible to see an eye in the raster in Figure 3.7. Using the proximity gestalt when designing a display or control unit to group controls after function, makes the purpose more clear for the user [26].

![Figure 3.7: Proximity helps group or connect objects [26].](image)

The similarity gestalt is the grouping of items that have similar properties [26]. This includes items with similar shape, size, colour, texture, value or direction [33]. Buttons that are similar in appearance, can be recognised to have the same function even though they are placed far away from each other [26]. The gestalt law of symmetry means that symmetrically placed objects are viewed as a whole,
even with a certain distance between them [34]. Symmetry creates a balanced, consistent, calm and stable feeling in the viewer [34].

3.2.3 Feedback

In order to let the users know that the system is working, feedback is an important factor. The user must receive the feedback immediately, as it could be confusing with even a short delay of a tenth of a second. It is also important that the feedback is informative. It is common for companies to use less expensive lights or sound generators in their feedback systems. Those are not that helpful but instead the simple beeps or light flashes are usually annoying for the users. In addition, they convey little information of what the actual problem is or how to handle the problem, it only tells that something has occurred. A problem with auditory signals is that in certain cases it is difficult to tell which device caused the sound. If using a light signal instead the risk is that the signal is not detected, if the eyes of the user are not on the correct spot at the time when the light signal occurs. [35]

Feedback is important in many different situations: feedback may be required continuously during use or the user may need confirmation or information of that various features have been activated. This feedback can be a brief flash of light or sound when you push something, or the feel of a brake pedal when you depress it and the resultant slowing of the vehicle. [28]

It can be worse with a poor feedback signal than no signal at all, since it is distracting, not informative enough and often irritating and could cause anxiety. Too much feedback from a machine can also be annoying, and can be dangerous since it is distracting. If people receive too much feedback they could start to ignore all of them or if possible the user disables them and as a consequence important and critical messages are not noticed. It is essential with feedback but not if it gets in the way of other things, as for example a relaxing and calm environment. In order to make sure that the important messages reaches the user, the feedback must be prioritised, which means that less important feedback should be presented in a more discrete manner. If the equipment continues to beep it could be dangerous since it affects the concentration that is required to solve the problem. It is of great importance with response but it has to be done in a correct manner. [35]

Auditory feedback

Sound is the media that best grasps peoples’ attention and directs their view to the correct area [25]. Sound can be used both to notify and to warn, but also to confirm that an action has been performed [25]. A common way to signal that an action has been performed is by using a “beep” [28]. This sound should however be carefully used as unwanted or unpleasant sounds evoke anxiety and a negative emotional state of the user, thus reducing the user’s efficiency [28].

The highest benefit of using sound is that it cannot be entirely ignored and can be perceived even if the user does not listen for it [25]. It can also be noticed no matter of the orientation from the feedback system [36]. It is therefore well suited
for alarm-systems since it will draw peoples’ attention despite their location, unlike visual feedback that is dependent on the users’ orientation relative the feedback system [36]. A negative aspect is that sound alone cannot be used to warn as some users may be deaf or the sound can be disguised by noise pollution in the environment in which it is used [25].

Auditory signals should not be used superfluously, or in a way that distracts the user [25]. It is possible to produce pleasant sound signals, for example the designers of the Segway HT, according to Norman [28], “were so obsessed with the details on the Segway HT that they designed the meshes in the gearbox to produce sounds exactly two musical octaves apart” making the engine sound like music [28].

It is important to consider the intensity, pitch and direction when designing a sound signal [25]. To make sure that the users can notice the feedback the relative level of volume should be 15dB higher than the surrounding noise [36]. Furthermore, the authors argue that the volume level should not be higher than 85-90dB, which is the danger level of noise, in order to be safe for the users so that they do not receive permanent disability caused by loud noises from the feedback system.

Visual feedback

The visual sense is the dominating sense that humans utilise and rely on. About 80 percent of all sense impression are collected through the eyes, and humans tend to rely on those impressions. The visual sense is however lacking, since it can only detect something or someone that is in our field of vision, which covers 170 degrees horizontally, and barely anything towards the edges. It is also the sense that is easiest to turn off, by closing the eyes. [25]

Plenty of parameters are of great importance for the processing of light: contrast sensitivity, colour and night vision, depth perception, movement detection. In addition, glare is a parameter that affects the visual cells, this means the occurrence of irrelevant light with high intensity. [25]

The design factors that are of great importance when something is presented visually are choice of colour, intensity, contrasts, viewing angle and luminance. If the task is demanding or if the situation is stressful it is even more important that the visual presentation is thought through and supports the user’s information processing. [25]

Tactile and Haptic Feedback

The tactile sense (or the sense of touch) includes perception of mechanical contact and pressure on the skin, but the perception of coldness, warmth, pain, tickling or itching. The tactile sense is of great importance for the well-being. The sense of touch is a collecting expression of information gathered from great number of receptors located in the skin. [25]

Tactile is defined by Monó [26] as "related to the sense of a surface structure by touching”. One of the benefits with tactile feedback is that it can replace visual.
Operators can find buttons on a control panel without using the visual sense if they for example are constructed of different textures. [26]

Haptic on the other hand include effects from touching or body movement. The word haptic means placing the hand on something to sense and touch it in order to clarify it. Haptic information consist of both passive and active information. The active information could consist of static and dynamic sensory stimuli. Weight, size, form and surface structure are examples of static ones and rhythm and vibration are examples of dynamic sensory stimuli. A technical product that uses a haptic feedback solution is hand controls for computer games which delivers a vibration feedback to the user. [25]

Care must be taken so that haptic feedback does not induce serious vibrations. Exposure of vibration is divided into full body vibration and hand or arm vibration. Different types of vehicles is the primary reason for occurrence of full body vibration that causes back or neck disorders. While using vibrating hand driven tools often causes hand or arm vibration. If the exposure is large over time/during a longer time it could lead to back disorders or vibration white finger syndrome. Permanent vibration injuries is a relatively common work related injury. Consequences of the injuries are often related to decreased quality of life and physical discomfort. [37]
Chapter 4

Methods

The methods that are used in the thesis are presented and described in this chapter.

4.1 Product Development Process

The product development process can be divided into six parts, according to Ulrich and Eppinger [38]. One of these parts is the concept development part which also is the most comprehensive one [38]. The primary step in the concept development is to identify the customer need and establish a requirement specification which could be made by studying the current state and the target users. The next step is to generate concepts in order to satisfy the customer need. This follows by an evaluation of the concepts against each other and against the requirements and finally result in a concept selection. The selected concept could then be verified by conducting a test with users. Iterations could then be made in order to improve the concept. [38]

The fuzzy front end (FFE) is the first part of the innovation process and is followed by the new product development and commercialisation. The FFE is often a period which is chaotic, experimental and uncertain; a lot of information is gathered and tested. The greatest opportunities for improvement of the overall innovation process is found in the FFE phase. In order to increase the value and probability of success for the concepts that enters the development and commercialisation phase, it is important to focus on the front end activities. [39]

4.1.1 User-Centred Design

It is important to establish a more user-centred product development in order to reduce the gap between the developer and the user. It can be difficult for the developer to know in which situation or manner the product will be used. The developer has more knowledge of the product than the user, due to participating in the process to develop the product. For that reason it can be difficult for the developer to establish an objective mindset regarding the product. User involvement
Methods

is an important part of the design process to make sure that the user understands the product. [40]

As the users are not always aware of their needs or behaviours, qualitative research is a way of finding these needs. Some needs are observable, and can be found by studying users in an observation. Other needs are explicit, and can be expressed verbally by the user in an interview or survey. Tactic needs are known to the user but cannot be expressed. Latent needs are subconscious, unknown and inexpressible by the user. [41]

4.1.2 Kansei Engineering

Kansei is Japanese for a person’s feeling or sense of a particular product, environment or situation, gathered using the senses of sight, hearing, smell and taste [42]. Kansei is a mental process activated by external factors, that is important in sensation, perception and cognition of an object [43]. Kansei value comes from the psychological interaction that occurs between products and people [44]. Thus, it can be referred to as affect [44].

Affective needs are increasingly important in product design, as it goes beyond functionality and usability [28]. To understand how the customer feels about a product, it is important that affective experiences and meanings are communicated [44]. Kansei Engineering is based on behaviours and actions, such as a person’s facial expression or body language, spoken words or physiological responses like heart rate or body temperature (see Figure 4.1) [42].

![Figure 4.1: Ways to reach Kansei](image)

Kansei Engineering can be seen as a framework for methods that translate a customers’ Kansei, or affective responses, into product design attributes [44]. These attributes include for example size, shape and surface [42]. Kansei Engineering includes ergonomic methods, psychological methods, heuristic methods as
well as statistical and probability methods. Exploratory Research can be used as a psychological method to grasp the customers’ Kansei. Methods that can be used to collect subjective data are Semantic Differentials and Likert Scales. To map or reduce data, methods like Affinity Diagramming and Kano Analysis can be used. [44]

**Affinity Diagramming**

Affinity Diagramming is a method where research insights are expressed and clustered, which enables the design team to make research-based decisions. The insights can be based on observations or relate to project concerns or requirements. Each insight is written down on an individual sticky note. Notes that share an affinity, or a similar issue or intent, are clustered together. The clustering is done from the bottom up, rather than into predefined categories, which is achieved by initially grouping smaller or more specific details and then creating more generalised or overarching categories (see Figure 4.2). [45]

![Figure 4.2: Example of an Affinity Diagram, where its highest and second highest cluster levels can be seen.](image)

**Likert Scales**

A Likert Scale is used to categorise attitudes [42]. The scale is often 5- or 7-graded but may have even higher grades [42]. For example, a 5-grade Likert Scale is constructed from Strongly agree to Strongly disagree (Figure 4.3) [46]. The three middle steps are then Agree, Neither and Disagree [42].

Although there are several scales that can be used, the 5-scale is the easiest to understand and the easiest for clients to use. The main advantage of this scale is that it is much less time-consuming to answer than a free-description questionnaire. [42]
Kansei Semantic Differential Scales

A semantic differential, or SD scale, is used to analyse connotative meaning. An adjective is paired with its autonym, and between the word pair a 5-grade Likert Scale is placed. The classic semantic differential, developed by Osgood and his colleagues in the 1950s, used autonyms, for example beautiful—ugly, set on each side of a horizontal line (the scale). [42]

In the Kansei semantic differential, the Kansei word is compared not to an autonym, but to its negation. Since the aim of Kansei Engineering is to achieve a beautiful design, never an ugly design, all Kansei words have a positive connotation. The Kansei words, describing feelings and sensations, are generated based on core values, magazines and from literature. An example of a 5-grade Kansei semantic differential of the word Safe is: Not safe  . . . . Safe. [42]

A reason for why Kansei SD scales use positive words and their negations instead of pairs of autonyms, is that not all words have an autonym with an opposite meaning. Another reason is statistical. When measuring on a beautiful—ugly scale, the statistical frequency distribution is distorted toward the beautiful side. Skewed distributions prevents applying most statistical analysis techniques, whereas in Not beautiful—beautiful, the distribution becomes symmetrical and thus normal (Gaussian) distribution analysis can be applied. [42]

4.2 Exploratory Methods

To understand the problem is key in developing successful products. If the problem is not fully conceived, design efforts are often in vain. [41] In the following section, methods for exploring the problem space and user needs are presented.

4.2.1 Observation

Observation is an objective method used to see how a user acts in a certain situation [17]. Its purpose is to gain understanding of the user’s situation without interfering with it [17]. There are two different observation techniques: structured and unstructured [47]. The difference lies in both the execution and the type of data being collected [47]. Both observation techniques include the risk of omitting an occurrence not deemed as important [47]. Regardless of level of
structure, observations should be systematically executed and documented using notes, sketches, photographs, or video [45].

Gillham [47] consider unstructured observations as very time consuming, and that they produce largely qualitative data that is possible to analyse in depth. They are suited for studying behaviour as part of a complex situation [47]. Unstructured observations are commonly used to gather information about a situation in the early phase of a study [17].

A structured observation is, on the other hand, relatively economical time wise and delivers largely quantitative data that is easily summarised but essentially superficial. It is not suited for studying extended or elaborate sequences of behaviour. In structured observations exact behaviours are specified and their frequency over short periods of time recorded. [47]

Checklists can be used to benefit the observer, as they enable a systematic approach for the observation mapping, while simultaneously providing the observer with an overview and allowing assessments to be made [17]. The level of structure of an observation is dependent on the degree of pre-structure utilised, such as using worksheets or checklists to systematise observed behaviours or events [45]. Examples of pre-structure are using predetermined behavioural categories, types of interactions or regular time intervals for observations, or counted successes and errors when observing use of an interface, prototype, or product [45].

Limitations of structured observation are the narrow opportunity of discovery and the lack of knowledge of the underlying reasons and motivation of the observed persons [47]. The observer also needs to be careful of “finding” what he/she is looking for, or tweaking an observation to fit into a predetermined category [45]. However, a structured observation needs to be preceded by an unstructured phase so that the observer knows what to look for [47].

Fly-on-the-wall is a non-participant observation method, which is appropriate when observing public places or work processes that could otherwise be disturbed [45]. The purpose of Fly-on-the-wall is to remove the researcher from direct involvement with the activities or people studied, thus minimising potential bias or behavioural influences [45]. However, if there is any contact with or awareness by those observed, the observation cannot be said to be entirely non-participant [47].

Observations can also be direct or indirect. Direct means that the observer is present in the situation and observes with his/her own senses [17]. If the observers are recognised as outsiders, people have a tendency to change their behaviour, as they are aware of being studied [45]. Indirect means that the situation is recorded by continuous filming by a discreetly placed camera with no observer present [17]. Video is a useful tool that enables the observer to later study a sequence over and over again, which is called retrospective observation [47]. It makes it possible to notice aspects that were elusive live [47].

It is useful to combine observation with a self-report method such as interviews [47]. Observations are helpful to do, as people do not always know their own behaviour in certain situations [47]. However, feelings, attitudes and wishes are not registered [17]. Interviews are therefore useful in order to receive additional information [47].
4.2.2 Interviews

In order to collect information about peoples’ thoughts and preferences, interview is the most common and basic method. Knowledge about users’ way of reasoning, what one values, and previous experiences can be collected with interviews. The method could be used in various situations, however the resulting information is subjective. Depending on the methods’ structure, either qualitative or quantitative data could be received. In general an unstructured interview is preferable when the aim is to collect qualitative data and a structured for quantitative data. Which form of structure that is preferable is therefore dependent what purpose the interviewer has. [17]

A semi-structured interview is a mix of a structured and an unstructured interview. A structure has been prepared in advance regarding subjects that will be discussed, but during the session the interviewer can change the order of the subjects and follow up the questions with new ones depending on the users’ answers. This form includes both predefined subjects as well as new subjects depending on the answers from the user. A systematic analysis is then easier to conduct compared to if the interview had been unstructured. Both quantitative and qualitative results could be collected using this type of interview. [17]

A benefit with the method is that it is flexible. The risk of misinterpreting the information decreases since the interviewer could use follow up questions to explain the information further. It is also possible to get the appropriate target group when using this method since they could be selected in advance depending on their qualities. A disadvantages with the method is that it is possible that the user changes his/her answers because of the interviewer’s attribute, qualities, acting or something else that influences the user negatively. It is not certain that the answers harmonises with the person’s real actions, it is therefore important to complement the method with observations to get a better understanding of how users behave in various situations. [17]

An interview that is conducted in the context or environment in which the service of the users occurs it is called a contextual interview. It is crucial for the success and result of the interview that the interviewee feels comfortable during the interview, in order to share intimate insights of their lives. It is always easier to provoke a more thorough discussion about work routines if the interview takes place in the environment where the processes take place. It also helps the interviewee remembering specific details that often gets lost in a traditional interview setting and is one vital benefit with this method. Additionally, it helps the researches to gain a more holistic understanding of the physical and social environment that surrounds the examined service if the interview takes place in the right context. [48]

4.2.3 Workshop

Design workshop is a research method that can be used to activate the stakeholders, in order to collect an understanding of the users’ experiences and to collect design parameters. The workshop can consists of mapping or diagramming exercises. One of the strengths with the methodology is that provides the designer
with valuable insights despite the effort it requires regarding time to prepare, organise and realise. Those activities are the most critical features of a workshop. It is difficult to plan the timing in advance and during the session maintain the plan and at the same time be able to adapt to changed or unexpected circumstances. There is also a need to document the result during the session and afterwards gather the result and outcome. [45]

4.2.4 Card Sorting

In order to generate optional structuring of information the card sorting method can be used, since it can describe different approaches of a problem [45]. The method could be used for several purposes depending on the designers’ aim [49]. The cards could be presented in different forms such as with images, objects or descriptions of items [49]. The participants are then supposed to name and group the cards [49]. Group names could be provided to the users if the researcher in advance knows of group names that are important for the study [49]. However it is also important to invite the users to come up with their own group names [49].

When performing a card sort it can be helpful to use the following guideline: Perform it with participants in small groups, maximum five people, or with individuals, and do it iteratively [45]. Allow the participants to add their own items by bringing blank cards and markers to the session [45]. Card sorting is an effective investigative method when handling plenty of concepts, there are few other investigation techniques that are as effective as cart sorting [49]. It could be made both web-based and face-to-face, however the latter gives a more qualitative result than the web-based [49]. Having the user sort cards with product attributes is helpful in developing a mental model of the problem or product [41].

4.2.5 Try It Yourself

To get a better understanding of physical, social and emotional implications for users of a certain product, it is valuable that the project team uses the product themselves. This is the basis of the method Try It Yourself, and it leads to understanding and to better appreciation of the users’ experiences. [50]

4.3 Ideation & Concept Development Methods

Methods which are suitable to use for ideation and concept development are presented in this section.

4.3.1 Brainstorming

In order to stimulate the creativity in a group of people brainstorming can be used. The purpose with the method is to generate ideas and concepts. Quantity is more important than quality in this method and negative opinions are not allowed. Odd ideas are beneficial in the method as they incite open minds and ideas. The aim of this guidance is to establish a confident environment for the participants
so that everyone are comfortable sharing their thoughts and ideas without being criticised. [45]

There is a risk that the participants who develop ideas in a group get more attached to a number of the generated ideas than other. As a consequence of this other concepts might be forgotten. Those concepts might consist of valuable information or twists that could have been developed further. Therefore it is of great importance that each one establish their own number of concepts before developing concepts in a group. [51]

Brainstorming can also be performed as Brainsketching, where all members sketch on their own idea for a short time before passing the sketch along to the next group member. The sketching continues, allowing all members to improve all sketches, until the sketches has gone one lap around the table. [52]

4.3.2 Random Input

Random input is a method to change thinking patterns. The method is simple and can be used both individually and in groups. In the method words are generated randomly, this can be done in several ways, by browsing a book, a newspaper or choose one word at a random page. It is of importance to try to use the first word you find without being distracted. Based on the random word should other words or ideas be generated. The next step is to try to apply your ideas or words on the problem at hand. [53]

4.3.3 Storyboard

A series of pictures or drawings that visualise a specific sequence of events is called a Storyboard. In the Storyboard a series of illustrations tell the story of the examined situation. By including many contextual details it is easier for the viewer to quickly understand what is going on. Storyboards are used to bring user experiences into the design process; the aim is to gain insights of the user experience being visualised. [48]

Storyboards can depict either imaginary or real-life scenarios, the latter could be made by using photographs instead of illustrations [48]. The scenario described in the storyboard can be based on future use of a product or service [45]. It may also be based on problems occurring with a current product or service offering [48]. Storyboards can be used to provoke meaningful analysis and discussion about either potential problems or areas of opportunity when the situation is placed in its proper context [48].

4.4 Concept Selection Methods

Concept selection could be made in several ways according to Roozenburg and Eekels [54]. In the following section, methods for selecting concepts are presented.
4.5 Verification Methods

4.4.1 Heuristic Decision Rules

Heuristics Decision Rules are rules used to make a decision. These rules may be used for less complicated selections, but for important and complex decisions there are better ways to choose a concept. One of the Heuristic Decision Rules is Searching for a satisfying alternative. The rule aims to find an alternative that meets the aspiration level of each criterion. The concepts are tested in a random order and the first that meets the criteria is chosen. [54]

4.4.2 Pro-Con Analysis

Pro-Con Analysis is a method to be used when considering an alternative in order make a decision to reject it or not. The method could be used when considering several alternatives but it might be too complex to make a decision when considering a great amount of options, although NASA is a frequent user of this method when evaluating numerous project proposals. A five step model is used for making a decision. Start by dividing a sheet of paper into two columns, write ”Pro” on top of one and ”Con” on top of the other. Step two is to fill in all the pros and cons in each column for the alternative. The importance of each pro and con is the estimated in step three. The final steps are to eliminate the pros and cons until one of the columns becomes dominant. The elimination could be made by identifying a pro and a con that are equally important and then cross them out, or by identifying for example two cons and three pros that are equal and then cross all five out. [55]

4.5 Verification Methods

When evaluating an innovation one should be careful in involving potential customers as it requires them to imagine something they have no experience with [28]. However Rettig [56] states that to receive a good final result the development process should be made iteratively and involve user evaluations. In the following sections, methods that can be used to evaluate and verify a concept are described.

4.5.1 Prototypes and Models

There are many different definitions of the word prototype. Roozenburg and Eekels [54] refer to it as a representation of the new product, as close as possible to the ones that will be manufactured. Rettig [56] on the other hand, describes two types of prototypes. According to Rettig [56], a lo-fi prototype may be used for evaluations early in the design process, and thereby enhance the possibility to make more and better improvements. The author describes that hi-fi prototypes on the other hand have other benefits: they could appropriately be used to promote the idea or evaluate the product’s look and feel. Further he means that when using hi-fi prototypes for evaluations, feedback on the overall design, flow or layout will not be received, for these aspect it is better to use a lo-fi prototype.
To improve collaboration between industrial designers and engineering designers, Loughboroug University has developed a joint taxonomy of key methods and design representations used during new product development, hence referred to as ID Cards. The ID Cards provide name, example and description of the representations, that are divided into four categories: sketches, drawings, models and prototypes. The stages of development when each representations is generally used is also included (concept design, design development, embodiment design and detail design), in addition to if the representation is best suited for design information, technical information, or both. [57]

Two of the design representations are *Functional Model* and *Operational Model* which both describe concepts that have reached the design development phase. In a functional model, the key functional features are captured. Regarding the appearance of a functional model, association with the final product is limited. An operational model, on the other hand, expresses how the product is used, which makes it possible to make an ergonomic evaluation of the model. [57]

### 4.5.2 Think Aloud

When participants are completing a task they are asked to verbalise what they are doing in order to reveal their thoughts, this method is called Think-aloud. It is a common evaluative method, which is easy to perform. The participants are asked to articulate what they are feeling, doing or thinking while completing a number of tasks. The method both reveals the process of the task and it helps to identify aspects of a physical or digital product that confuse, delight or frustrate people so that the researchers can change and improve it. [45]

### 4.5.3 Kano Analysis

Kano Analysis is used to determine customer satisfaction of certain product attributes and thus prioritise their importance. It shows what attributes to improve first, or the order in which attributes should be added. Each attribute (a feature, offering or other benefit) is assigned into one of five categories: Required, Desired, Exciter/delighter, Neutral or Anti-feature, (see Figure 4.4). [45]
Figure 4.4: The five attribute categories showing customer satisfaction [45].

Required attributes are quality elements that must be included in the product, examples are attributes related to safety, security, privacy and legislative requirements. Features in this category does not increase customer satisfaction, but if absent, has a negative impact. Desired features on the other hand, have a linear relationship between attributes and customer satisfaction, which means that when an attribute is included, the satisfaction is increased. In the same way, when excluded it will decline. These features are thus recommended to include in the product. Exciter/delighter attributes will improve customer satisfaction if included. These attributes represent latent needs that, unlike Required and Desired attributes, will not be missed if excluded from the product. Neutral attributes are features that customers are indifferent about. Anti-features are attributes that should be excluded from the product, else they will negatively impact customer satisfaction. In some cases, customers will pay extra to have these attributes excluded. [45]

For each attribute to evaluate, two questions are written down: the first asking how the customer would feel if the attribute was present, and the second how he/she would feel if it was absent. The customers answer with one of the following: "satisfied", "neutral" or "dissatisfied". Then a cross reference is made according to Figure 4.5. This will determine the category for each attribute. The category determines if the attribute should be included in the product or not. [45]
4.5.4 System Usability Scale

System Usability Scale (SUS) is a low-cost, reliable usability scale which can be used for global estimation of the usability of a system. It uses a ten-item Likert Scale which gives a thorough view of subjective usability assessments. The respondent indicates agreement and disagreement to the statements on a five-grade Likert Scale. The statements have been carefully selected. The items for the SUS are identified as examples of things that resulted in extreme expressions of the attitude being captured. Positive and negative items are altered in order to prevent response biases which is caused by respondents who do not have to reflect on each statement. A variety of aspects are covered in the selected statements for system usability, examples are need for training, support and complexity. In general the SUS are used after the respondent has used the system which are evaluated but before any discussion or debriefing takes place. The respondent’s immediate response should be registered, instead of thinking too much about each item. If the respondents have problem responding to one of the items, they should mark the middle point of the scale. [46]

For the uneven statements the score contribution is the scale number minus one. For the even statements the contribution instead is 5 minus the scale number. The sum is then multiplied by 2.5, to receive the overall value of System Usability. The SUS have a range from 0 to 100. The items that are used in the SUS are shown below [46]:

1. I think that I would like to use this system frequently
2. I found the system unnecessarily complex
3. I thought the system was easy to use
4. I think that I would need the support of a technical person to be able to use this system
5. I found the various functions in this system were well integrated
6. I thought there was too much inconsistency in this system
7. I would imagine that most people would learn to use this system very quickly
8. I found the system very cumbersome to use
9. I felt very confident using the system
10. I needed to learn a lot of things before I could get going with this system

A SUS score of 68 can be considered above average, and if the value is greater than 80 it can be considered a success and the user would probably tell others about it [58].

4.6 Process and Method Use

The master’s thesis follows the concept development process based on Ulrich and Eppinger [38]. As the thesis initially has a loosely defined objective, it is necessary to specify the project direction, and therefore exploratory research is required. Thus an iterative, investigative process is chosen which corresponds with FFE. The process of the master’s thesis is divided into three phases: Situation Identification, Concept Development and Concept Verification.

4.6.1 Situation Identification

An illustration of the use of methods during the Situation Identification phase can be seen in Figure 4.6.

![Figure 4.6: Process of the Situation Identification.](image)

The first part of the thesis is to identify relevant situations by using first Unstructured Observations, while recording, and by following the principle of Fly on the Wall. The identified situations are filtered using a Checklist in a Structured Observation. Kansei words are generated and clustered using Affinity Diagramming. Additional situations are added after the method Try It Yourself is performed. The remaining situations and the new ones are developed further and filtered in
a second filtering using Kansei Semantic Differential. The situations that are remaining afterwards are evaluated in a user Interview, in a contextual setting, and in a Workshop with a reference group. In the workshop, the situations are illustrated with a picture and described as a more specified scenario on a card. The reference group organises the cards in categories according to Card Sorting. The situations are plotted on a coordinate system with frequency and level of seriousness of the axes. The situation that is most frequent and has the highest level of seriousness is then selected.

4.6.2 Concept Development

The use of methods during the Concept Development phase is illustrated in Figure 4.7.

![Figure 4.7: Process of the Concept Development.](image)

First, a List of Requirements is put together, so that concepts can be compared and evaluated. Ideas are developed in order to come up with a solution to the selected situation. Ideas are generated using the methods Random Input and Brainstorming. The ideas that are developed are evaluated and further explored during a brainstorming session to get more input on ideas. During concept generation the best ideas are combined into concepts. These are documented in a Function Concept Paper and a Pro-Con Analysis is performed on each concept. The concepts are evaluated using the list of requirements, including the same Kansei words that were used in the second filtering from the Situation Identification. The concept with the best improvement, and that fulfils the requirements, is chosen.

4.6.3 Concept Verification

The Concept Verification phase is illustrated in Figure 4.8, where the process of making visualisation models and performing evaluations is clarified.
Three evaluations are performed in order to verify the concept: a pre evaluation with developers from BTP and two evaluations with truck drivers. These are hence referred to as pre, first and second evaluation. The chosen concept is demonstrated with a *Functional Model* which is verified in the pre evaluation. The pre evaluation is performed in order to utilise the developers’ experiences to improve the concept. With the result from the pre evaluation a first evaluation with truck drivers is performed. The evaluations are made using *Think Aloud* during *Observations*, followed by *Semi-structured Interviews*. *SUS*, and *Kano Analysis* are performed to receive quantitative insights. The result from the first evaluation is analysed and an enhanced concept is demonstrated with an *Operational Model*, which is verified in the second evaluation with the same truck drivers. The final concept improvements are made after analysing the insights; the prototype is updated, and an illustration of the concept is produced.
Chapter 5

Situation Identification

The execution and result from the situation identification are presented and discussed in this chapter.

5.1 Execution of Situation Identification

To identify situations, observations were performed in the THME warehouse and production. First Unstructured Observations were performed to form an idea of what happens in this type of environment. All situations were filmed: some using hand cameras, and others using a camera that was left unnoticed by the drivers. A checklist was developed where common movements and incidents were listed as checklist parameters, and while reviewing the films in a Structured Observation, a mark was placed for when the parameters occurred or ought to have occurred in the situation. Using the checklist, the situations were filtered down, and the ones with high potential for improvement remained. Hence, this will be referred to as the Checklist Filtering.

Through performing Try It Yourself (one week of truck education), a deeper understanding for what it is like to drive a truck as well as what the driver needs was realised. Thus, four additional situations were added. All situations were then analysed and developed into more concise situations for an equal weighting in the Kansei Filtering to come.

A large number of Kansei words were generated based on the TMHE core values, truck magazines and from literature. These Kansei words describe feelings and sensations, that can relate to situations. All Kansei words had a positive connotation. Affinity Diagramming was performed to cluster the many Kansei words into categories, so that the most relevant words ended up highest in the hierarchy. The Affinity Diagramming was carried out by the authors together with four other employees at TMHE, and verified during a reference group meeting.

The words in the highest level are categories under which the second highest level words fall. The words in the highest and the second highest levels were ranked and worked as requirements for the Kansei Filtering; the situations were then graded for how well they fulfilled the Kansei words. The Kansei Filtering
was used to select a fewer number of situations which had the highest potential for improvement.

These situations were discussed in a Semi-Structured Interview with two truck drivers. The interview was performed with both truck drivers together so that they could discuss the questions with each other. Questions had been prepared but additional and follow-up questions were asked at the occasion. The interview was Contextual, as it took place in the warehouse break room where the drivers felt at home.

The remaining situations were also evaluated in a workshop with the reference group. Here they were described as scenarios using a representative illustration for each, and accompanying text on a card. The reference group was asked to organise the scenario cards into categories according to Card Sorting. The purpose was to identify similarities between situations so that a future solution could possibly work for more than one situation. The situations were also plotted on a coordinate system with frequency and level of seriousness of the axes.

Analysing the interview and workshop, the three situations that had the highest frequency and level of seriousness relative to the others were selected. These were evaluated using Pro-Con Analysis, and the situation with highest potential was identified.

5.2 Result of Situation Identification

In the following sections, the observation and filtering results as well as the interview and workshop results are described and at last the selected situation is presented.

5.2.1 Observation and Filtering

The observations resulted in 74 individual situations identified from the TMHE warehouse and production. The Checklist Filtering then resulted in the selection of 20 situations that were important to solve due to high potential of improvement regarding productivity and safety. The situations and filtering process are described in Appendix A.

The method Try It Yourself resulted in some new insights for the authors. One of those was that it is serious to hit a storage rack, as if the structure is damaged there is a risk of it falling over, together with all freight stored in it, and creating a warehouse domino effect. The risk of ankle fractures on persons trying to sneak past a truck, thinking the driver notices them, was prevalent. This corresponds with the statistics in 3.1 Automation. Another lesson was the difficulty to place pallets and adjust the truck to the pallet tunnels. A few new situations were identified after the method was completed. An example of a new situation is: "Forgets to tilt forks before putting down pallet in storage racks", the rest (Situation 26-29) can be seen in Appendix A.

The Kansei Filtering (see Appendix B) using clustered Kansei words resulted in ten situations, that are presented in Table 5.1.
5.2 Result of Situation Identification

Table 5.1: The ten situations selected from the Kansei Filtering.

<table>
<thead>
<tr>
<th>Situation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Situation 10</td>
<td>Obscure view when entering intersection in wrong lane</td>
</tr>
<tr>
<td>Situation 15</td>
<td>Changing driving direction to adjust position, while focusing on pallet</td>
</tr>
<tr>
<td>Situation 16</td>
<td>Problem positioning pallet on high height, problem viewing</td>
</tr>
<tr>
<td>Situation 17</td>
<td>Steps in intersection and block intersection</td>
</tr>
<tr>
<td>Situation 18</td>
<td>Truck driver walks over to other truck and hands over a paper</td>
</tr>
<tr>
<td>Situation 19</td>
<td>Truck entering intersection while focusing on paper</td>
</tr>
<tr>
<td>Situation 20</td>
<td>Truck reverse in crowded situations without looking</td>
</tr>
<tr>
<td>Situation 27</td>
<td>Forgets to tilt forks before putting down pallet in storage racks</td>
</tr>
<tr>
<td>Situation 28</td>
<td>Difficulty to estimate weight and centre of gravity of the freight</td>
</tr>
<tr>
<td>Situation 29</td>
<td>Problem positioning truck, hit storage racks</td>
</tr>
</tbody>
</table>

5.2.2 Interview and Workshop

The interview with two TMHE drivers resulted in many different inputs, that were considered in the choice of situation (see Appendix C). When presented with the situations, the drivers noted high seriousness and frequency of ”Changing driving direction to adjust position, while focusing on pallet” (no.15) and ”Truck reverses in crowded situation without looking” (no.20). When changing travelling direction, they pointed out that there is a lot to focus on: the pallet in front, right level of fork tilt and that the forks are in the middle of the pallet tunnel, at the same time as checking that no one appears from behind or from the sides. It is worse if something happens or if someone appears unexpectedly, than driving in an area where you know there are a lot of people. One of the drivers stated that ”Currently if someone is in the way, you honk or signal to them to move”.

Additionally, the drivers do not trust the ”right hand rule” when driving in the warehouse, they use the warehouse dome mirrors to spot trucks but personnel walking are difficult to detect in them. People walking or on kickbike are the most dangerous ones, because they think they are visible when in reality they are difficult to discover. One of the warehouse trucks changes the tilt of the forks automatically, which makes the drivers unsure of the tilting feature in all the other trucks. If pallets over and under each other in a storage rack are not aligned, it is difficult to estimate the location of the pallet tunnels. Pallets adjacent to the one the driver is picking up may be pulled down from the racks if they are placed askew.

In the reference group workshop, the situation ”Trucks going in the same direction, the speed of the last is limited by the first” (no.22) that had been excluded in the Kansei Filtering, was brought back and included in the workshop. The result from placing situations on a coordinate system with frequency and level of seriousness on the axes is presented in Figure 5.1). The three most relevant situations, that are most serious or frequent, are circled in red. These are ”Changing driving direction to adjust position” (no.15, top left in the figure), ”Obscure view when entering intersection in wrong lane, while focusing on pallet” (no.10, middle) and ”Difficulty to estimate weight and centre of gravity of the freight” (no.28, bottom right).
A result from the workshop Card Sort was that the reference group thought they could easily group situations, but they realised that there were many different ways of doing this. As a result "Difficulty to estimate weight and centre of gravity of the freight" (no.28) and "Obscure view when entering intersection in wrong lane" (no.10) were grouped as similar under the category “Lack of information” (see Figure 5.2). "Changing driving direction to adjust position, while focusing on pallet” was placed under ”Unpredictable” (no.15).

Figure 5.1: Coordinate system where the situations are placed according to relative frequency and level of seriousness.
5.2 Result of Situation Identification

The workshop and interview inputs resulted in the choice of three situations (See Figure 5.3). The problem with "Changing driving direction to adjust position, while focusing on pallet" (no.15) is that the driver is more focused on the pallet rather than on the surroundings, which could cause serious injuries if someone or something is behind him. "Obscure view when entering intersection in wrong lane" (no.10) could result in an accident or collision if someone else is arriving from the opposite direction. This is a problem since there is a lack of traffic rules for truck driving within warehouses. "Difficulty to estimate weight and centre of gravity of the freight" (no.28) is problematic since the weight that the truck is able to lift depends on the truck type as well as on the height you are lifting at. Not all pallets are marked with weight and centre of gravity. If lifting pallets or freight which is above the allowed weight the truck could tip over. The same applies to centre of gravity, if it is positioned skewed it might cause imbalance when for example making turns in intersections.
5.2.3 Situation Choice

Using Pro-Con Analysis, the situations were ranked (see Table 5.2). As "Pros", aspects that demonstrated that the situation needed to be addressed are listed. Here, a high degree of seriousness was seen as a reason to choose a situation, as well as if it occurs with high frequency. In addition, if a solution to the situation could help experienced or inexperienced drivers were seen as "Pros", or reasons for choosing the situation. Elements pertaining to the specific situations, such as if a solution could help the fact that people on foot are difficult to spot or the difficulty of focusing in two directions at once, were added to the "Pro" side. A "Con" is the difficulty to find the right level of solution, which refers to the aspect of an All-knowing System that is key in the thesis. Part-solutions that exist were seen as a reason against choosing the situation, as this means the driver is already assisted in some way.

Table 5.2: Pro-Con Analysis of the three situations, resulting in choice of situation 15.

<table>
<thead>
<tr>
<th>Situation 15: Changing driving direction to adjust position, while focusing on pallet.</th>
<th>+</th>
<th>-</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High frequency</td>
<td>Difficult to find right level of solution</td>
</tr>
<tr>
<td></td>
<td>High degree of seriousness</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Difficult to focus in two directions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>People on foot currently difficult to spot</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Helpful for inexperienced drivers</td>
<td></td>
</tr>
<tr>
<td>Situation 10: Obscure view when entering intersection in wrong lane.</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>High frequency</td>
<td>Part-solutions already exist</td>
</tr>
<tr>
<td></td>
<td>People on foot currently difficult to spot</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Helpful for inexperienced drivers</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Helpful for inexperienced drivers</td>
<td></td>
</tr>
<tr>
<td>Situation 28: Difficulty to estimate weight and centre of gravity of the freight</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>High degree of seriousness</td>
<td>Low frequency</td>
</tr>
<tr>
<td></td>
<td>Helpful for inexperienced drivers</td>
<td></td>
</tr>
</tbody>
</table>

The Pro-Con Analysis resulted in the choice of Situation 15 "Changing driving direction to adjust position, while focusing on pallet" (see Figure 5.4). The situation was deemed as a serious and frequent situation, due to the result from the workshop and interview, and selected after the result of the Pro-Con Analysis.

Figure 5.4: The situation "Changing driving direction to adjust position, while focusing on pallet" (no.15) was selected.
5.3 Discussion of Situation Identification

In the Checklist Filtering the parameters in the checklist were not ranked, which may have affected the result. The reason was that each situation had different components that were important, such as safety, positioning, aligning and inefficiency. These were not equally relevant in other situations, therefore a ranking was deemed to bias the result. Additionally, the identified checklist parameters were developed when the authors had no experience of driving trucks. Thus, some situations did not translate as well through the checklist parameters. To compensate for the possibly skewed result from the Checklist Filtering, ten interesting situation were added, based on the experience gained from Try It Yourself. Conclusively, 20 relevant situations were selected.

In the Kansei Filtering, the relative rating of highest level Kansei words was made so the TMHE core values Safety and Productivity had the highest impact on the result together with Communication which was deemed relevant for the thesis. A different rating would have resulted in other situations being selected from the Kansei Filtering. An estimation was made by the authors to which level each situation correspond to the Kansei words. This estimation is not entirely certain, and likely varies depending on who performs the rating.

The result from the Card Sort was that depending on how a group name was perceived, many different situations could be grouped with each other. In the Card Sort the two situations ”Difficulty to estimate weight and centre of gravity of the freight” (no.28) and ”Changing driving direction to adjust position, while focusing on pallet” (no.15) are not very similar but both assist the driver with necessary information, which was the grouping criteria. A solution for one does not necessarily include a solution for the other.

The situations which the drivers reflected on as most serious and frequent, ”Changing driving direction to adjust position, while focusing on pallet” (no.15) and ”Reverse without looking in crowded situation” (no.20), are similar to the Reference group’s opinion. However the reference group also considered ”Difficulty to estimate weight and centre of gravity of the freight” (no.28) as highly serious, whereas the drivers did not see this as a problem.

The Pro-Con Analysis resulted in a single situation to continue with. It is not guaranteed that the chosen situation is the most appropriate. For example Situation 10 ”Obscure view when entering intersection in wrong lane” got the highest combination of frequency and seriousness from the reference group and the drivers deemed this as a risky situation that makes them slow down before an intersection. However it was deemed as less important than the chosen situation due to the result of the Pro-Con Analysis as well as of the Kansei Filtering, where it was the 6th most relevant situation.

Worth to note is that the selected situation did not have the highest rating in the Kansei Filtering. Here Situation 29 ”Problem positioning truck, hit storage racks” was ranked with highest potential of improvement (thus the lowest score). However, the reference groups’ opinion was that this situation is not that serious relative to the other situations and on the medium frequency, causing it to be eliminated after the workshop. The secondly ranked situation was number 27
"Forgets to tilt forks before putting down pallet in storage racks" which, similarly to situation 29, the reference group ranked as low to medium seriousness and medium frequency. Situation 20 "Truck reverses in crowded situation without looking" was ranked as third highest potential for improvement. Interestingly, it was pointed out in the interview with drivers that if driving in a crowded area you are more aware of your surroundings. Therefore, the risk of forgetting to look before changing direction is lower than in a similar situation where you think you are alone. The reference group ranked this situation relatively high on frequency and seriousness. The chosen situation, which was ranked as fifth highest potential for improvement (see Table B.3 in Appendix B), is similar to Situation 20 but ranked more serious and frequent by the reference group which corresponds to the drivers’ opinions. Likely it received a lower potential improvement score than Situation 20 as the authors rated the risk of injury higher in a situation where people are close to the truck.
Chapter 6

Concept Development

The execution, result and discussion of the concept development phase is presented below.

6.1 Execution of Concept Development

A List of Requirements was put together based on the sections 1.2 Purpose and 1.3 Objective, as well as the requirements mentioned in chapter 2 Prerequisites.

To come up with a solution to the selected situation, several ideas were generated using Brainstorming. Additionally, the method Random Input was utilised to help the writers develop ideas that were unconventional and innovative.

A Competitor Analysis was performed to get a better understanding of which competitors TMHE have, and what their strengths are. The focus was on competitors' features that were related to the selected situation. Images from similar products and systems were selected to work as inspiration for the idea generation.

When sketching solutions, the selected situation was investigated further and divided into two parts. The first was that the driver has positioned the truck crookedly to the pallet so that there is a need to adjust the position of the truck. In order to do this, the driver has to change travelling direction. The second part was to eliminate the risk for the driver to end up in the situation were the truck is positioned wrongly, by solving the problem in an earlier stage. Ideas were developed focusing on these parts one at a time. The ideas were sorted according to which sense they represented: visual (where light and display solutions were kept separate), auditory, haptic and tactile. This was done in order to achieve a more structured presentation of the concepts and to facilitate the concept development process.

A brainstorming session was performed with a group of personnel from TMHE. Six people participated in the session, from different departments at TMHE: Driver environment, Industrial design and Computer simulation engineering. A Brain Sketching activity was performed with the participants to obtain their ideas without influencing them. Finally, the ideas that the authors had produced earlier
were described, discussed and brainstormed to gain more input and to evaluate them.

During concept development, focus for the *Add-on* design lay on the reach truck Reflex E-series, to simplify the ideation process. This truck type was chosen as focus because the E-series is the most complex of the Reflex series that the *Add-on* design should work on, as well as being easily available for driver evaluation tests later in the process.

In order to visualise all possible scenarios that could occur in the selected situation, a Storyboard was made. The Storyboard was also a document that helped the writers to develop solutions for the situation.

After discussing the solutions, during a reference group meeting, the solutions regarding correcting the positioning were seen as preferable to the ones preventing the situation from occurring. As the driver assist will be implemented in a semi-autonomous environment, where there will always be a risk that the pallet itself is crookedly placed (due to the human factor). Thus, there will always be a need for a solution that corrects the problem.

Concepts were established of the remaining ideas and documented in a Function Concept Paper (FCP). In that document, each concept was evaluated according to the list of requirements, and a Pro-con Analysis was performed on each concept, see Appendix E. The concepts that best fulfilled the requirements were identified. The authors analysed which part of the concept that was the reason for getting a higher score. These parts were gathered into a 14:th concept, which thereby fulfilled the requirements even better than the previous concepts.

### 6.2 Result of Concept Development

A list of requirements was developed, and divided into Necessary, Desirable and Kansei requirements (see Table 6.1). Necessary and Desired requirements were compiled from the TMHE prerequisites. "Implementable in new trucks and Impart knowledge to the driver" where seen as necessary requirements, due to their close connection with the thesis’ purpose and objective. "Implementable in existing trucks”, whereas also a part of the thesis’ objective, was not possible to determine due to the fact that the concepts were not that developed in this phase. To avoid excluding potentially successful ideas, this was put as a desirable requirement. The same reasoning was applied for ”Harmonised solution”. To warn about trucks and personnel on foot were seen as necessary for the concept to be selected. The two were separated, as a solution may fulfil one but not the other, and both were necessary. Similarly, prevent incidents with trucks and personnel were separated into separate requirements. It was seen as less important to prevent injuries than to warn of them, as a prevention in itself demands some type of autonomous control taken from the driver, which is limiting in the development phase.

The Kansei requirements contain looser design aspects and are emotionally based. The Kansei words in the requirement list were the same as in the situation filtering, with the same relative values (see Table B.1 and B.2 in Appendix B). In the requirement list, the values were normed to facilitate comparison.
The inspiration gathered from competitors, together with solutions used in other fields, were implemented into an competitor analysis with images. It focuses on competitors’ solutions to situations similar to the selected situation (mainly parking assistance for personal vehicles), and can be seen in Appendix D.

### 6.2.1 Ideation

The problem was divided into two separate parts with different types of solutions: one to prevent the situation from happening and another to solve the situation retrospectively. The idea generation, where Random Input was performed, resulted in several ideas including tactile and haptic feedback as well as feedback in the form of directional sounds (see Figure 6.1).

Examples of ideas are laser projections, light signals, air gusts, vibrations in the chair or steering wheel, a tilting chair, as well as warning zones. Other solutions that were generated included display solutions of symbols, cameras and floor maps, such as showing positions of other personnel, trucks and relevant information regarding the order locations to the driver. The retrospective part mentioned...
earlier was chosen as most relevant to solve and these ideas were developed further.

![Figure 6.1: Ideas of visual, tactile and auditory feedback generated using Random Input.](image)

Further ideation was performed using the method Storyboard. The chosen situation "Changing driving direction to adjust position, while focusing on pallet" (no.15) was divided into separate scenarios in the form of a couple of storyboards (see Figure 6.2). The scenarios distinguish between occasions which involve humans, trucks and freights. The driver is protected when inside the truck, thus it is more serious to hit a person on foot than in a truck. They also differ for if the object is in movement or stationary. The resulting storyboard scenarios are the basis for concept generation. One of the scenarios is that, while the driver adjusts the truck position, a person approaches.
The result from the concept generation was several concepts (see Figure 6.3) solving the different scenarios described in the storyboards. Several of the developed concepts included the travelling direction switch that is contained in all Reach trucks (see Section 2.1.1) as the main component to activate the All-knowing System. The system knows where all objects are in the warehouse, through continuous scanning of the area around the truck. When the driver is positioned by the racking shelves and uses the switch, the system notifies the driver if anyone or anything is close by. In one of the concepts a display flashes in yellow or red colour to notify the driver of how serious the situation is, consequently how close the object is. In one of the other concepts, the All-knowing System takes over the steering of the truck and notifies this by changing the engine sound and showing a symbol on a display together with the text "Automatic driving".

Concept selection (see Appendix E) resulted in choosing Concept 14 (see Figure 6.4), which was developed from the best features among the previous concepts.
6.2.2 Selected Concept

A system continually scans the truck’s surroundings. When the driver is positioned crookedly towards the pallet, and uses the switch to alter direction, the system informs the driver of what is around the truck. The concept is divided into two zones, in which the driver receives different assistance and feedback.

If something is semi-close in zone 1 (the left side of Figure 6.4), the driver receives a warning. This warning consists of sound from behind the driver’s neck, from the side that the object is located on. This makes the driver turn his/her head in the correct direction. The sound is different for different types of objects (trucks, people walking or pallets), since it is more serious to hit a person and less serious with material damages. The display also gives information by showing a symbol of the object (possibly in relation to the truck’s position).

If something is very close in zone 2 (the right side of Figure 6.4), the system takes control of the truck. It stops until it is safe to drive and then positions the truck autonomously. To signal autonomous driving, the ”engine sound” changes. Simultaneously, the display makes a short blink and shows ”Autonomous Driving”. Additionally, a symbol of the planned positioning route is shown on the display. When changing to autonomous drive, the display also produces a sound to call the driver’s attention towards it. When the object is out of the way and the positioning is done, the system returns the control to the driver. The display blinks, makes a sound, and shows ”Self Driving” shortly before switching back to its normal screen. The ”engine sound” is also changed back to the normal sound.
Figure 6.4: Selected concept: When the driver uses the travelling direction switch, feedback is given if a danger is near. If it is semi-close in zone 1 (left side of sketch) a warning is given. If the danger is close in zone 2 (right side) the truck stops and positions itself.

### 6.3 Discussion of Concept Development

The retrospective approach (to solve the situation that the truck is positioned askew relative to the pallet) was chosen since there will always be a risk that the pallets are positioned incorrectly caused by the human factor, when the pallets are positioned manually. With only autonomous trucks this risk might be eliminated, but the current concept is for the transitional period. It would have been interesting to further develop the solutions for the preventive part of the situation, however this was not possible due to the time factor. A different result may have incurred if this had been investigated further.

However, "Changing driving direction to adjust position, while focusing on pallet" is the most important part of the situation since it corresponds closer with the chosen situation from the Situation Identification. In addition, the solutions that were identified for preventing the situation have a lower LOA (see Section 3.1) than the ones for the first part. Preventive solutions such as painted lines or laser projections that guide the driver towards the pallet might be suitable, but require a low or no level of automation. The LOA is key for the master thesis since it should include an All-knowing System.
In order to make sure that all possible scenarios are solved with the developed solution, the situation was divided into six separate scenarios in the storyboards. Another reason is that incidents involving humans walking are worse than manned or unmanned truck incidents, and may require different feedback. It was also a way to separate scenarios where personnel or a truck is working next to the truck that is about to change travelling direction. The latter scenarios are not a high risk for the driver and therefore the solutions for these kinds of scenarios should differ from the more serious ones.

Certain ideas were not developed further in response to guidance in the theoretical framework (see Section 3.2.3). The assisting device will probably be used several times daily, hence a device with tactile or haptic feedback is not a good solution. One of the ideas was to have feedback in the steering wheel knob, but it was rejected since it may cause harm to the drivers’ fingers. A reason not to investigate these solutions further is that it will require deeper knowledge about haptic and tactile feedback. In addition, several evaluations are required to make sure that there is no risk of injuries. Because of lack of time in this thesis, no further development of the ideas was possible. Further investigation had however been interesting, and could be performed in future studies.

Another idea was that the drivers’ chair could tilt or vibrate to notify that something or someone is close and thereby make the driver observe the object that is in the risk zone. According to HMI, this might cause permanent injuries to the driver, for example the drivers’ back or neck could be affected badly (see Section 3.2.3). Because of that no further development of these ideas were made. Other ideas that were rejected included feedback in the form of light. The reason was that according to HMI (see Section 3.2.3), it is preferable to use sound instead of light because it is not dependent on where the person receiving the feedback looks. Additionally, a simple light signal does not convey enough feedback for the driver, it is not obvious what it signals since it is too complicated to translate into relevant information for the driver. According to Norman (see Section 3.2.2), it is crucial that the information given to the user is useful and understandable. A display is preferable to light signals, as its contents are more flexible, and as other solutions also can be implemented to avoid a light for each peace of information that needs to be conveyed.
Chapter 7

Concept Verification

The execution and result from the concept verification process is presented and discussed in this chapter.

7.1 Execution of Concept Verification

The selected concept was developed further and a first lo-fi prototype (a functional model) was constructed in order to verify and improve the concept. A pre evaluation was performed with developers from BTP’s Driver Environment, in order to receive input on different concept ideas. This was followed by two evaluations with truck drivers, that will be referred to as the first and second evaluation. Between the two driver evaluations, the concept was enhanced in response to the received feedback.

During all evaluations, the evaluator was positioned in a reach truck to make the experience more genuine. All evaluations were performed in the same location, in a demonstration facility at TMHE. It was not possible to perform them in the production facility, but to recreate a similar experience a production sound was played in the room. To make the evaluation environment more reliable the authors measured the level of noise (which was 69,6 dB when equalised based on a time interval) in the production facility and matched the sound levels in the demonstration facility with that.

The functional model consisted of two small speakers and a 7” touch display (with similar size and technical performance as one that is currently under development at TMHE). This tablet was then placed on top of the current log-in screen in the truck’s right hand module. The speakers were placed to the right and left of the driver’s head in a reach truck. Since the concept consists of different sounds for each object, research for suitable sounds was performed. Four different types of sounds were included in the concept: warning of person, warning of truck, warning of pallet or other immobile object, and a notification sound from the display for when the autonomous driving starts and stops. The sounds that were included in the concept verification were chosen through a research of sounds in Internet-based sound libraries. Heuristic evaluation, i.e. searching for a satisfy-
ing alternative, was performed when choosing appropriate sounds for the concept. The authors chose three different sounds for each of the four types to be evaluated in the pre evaluation. Symbols for the display, to match the number of sounds, were also designed. The Competitor Analysis (see Appendix D) in combination with the theoretical framework was used as a basis when designing the symbols. Similarly to the sound choices, three alternatives for each symbol were designed for the pre evaluation.

In preparation of the pre evaluation, a plan was conducted with instructions for the observation. The plan consisted of tasks and questions for the evaluators, estimations of time for each part, and an observation protocol to be filled out by the authors. The purpose of the pre evaluation was to decrease the number of alternatives (sounds and symbols) to verify with the truck drivers. This was necessary since evaluation time with drivers was limited as it is expensive to hire personnel from the production. Both BTP developers have a truck driving license and drive trucks on occasion, although neither drives reach trucks often. Both of them are familiar with the current layout and construction of the Reach trucks' driver environment. The pre evaluation session was carried out in two parts: one which focused on the sound and another that focused on the display and symbols. In the sound part, the developers were placed in the truck and asked to explain what they are experiencing according to Think Aloud methodology. The symbols were evaluated according to the same method. After the pre evaluation, one symbol and sound for each function was selected out of the three.

The resulting sound and symbol design was then presented in the first evaluation with the truck drivers. The aim of the evaluation was to identify how the drivers felt about the different functions and also to identify areas of improvement. The execution was similar to the pre evaluation, but included three short surveys: a general one for personal information, a Kano questionnaire and a SUS. The first evaluation was carried out with six drivers, two drivers at a time. One driver was asked to sit in the truck where a sound and symbol simultaneously and unexpectedly appeared. When the first driver had completed a "truck session" a survey was filled out, while the second driver sat in the truck. Three truck sessions were carried out, where the drivers took turn, and where the sounds and symbols appeared at different intervals. Thus, it was possible to observe if the drivers thought that the sounds were irritating or the symbols unintuitive when subjected for a longer time period. The truck was stationary during the first evaluation and the drivers were asked to express their thoughts according to the Think Aloud method. It was observed if the drivers reacted to the directional sounds (looking left or right), and if they reacted with surprise or annoyance. The symbols for person, truck, pallet and for autonomous control were tested together with the sounds, to see if they were considered intuitive, complex or confusing. During the truck sessions the drivers were also asked questions to explain their thoughts further. The observations were followed by a semi-structured interview, where the two drivers could discuss how they perceived the feedback. Analysis of the first evaluation was performed and potential for improvement and changes were identified. The results and identified improvements were discussed during a reference group meeting. An improved prototype - an operational model - was designed and constructed.
The operational model was then presented in the second evaluation. The execution plan for the second evaluation consisted of a couple of tasks for the drivers. The tasks were constructed so that the driver would naturally end up in the intended situation that the concept is developed for. The entire second evaluation was conducted individually with five of the drivers from the first evaluation. Each driver was encouraged to drive the truck while expressing his thoughts out loud. When the driver ended up in the intended situation he received the auditory and visual feedback simultaneously. For the auto feature the driver was given instructions that he should imagine being a beginner at driving trucks, and therefore would like the truck to position itself autonomously. No specific observation protocol was conducted, instead the observers simply wrote down all observations of interest. The driver then filled out a SUS and another survey. The questions in the other survey were considering the relevance and need of using text in addition to the symbols. The responses were marked onto a Likert scale. A short discussion with each driver was carried out individually, conducted according to a semi-structured interview. Analysis of the last iteration was then performed and a reference group meeting was held, where the result was presented. Input from the reference group meeting together with the analysed material from the evaluation then resulted in a final design of the concept.

### 7.2 Result of Concept Verification

The result of the Concept Verification is divided into functional model, pre evaluation, first evaluation, operational model, second evaluation and final concept design.

#### 7.2.1 Functional Model

The functional model of the concept was constructed of two small speakers which were positioned on each side of the headrest (see Figure 7.1). These were hooked onto the roof of the truck using wire. The three alternative sound concepts can be seen in Table 7.1.

Table 7.1: Sound alternatives divided into three sound concepts (A, B and C) used in the pre evaluation.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Person</td>
<td>Person walking</td>
<td>Crowd talking</td>
<td>3 fast clicks</td>
</tr>
<tr>
<td>Truck</td>
<td>Start lorry engine</td>
<td>Wrom</td>
<td>2 clicks</td>
</tr>
<tr>
<td>Pallet</td>
<td>Wooden stick</td>
<td>Cracked wood</td>
<td>1 slow click</td>
</tr>
<tr>
<td>Display Alert</td>
<td>-</td>
<td>Pop</td>
<td>Gong</td>
</tr>
<tr>
<td>Engine Sound</td>
<td>Engine sound</td>
<td>-</td>
<td>Engine sound</td>
</tr>
</tbody>
</table>
Two of the sound concepts consisted of representative sounds for the objects that they are warning of. For example, to symbolise a pallet in sound concept A, the sound is of a wooden stick dropped on the floor. The last sound concept consisted of three clicking sounds: three faster clicks to symbolise a person, two medium-fast clicks for a truck and one click to symbolise pallet or other immobile objects. The reason for different sounds and varying frequency is that injuring a person is considered more serious than hitting a pallet. Sound concept A and B were designed to see if either a display alert or engine sound was sufficient.

Figure 7.1: The Auditory Functional Model used in the pre and first evaluation.

The display, with the visual part of the concept - symbols for person, trucks, pallets and autonomous drive - was positioned on top of the small, existing display on the right hand module during the first evaluation (see Figure 7.2).
In the pre evaluation three alternatives of symbol design with varying levels of detail were presented and discussed with the developers. These designs depicted the same symbols (person, truck and pallet) using different colours: showing only the contours, using grey and black colour, and lastly using only black colour. The three alternatives for the truck symbol can be seen in Figure 7.3. The three alternatives for the person and pallet symbols can be seen in Appendix F.

Figure 7.3: Example of the three alternative designs for the symbol.
In the pre evaluation three alternatives of symbol colour for the autonomous driving and self driving were also presented, with same same colour schemes as seen in Figure 7.3. An example of the two symbols in black can be seen in Figure 7.4; the three colour alternatives can be seen in Appendix F.

Figure 7.4: Example of the black design of the autonomous driving and self driving symbols.

The resulting alternative, chosen after the pre evaluation, was the one consisting of grey and black colours. It was also the one that was used in the first evaluation, with some modifications to the symbols. The warning symbols can be seen in Figure 7.5.

Figure 7.5: The symbols for person, truck and pallet used in the first evaluation.

The autonomous control and driver control symbols that were used in the first evaluation to indicate that the All-knowing System had taken control of the driving can be seen in Figure 7.6. The picture to the left (see Figure 7.6) is displayed when the system has taken control of the driving: It shows the route that the truck will take when positioning it self correctly towards the pallet in orange. The right symbol shows that control of the driving has returned to the truck driver, hence that the All-knowing System is no longer in control.
7.2.2 Pre Evaluation

The evaluators preferred the symbols that consisted of grey and black design, since the alternative with contours consisted of too many details, and the all black alternative did not have enough details. In the black alternative, they believed that it was difficult to see what the pallet symbol depicted. Information of a future display under early development by BTP, and its possible layout, was also received in the pre evaluation. In the future display a grey overlay will appear when a warning message is presented to the driver and there will be a number of touch-buttons. Regarding the text used when the driving control has returned to the driver, the evaluators pointed out that it was not appropriate to use ”self drive” since it could be interpreted as an expression for autonomous drive, consequently it will be confusing for the driver. It would also be more logical to turn the pallet 90 degrees since that is the usual orientation of how you see a pallet when you collect it.

Regarding the directional sounds from behind the head, the evaluators preferred the click sound (Sound concept C) instead of any of the representative sounds. They thought that the representative sounds would disappear in the surrounding noise. They mentioned that the sound of ”people talking” might be confused with actual people talking close to the truck whom are not in the risk zone. At first they were reluctant to use the engine sound to symbolise autonomous driving, but when it was explained that it was the current engine sound that would be changed (similar to the segway example in Section 3.2.3), they became more positive. Regarding the display alert sound they thought it was an appropriate sound to use for drawing the driver’s attention towards the display.

7.2.3 First Evaluation

To evaluate the selected concept from the pre evaluation, a first evaluation with drivers were carried out. The insights that resulted are summarised here. Most drivers (4 of 6) found it difficult to hear the directional click sounds. All of them wanted the sounds to be louder or more distinct to be heard over the production noise. They were also reluctant to have different sounds for different objects (per-
son, truck and pallet). Most of them thought it would be better with one sound for all objects, as it is confusing with different sounds. The truck drivers discussed whether pallet symbol was needed or not, and what it means. Several drivers said that they did not perceive the symbols as a warning, but rather as information. In order to clarify that it is a warning, they suggested that the symbol could be placed inside of a warning triangle (most preferred this) or have a warning text next to it.

Regarding the location of the display, there were divided opinions, some preferred the position used in the evaluation while others would like to move it to the vertical or horizontal e-bar (see Figure 2.7 in Section 2.1.1). Most (4 of 6) said they would prefer it on the horizontal e-bar. They were also dubious to how the public reception of an autonomous driving feature will be. The drivers would prefer if it was possible to choose to turn on and off the feature. Some of the drivers pointed out that they believed they could position the truck faster towards the pallet than an autonomous system could, and therefore they wanted to do the positioning themselves. In addition, inexperienced drivers would probably like to use this feature before you positioned the truck wrongly. The resulting observation notes and driver comments from the first evaluation can be seen in Appendix G.

In the SUS survey carried out in the first evaluation, all drivers gave individual scores, that evaluated how well the concept worked. Results from the SUS-evaluation can be seen in Figure 7.7. The average SUS score was 81.67.

![Figure 7.7: The resulting SUS from the first evaluation is presented here.](image)
The drivers were asked to rate the overall helpfulness of the concept, the result of which can be seen in Figure 7.8.

![Figure 7.8: The result from what the drivers thought of the concept in its entirety.](image)

In the Kano Analysis, questions were asked of which features were wanted and unwanted. The drivers’ answers can be seen in Figure 7.9. The darker green, the more desirable was the feature. Yellow means the drivers were neutral to the feature, orange that they did not want it. Grey is used for invalid answers.

![Figure 7.9: The result from the Kano Analysis is presented here.](image)

Results from the reference group meeting were that one of them mentioned that in general BTP are trying to avoid to use texts when they design the symbols and icons for display interfaces. The reason is to avoid problem with writing manuals in several languages. If text is necessary it is better if the text is written in English.
7.2.4 Operational Model

The feedback from the first evaluation with truck drivers resulted in a concept redesign and the construction of an operational model. This operational model consists of speakers mounted in the headrest, as can be seen in Figure 7.10, which are connected to a bluetooth device. The speakers are not visible for the user when the operational model is mounted in a reach truck, as can be seen in the right picture in Figure 7.10. This allows the authors to play warning signals through the speakers from a distance, without cords, thus making the truck drivable.

![Figure 7.10: The Auditory Operational Model used in the second evaluation.](image)

The display is also controlled using bluetooth, so that the symbols appear simultaneously as the sound signals. Using a bluetooth-enabled keyboard, a PowerPoint presentation with a display interface is clicked forward, showing a symbol for a certain time. The display is mounted in the truck on the horizontal e-bar, as a result of the first evaluation suggestions (see Figure 7.11).

The interface of the display was developed further and the resulting home screen can be seen in Figure 7.12. More icons were added to evaluate if the drivers notice the relevant symbols. The home screen interface has an information bar at the top, that displays items that the driver needs. These items include a clock, symbols of the functions that are currently active and how much battery there is left. Examples of active functions that are shown here are if the truck is controlled by the system or the driver, using small AUTO or Driver Control symbols. A column on the left side of the display contains pressable buttons (where the focus of the thesis is on the AUTO-button). In the main area of the interface is a large reach truck icon, showing the travelling direction with an arrow.
Figure 7.11: The Visual Operational Model used in the second evaluation. The display is mounted on the horizontal e-bar.

Figure 7.12: The home screen interface of the display.
The theories of gestalt and colour (Section 3.2.2) were applied in the design of the interface. All buttons have the same shape and size and are positioned close to each other in accordance with the laws of similarity and proximity. Colours are adapted to achieve a high usability: the interface as a whole uses a limited amount of colours, with a maximum of four colours being displayed at once, and is largely monochromatic thus enabling use for colour-blind drivers.

A result from the pre evaluation was that a grey overlay may be used to enhance the warning symbols that appear on the screen. This semi-transparent overlay will cover the main part of the screen for the duration of the warning symbol’s appearance (five seconds). An example is shown in Figure 7.13.

A result from the pre and first evaluations was that the warning symbols ought to be divided into warning symbols and stop symbols. Additionally, a result from the first evaluation was that the drivers prefer to start autonomous control themselves. In the operation model, warning symbols are displayed when an object is semi-close in zone 1 and stop symbols are displayed when the truck stops, as it does when an object is very close in zone 2 (see Figure 7.14). The zones are shaped to include the areas of which the driver has limited visibility. The most dangerous area is straight behind the driver’s back, as there is a ”wall structure” of the truck here.
7.2 Result of Concept Verification

Figure 7.14: Zone 1: Warning, as an object is semi-close. Zone 2: The truck stops and a stop symbol is shown, as an object is very close.

In the first evaluation, the drivers were not notified of why the truck stopped and the autonomous control began (as an object was very close in zone 2). This caused some confusion, and as a result these functions have been separated. Autonomous control has been divided into Automatic Safety Stop and Autonomous Positioning. Stop symbols, that show the type of object that caused the truck to stop can be seen in Figure 7.15, together with the corresponding symbols that warn of an object in zone 1.

Figure 7.15: Warning symbols have an orange triangle and stop symbols have a red stop sign, together with the symbol of the object that caused the symbol’s appearance.

Warning triangles and stop signs are easily recognisable in a stressful situation. The colour red is used for the stop symbols as, according to Osvalder and Ulfvengren [25], it means stop and danger. Yellow is commonly used for warnings and to signify "slow". Here, orange is chosen for the warning signs as it is a mix of red and yellow, and easier than yellow to spot against a white background (see Figure 7.15). The warning and stop symbols all appear on the grey overlay (see Figure 7.13) in their respective situations. If a driver does not heed a warning and the danger moves into zone 2, the system will take control and stop the truck.
In the operational model, the sounds are still heard simultaneously as the warnings or stop symbols appear. Additionally, they are still directional, thus heard from the right or left of the headrest depending on where in the zone the object is. As a result from the first evaluation, where the drivers commented on that they will stop the truck no matter what type of warning is heard and that it is easier if it is always the same, the sounds are now changed. The same sound is heard for person, truck and pallet. The sound does not differentiate between warnings and stops. The headrest sound is now more synthetic, adapted from a piano key, so that it cannot be confused with other sounds in the production and warehouse (Figure 7.16a). The sound from the display is also changed to correspond with the headrest sound. It is also adapted from the synthetic piano key (Figure 7.16b). As a result of the previous evaluations, there is a display sound when Autonomous Positioning begins and another when driver control is regained; there will not be a modified engine sound in between.

![Figure 7.16: Sound waves of the adapted sounds used in the operational model.](image)

As a result from the evaluations of the functional model, the autonomous function is changed in the operational model: the Automatic Safety Stop is separate from the Autonomous Positioning, which is started as the driver clicks a button. The entire flow of the interface from this click, until control is regained by the driver, can be seen in Appendix I. The Autonomous Positioning is now a choice, as it is initiated by the driver. However, it can also be started in different position, for example before the driver has attempted and failed to align the truck to the pallet tunnels. Drivers can use the AUTO-button to make the truck position itself towards the pallet in narrow or busy isles. This is particularly useful for beginners, temporary personnel and tired or frustrated drivers.

The symbols used to give the driver feedback of the Autonomous Positioning are shown in Figure 7.17. Top left is a symbol that appears as the touch button AUTO is being pressed. It only appears for 2 seconds. The bottom left symbol is shown when the driver regains control of the truck. Both these symbols are accompanied by the display sound, to draw the driver's attention towards the display. The six images with blue arrows are the different symbols that appear to show the driver which path the truck will take during the Autonomous Positioning. The symbol most similar to the real situation is displayed. The blue colour of the arrows that show the projected path was chosen as blue means calm, according to Osvalder and Ulfvengren [25], and the driver can relax when this function is active.
7.2 Result of Concept Verification

Figure 7.17: Symbols for Autonomous Positioning (top left), driver control (bottom left) and the different projected paths that the truck may take.

7.2.5 Second Evaluation

To evaluate the improved concept the truck is drivable during the second evaluation, which is an opportunity to better illustrate how the concept will work in reality. Many insights resulted from the second evaluation; these are summarised in this section.

The majority (4/5) of the drivers pointed out that the new sound from the headrest was much better and more distinct than the last. Now they believe that the sound is distinguished enough compared to the surrounding noise. The majority also stated that the sound would not be irritating in the long term since it is a softer sound. Two of the drivers mentioned that the sound for a person could be a different one, but most of them thought that it would be confusing to implement additional sounds. None of the drivers had difficulty hearing from which direction (left/right) the sounds came from. As the sound is so close to the ear, you can listen to radio and still hear the sounds, one driver commented. Several of the drivers approved of the speakers placement. One driver commented on a benefit: since the speakers are mounted in the headrest, the distance between the driver and the speaker is independent of the driver’s height. The radio speakers are mounted in the frame of the truck, thus the sound is different for short and tall drivers. One of the drivers would like the sound volume to be adjustable depending on the environment or the driver; however three of the others thought it could be a risk that some personnel turn it off or that it is better if the sound “just works” without them having to change any settings. An idea that came up was to have a couple of predefined volume levels which the drivers can choose from to avoid that. For people with bad hearing it will be beneficial if the sounds can be made louder for them. One of the driver mentioned that a problem with the warning signals is still the truck drivers that are using their own in ear headphones which many do although it is forbidden. A solution according to the same driver could be for the drivers to plug in their headphones in the truck’s AUX and then have their music played in the headrest, and then overridden when the warnings sound.
Almost all (4/5) of the drivers think they will try Autonomous Positioning, and most (3/5) said they will use it on occasion (when tired or annoyed with their own driving). The majority of the drivers thought that the Autonomous Positioning would mainly be used by new reach truck drivers. Since aligning the forks correctly to the pallet tunnels is one of the most difficult procedures when driving a reach truck, the Auto-function will be very efficient time-wise for inexperienced drivers and stand-in personnel. It might also teach beginners how the best path looks like from different positions.

Regarding the AUTO-button most of the drivers identified it quite fast. They had thought mixed views regarding if the button looked pressable. The symbol during Autonomous Positioning (that shows the path the truck will take) was clear to all drivers. However, one driver commented that he would prefer if the arrow was animated or bigger. Regarding the sound from the display all of the drivers thought the volume was too low, but the sound was not annoying and was different from the normal production noises. One driver commented that one type of sound could be used to signal start (a fade in) and another to signal that Autonomous Positioning stops (a fade out).

Regarding how to “cancel” the Autonomous Positioning, most (3/5) of the drivers thought that it would be easier to just press the brake pedal than using the return-button on the display. Most of them understood that the existing button could be used to cancel, thus returning to driver control, and did not find this button annoying. However, the symbol should appear sooner, when the big AUTO-symbol is shown. Several of the drivers pointed out that one of the reasons why it should be possible to terminate the Autonomous Positioning is if something does not work, that the system fails (a safety feature). During Autonomous Positioning, the drivers had mixed views as to whether you want to accelerate by yourself or not (one wanted to accelerate manually, two did not). Furthermore, some mentioned that they want to have their foot on the safety pedal (the pedal only exists in trucks) or else the truck should not move.

Regarding to use text in addition to symbols several of the drivers believed that it would be beneficial, the first times you see the symbol, but none of them had problem understanding what they were symbolising (person, pallet, truck). For the Auto-button they believed it was necessary with a text to distinguish it from the driver control symbol.

The drivers did not perceive the top section of the display interface as an information bar. Therefore they confused this bar with the buttons placed in the section to the left of the display. Two of the drivers mentioned that the grey overlay on the display when the symbols appeared was beneficial, as they focused their attention on the warning. One driver mentioned that the symbols with a warning triangle and stop sign were too similar to each other (and would therefore prefer traffic signs instead), while others thought they were different enough or that they might only look at the display when the truck stops. With the design of the symbols today none thought they would be mistaken for other warning or stop signs. Five seconds is long enough to see the symbols. One driver commented that perhaps it is not necessary to have warnings for still objects such as pallets, as these are not as important as people and trucks. It is important not to implement
too many features, one driver comments, as drivers tend to put tape over annoying light signals or cut cords of annoying safety features.

The sounds accompanying warning and stop symbols are currently the same, and 2/5 of the drivers felt the sounds should be different for the two. Some thought that it was good with consistent sounds (the same for warning and stop), and 1/5 that the truck stopping is enough of a difference. One driver questioned if it was necessary at all with a sound when the truck stops.

One driver mentioned that a risk with the system is that people will rely on it in other situations as well and therefore in general might pay less attention since they will be used to the new safety system. According to the same driver several accidents occur as a result of drivers pay less attention to the surrounding and focus more on their technical products (cell phones etc).

All resulting observation notes and driver comments from the second evaluation can be seen in Appendix H.

Results from the SUS-evaluation carried out in the second evaluation can be seen in Figure 7.18. The average SUS score was 85.5.

![Figure 7.18: The result SUS from the second evaluation is presented here.](image)

After the second evaluation the results were analysed and a reference group meeting held. The result from this meeting was that they approved of the concept in general, however one of them questioned the use of orange instead of yellow for the warning triangles. Whether or not pallet warnings and stop symbols should be included was discussed, and it was concluded that the All-knowing System must be good enough that unnecessary warnings regarding pallets are not given, so these symbols should remain.
7.2.6 Final Concept Design

The final concept design is very similar to the Operational Model described in Section 7.2.4 but with some minor changes.

The volume in the auditory part of the concept consists of a preset interval. It is only possible to make the sound level louder than the one presented in Operational Model. This will be beneficial for drivers with impaired hearing.

When the warning sounds appear, the radio volume is lowered or muted so that the driver will notice the sounds. For the next generation trucks, the radio will be integrated into the headrest. Since the auditory part of the feedback solution is limited to seats with a headrest, customers have to order this seat to be able to use the solution. This is not an issue for the Innovation design, as many features are marketed this way. The possibility to order the Add-on solution is also limited to this seat, and the customer has to change the entire backrest part of the seat in their current truck.

Warnings for still objects such as pallets remain in the concept, even though this was something the drivers were critical about. After discussion with the reference group it is assumed that the technology is good enough to warn only when there is a risk of collision. Consequently, the system would not warn all the time, such as when someone has placed a pallet pile on the floor, as the drivers were concerned.

Regarding the two zones, the size of them will depend on the speed and direction of the object. The All-knowing System calculates the danger level for each object and only delivers a feedback if there is a risk of collision. The warning or stop symbols disappear after 5 seconds. If the danger is removed before this, the symbol still remains to notify the driver of why a warning sound was made. If the driver does not react when receiving a warning, by either braking or stopping, the truck stops autonomously when the object moves into zone 2.

The display interface is also slightly changed in the final concept design. The colour of the information bar is changed from white to teal (see Figure 7.19). This is made due to input from the second evaluation, when drivers did not perceive this as a information bar with necessary information such as time and battery level.

In the final design, it is also possible to exit the Autonomous Positioning by pressing the brake pedal, which was something the drivers requested in the second evaluation. However, the return button on the display will remain although it is shown immediately after the driver presses the AUTO-button, when the big AUTO-symbol is shown. The design of the return button is changed to the driver control symbol, as a result of the confusion of what the return button did. The display interface can be seen in Figure 7.19.
7.2 Result of Concept Verification

The *Innovation* design of the display interface will appear as shown in Figure 7.19. The current, small display will be substituted for a 7” display, thus the new features of this concept will be a part of this. The display interface for the *Add-on* design will only consist of the features related to this concept. Consequently no other buttons than the AUTO-button are to be found in the display, unless BTP chooses to implement these other functions as well. Other features may be possible to include, but for the *Add-on* design, these are not necessary as the small, current display exists.

The final concept design is compared to the list of requirements presented in the Section 6.2 and a new score is received (see Appendix J) which is significantly

Figure 7.19: a) Home screen. b) The AUTO-button is clicked. c) The truck goes into Auto-mode, the driver can click on the driver control button to cancel. d) The projected path is shown until the truck is positioned. e) Driver regains control.
higher than for the situation without any feedback solution.

Illustrations for the final concept design can be seen in Appendix K. Two illustrations were made: one for the warning and stop system, and one for the Autonomous Positioning.

7.3 Discussion of Concept Verification

The discussion is divided into Warning and Stop Symbols, Sounds, Autonomous Positioning and Concept Compatibility.

7.3.1 Warning and Stop Symbols

Improvement of symbols has occurred in three iterations. The feedback from the pre evaluation resulted in a decision to use the grey and black symbols since they were more clear than the others, with enough level of detail without being too detailed. However, increased use of colour for example through a different monochromatic scale or background colour of the interface could have been investigated, if there had been more time.

The developers stated that it would be beneficial to use the symbols within a warning sign and a stop sign. The truck drivers also pointed that out in the first evaluation, since they perceived the symbols as information rather than warnings. However, the reference group pointed out that it could be confusing and that the symbols could be mistaken for existing symbols and signs in the truck if using stop and warning signs. The warning symbol is used when a technical problem occurs with the truck, as described in Section 2.1.1. This contradictory feedback resulted in the current symbols that combine the warning and stop symbols with the icons of what the warning was caused by. Different combinations and designs were made, but this was selected as the most promising. All the same, further design could be made and evaluated with the drivers, to ensure optimal intuitiveness of the feedback. The stop symbol is currently used when the truck has stopped due to critical error: it could be that the driver's foot is not on the safety pedal. Thus, the use of the stop symbol is connected to the same type of occurrence (the truck stops) and the icon explains why the truck stopped. The benefits of being consistent with the use of symbols can be compared to the need to give feedback of why the truck has stopped, as it will do this because of different reasons.

The addition of warning and stop symbols to the objects (person, truck, pallet) was made as a clarification that it was serious and not just information being displayed. The truck drivers understood and preferred the improved symbols but the reference group questioned why orange colour was used instead of yellow. Orange was selected since it is clearer: the yellow colour was too indistinct in relation to the white background. Orange is also common for representing warnings.

The reference group mentioned that it is important to use standardised symbols. Even though no design standard exist for the truck industry, similar auto features exist and are becoming more common and standardised for the car and lorry industries. Since it is common in those industries, it might be appropriate to use the same symbols, design and sounds for trucks. However, it is important to
take into consideration that the systems are used in different environments. The
truck is driven inside a warehouse with a lot of noise and shorter distances than a
car or lorry, which has an enclosed driver environment with windows that isolate
the driver from the surroundings.

Disagreements regarding warnings for still objects such as pallets exists. In
the Kano Analysis, one driver considered warning for pallet an anti-feature. It
might not be necessary to warn for still objects since as a driver you are already
aware of these objects, as they are not movable without involving a truck. Persons
and trucks are movable and could appear unexpectedly, and are therefore highly
relevant to include in the feedback solution. As a comparison, in reversing sensors
for cars still objects are included, which is a motive for including it in this concept
too. Further comments about the pallet symbol is that it could mean several
things, as freight or racking shelves. It is therefore relevant to consider if more
symbols should be included in the concept. However, it is a risk to implement
too many symbols since it might be confusing and irritating for the driver. As
one of the truck driver mentioned "if some feature in the truck is irritating some
drivers start ignoring it or even covers it with tape". Another motive for removing
the pallet symbol is that some drivers believe it is less serious to hit something
material than a human. However, from the warehouse manager’s point of view it
is very important to minimise freight damages, for economical reasons.

7.3.2 Sounds
In the pre evaluation the sounds were representing different objects. Two of the
alternatives were representative sounds, which the developers did not like. Re-
garding the directional sounds, they preferred the click sound since they thought
it would be easier to notice when driving in the production. The truck drivers on
the other hand believed that the sound was to indistinct to be noticed in the pro-
duction. They also pointed out that it was not necessary to have different sounds
for different objects. One of them stated "you do not want to hit anything" as the
reason to only have one warning signal. They also believed it might be confusing
since you might mistake one signal for another. For the second evaluation the
sound was changed and only one signal was used no matter what object, which
the drivers appreciated. This indicates that the improvement was good. It was
discussed if the radio should be muted or lowered when the warning sounds appear:
one of the drivers thought it is better if it is just lowered since it might increase
the drivers’ acceptance of the system.

In the pre and first evaluations the engine sound was changed during the Au-
tonomous Positioning. This sound was removed after the participants’ comments
and since in the Kano Analysis, the sound was considered an anti-feature for one
driver, and three drivers were neutral to it. This also corresponds to what the
theory recommend since too much feedback can be irritating according to Sec-
tion 3.2.3. The display alert sound was also changed from the first to the second
evaluation, to correspond with the improved directional headrest sound. It was,
however, made less intrusive as its purpose is to notify that an action is carried
out rather than to warn. The feedback of the improved sound was good, however
more sounds could always be investigated. One driver wanted the display sound to come from the headrest. This would however defeat the purpose of signalling of danger behind the driver from the headrest, as this is a directional warning signal unrelated to the display sound, which is used to notify the driver that information is shown on the display.

7.3.3 Autonomous Positioning

In the first evaluation, all symbols were grey and black except for the arrow in the "autonomous control" symbol, which was orange. Here orange was used to indicate movement, however the reference group commented that the "driver control" symbol also ought to have orange in it if this was the reason. In the second evaluation, colours were altered in accordance with colour theory (Section 3.2.2). After the first evaluation, the reference group mentioned that it is important to minimise the use of text, so in the operational model all text was removed, except for "AUTO". It could be discussed if "AUTO" is text or if it has reached the status of symbolism due to its common usage. In the second evaluation "AUTO" worked, but further alternatives could be designed and examined.

Regarding how the Autonomous Positioning would work, improvements have been made according to the drivers' opinions: instead of the system immediately taking control of the driving, the driver has to request an Autonomous Positioning. The reason for the change is because the drivers believe they could do the positioning faster themselves, which is probably strongly connected to professional pride; they want to do difficult tasks by themselves. However, since it is a matter of safety, the truck still stops automatically to avoid collision in zone 2.

One driver would prefer a physical button over a display button, since you cannot feel the button on a display, you have to look. However, when using the Autonomous Positioning the driver is encouraged to view the display. For a smooth positioning, the driver presses the button before he gets wrong. It might be better with a physical button as he mentioned, however, further evaluation have to be performed to investigate this. A benefit with the display is that functions are more easily updated and changeable.

7.3.4 Concept Compatibility

It is possible to chose between two chairs for the existing reach trucks and one of them is not compatible with the headrest that the speakers are mounted in. Thus, it will not be possible to implement the feedback solution into all existing reach trucks. However, the chair that is not compatible is the cheaper one for budget trucks. The customers that uses a budget truck would probably not invest in this solution, hence they are probably aware that a budget truck do not include all additional features. In the Add-on design, as well as the Innovation design, this is not an issue, as for new purchases a notice could be made to the buyer that the solution requires a certain chair. Similarly, the e-bar is optional in a few reach trucks, so if the feedback solution is desired the e-bar is necessary to include.

To implement the concept on reach trucks with cold store cabin, small or no
alterations might be necessary. Since the cabin is isolated, the volume of the
sounds could possibly be lowered. No modifications is necessary for the display.

Regarding the LOA it varies between the three parts of the concept. For zone
1 (outer one) the driver is simply informed by the system to be aware of persons,
trucks or still objects that are near the truck. Hence, the driver still has the control
of the vehicle. This corresponds to level 4 “one alternative is suggested” in Section
3.1.1 or “Manual control” from Figure 3.1. While if the object moves into or is in
zone 2 (inner one) the system takes control and brakes, thereby the human is no
longer in control. This corresponds to level 7 “execution is made automatically,
then if necessary the human is informed” as in this case the human is informed of
what object that is near, or “Fully automatic control” from Figure 3.1. Regarding
the Autonomous Positioning, the system is in control. However, since the driver
can abort the procedure whenever he wants to, this corresponds to level 5 “if the
human approves it, the computer executes the suggestion”. If comparing to the
the picture in Section 3.1.1 this is “Supervisory control”.

The placement of the speakers makes the concept suitable for both tall and
short truck drivers. Although if the driver has his or her head turned or leaned
forward it can be difficult to hear if the sound is coming from left or right.

Between the first and second evaluation the SUS increased from 81.67 to 85.5.
This implies that the improvements that were made correspond to what the drivers
want. However, the first score was also high if it is compared to the SUS method-
ology (Section 4.5.4) where all scores above 80 are considered good. The reason
for receiving a high score in the first evaluation could be because some drivers were
too generous. In the last evaluation it was only five drivers, one of them could
not participate in the last one, which also could have affected the result. It would
have been interesting to see if he also liked the improvements.

That the truck did not stop automatically in the evaluations, when the stop
symbol and sound appeared, may have affected the feedback and result of the
evaluation. It might not be necessary to implement a different sound to inform
the driver that the truck has stopped, which some drivers requested, since the
stop itself is a form of feedback. It was difficult to establish a realistic evaluation
of this part of the concept verification since the system does not exist and since
there were no simple way for the authors to make the truck brake from outside
the vehicle.

7.3.5 Effects of Concept Adoption

It is important to consider that the driver might become unstimulated if too many
tasks are replaced with automation, hence LOA (Section 3.1.1) is important. In
the resulting Automatic Positioning, the driver still has the main control of the
truck, but supervisory control during the actual positioning process. Regarding
the warning and stop solution, if the driver reacts to the warnings no automation
is necessary, as the stop is simply a last resort to avoid collision, or if the danger
is imminent. The risk with the safety feature is if the driver gets too dependent
and becomes confused or careless when driving in other trucks where the system
is not implemented.
An additional risk is that the drivers' alertness will be reduced when more autonomous features are implemented, as stated in Section 3.1.2. In the resulting concept, the driver maintains the driving function unless he or she desires assistance (Autonomous Positioning) or is in danger of colliding with a person, truck or immobile object (Automatic Safety Stop). As increased automation extends the reaction time, the Automatic Safety Stop is, once implemented, necessary to retain. According to Section 3.1.2, the interface needs to help the drivers make strategic decisions and allow them to override the automation when necessary. For these reasons, providing a warning allows the driver to maintain control while also increasing safety and productivity. To enhance the drivers' acceptance of the Automatic Positioning, it is driver activated and can be exited using either brake pedal or driver control-button.

Implementing the resulting feedback concept could have several benefits, since the safety in the warehouse is increased on behalf of the Automatic Safety Stop. This will result in less injuries, which is beneficial since truck accidents are currently common according to Prevent in Section 3.1. It will also result in higher productivity since less goods will be damaged which provides economical benefits for TMHE or the customer that utilises the feedback solution.
Chapter 8

Method Discussion

The methods used in the thesis are discussed in this chapter.

8.1 Prerequisites Discussion

There were plenty of wishes from the beginning. The thesis was seen as an opportunity to receive new input regarding how productivity and safety could be improved, what feedback the drivers could need, and how to implement this. More demarcations could have been made in order to focus on one aspect instead of several. A way could have been if the thesis had started with a set situation, more time could have been focused on developing concept ideas, evaluating with drivers, and in the end have reached a higher level of finished Add-on design. As the situation identification using Kansei was a prerequisite, several weeks were put into the study and selection of a situation. Here a different approach, such as having a pre-set situation, or selecting the situation in a less complex manner, could have been beneficial. Additionally, the process utilised at BTP has had an affect on the thesis. Although suited for larger projects, the number of meetings has been time consuming for the thesis. However, using BTP’s process have been an experience and a way to establish the thesis’ result into the company.

8.2 Product Development Process Discussion

In order to make sure that the product development corresponds to the users’ needs and requirements, it is important to involve them early in the development process. When involving users in an early stage, the possibility to make changes increases since requirements and specifics are not fully decided yet. However, when evaluating an innovation it can be difficult for the users to imagine how it will work in the future. In the thesis, plenty of feedback was received by the users, which is important since they are the ones that will use the product when it has been produced.
When involving potential users for evaluation of the prototype, other answers are given than if performed with developers. Developers know how the product is supposed to be used, whereas the users have more experiences and can relate to situations in their daily activity when the product might be useful. When explaining about a future feature that does not exist, such as the All-knowing System, the developers had an easier time understanding. The drivers however had more knowledge of the current situation and need. Therefore it was beneficial to perform evaluations with both developers and drivers.

It can be noted that Kansei Engineering is a complex and thoroughgoing method, with many sub-methods that are best used cohesively. Kansei Engineering usually uses statistics as a main part of its analysis and verification methods, something that was not possible in the thesis due to a limited time frame. The main idea of Kansei Engineering is to translate Kansei into product parameters, using statistics, which was not possible to do in the thesis. When used, this method would likely serve its purpose better when used throughout. As used in this thesis, with only minor sub-methods implemented, it does not fully fulfil its function.

8.3 Exploratory Methods Discussion

Observation is a thorough but time consuming method. It provides information that sometimes can be difficult to interpret. The observers had no experience of trucks and the warehouse environment before the observation was performed, which was both beneficial and disadvantageous. It resulted in new inputs for BTP, and new identified situations but it also resulted in data and situations which were not relevant or that were mistaken since the observers had no insight in what was happening. When observing complex products as trucks it could be relevant with some basic knowledge before observations are performed, since otherwise a lot of actions could be misjudged due to lack of knowledge. However, the observers learnt a lot while completing the observations and during the truck education when Try It Yourself was performed.

Try It Yourself is useful to understand the situation in which the product will be used. Other methods can be used to the same purpose, but without trying yourself, the real problem may be eluded. It increases the developer’s knowledge and understanding for the user’s needs.

The first days were spent filming in the production and warehouse. All these films were reviewed, and situations were documented and filtered down to a fewer number after checklist parameters. This, in hindsight, was perhaps more complex than needed. Using a more structured observation might have resulted in less material, and situations which are more comparable, although it is difficult to know what to look for without any experience or insight of the actions.

In the checklist, parameters may be ranked in different manners, such as after importance. In the thesis they were not ranked relative to each other. Additionally, parameters that did occur versus ought to have occurred were seen as equally relevant. A different approach might have affected which situations were seen as most relevant.
During filming, some situations were filmed using hand cameras, where the drivers knew the researchers were there which might have influenced their behaviour. Others were filmed by placing a camera and leaving it (indirect fly-on-the-wall observation). In the filtering process, situations identified from hand cameras and cameras left behind were not separated, which could have been interesting to know. Regarding to film observations one of the benefits is that it is possible to go back to the films later. However, it can be very time consuming to go back and forth in the films.

During the Concept Verification, situation-specific observations and semi-structured interviews were performed. Those observations produced a more to-the-point result than the ones performed early in the thesis, as the knowledge of the area had increased. Additionally, more planning was performed before performing the methods which was beneficial.

A benefit with using semi-structured interviews is that they are very flexible, and can be directed into a direction that suits the interviewee. Since it is difficult to know from the beginning how the interviewee will respond to the questions asked. However, when performing an unstructured interview it is of great importance to know what answers you are searching for, so that the interview take a direction which correspond to the aim. To complement the interview surveys can be useful, since it is possible for the users to be anonymous. However, it is preferable if the users completes the survey before any interview with them is performed, in order not to affect their result, which was the case in the evaluations in this thesis.

8.4 Ideation & Concept Development Methods Discussion

During ideation, methods like Brainstorming, Random Input and Storyboards were used. These methods worked relatively well, however the methods, and the Concept Development phase in general, would have benefited from a longer time frame. A longer development process was originally intended, but it was shortened due to an extended FFE in the Situation Identification phase.

The benefit of the brainstorming session was to receive input from other developers regarding possible solutions. A negative aspect was that it was relatively time consuming and that the authors had already thought of many ideas that were thought up during the session.

Storyboards were successfully used to illustrate and communicate how the product is used in its context. It was a way for the authors to see the situation from the drivers’ point of view. The benefit with using storyboards was structuring the problem area; it was a way to receive an overview of variations in the situation. This was necessary in order to avoid forgetting any important parts of the situation.
8.5 Concept Selection Methods Discussion

Pro-Con Analysis is a suitable method when choosing between a few different concepts since the result is visual and clear. The method was suitable for choosing which situation to focus on in the Situation Identification since there were only three options left after the workshop and interview was performed. When choosing between the 13 concepts that were included in the FCP, the Pro-Con Analysis worked more as an argumentation for other employees at BTP, whereas the decision was mainly based on the requirement list. Although after comparison was made with the requirements, several concepts fulfilled the requirements equally, therefore the Pro-Con Analysis worked as a way to see why the concept received a high score. These aspects could then be transferred to a final concept which consisted of all these beneficial aspects.

Heuristic Decision Rules are useful when less important decisions are made, or in situations when the requirements are not that specific. Consequently the method was well suited for choosing sounds, since none of the authors have experience of auditory feedback solutions. However, other methods that can be useful in this situation is to involve others in the decision, or conducting a survey. This was achieved since the developers at BTP, that were performing the pre evaluation, was part of the decision to pick a suitable sound, since three Sound Concepts were presented to them.

8.6 Verification Methods Discussion

To evaluate a concept with two participants simultaneously could have several benefits since they have someone to discuss with and important factors and issues can be brought up. However, if one of them is too determined in his opinion it might lead to no discussion and instead just one of the participants are sharing his thoughts. On the other hand when conducting discussions or interviews individually, a risk is that the participant is not comfortable sharing his opinion, and therefore acts more ingratiatingly, hence tries to respond correctly.

Benefits with using a lo-fi prototype for evaluation is that the users’ are often more comfortable sharing their thoughts of something that does not feel completely finished. It is easier to question and criticise aspects that they do not like. Therefore a lot of feedback was received in the two evaluations. In the second evaluation a more developed prototype was used, an operational model, and the changes that were made were approved by the drivers. However, still plenty of feedback was received but regarding more details compared to the first evaluation.

During the evaluations, the method Think Aloud was performed to make the participants express their thoughts in words. This resulted in further understanding of what the drivers thought about the feedback solution, however this large amount of data is also a downside as it is time consuming to analyse.

Kano Analysis was used to reveal information of relevant and less relevant features and functions with a product, hence what to develop further and what aspects are less important. Consequently the method was suitable to use in this
thesis, as aspects which the drivers disliked was excluded from the concept, such as the engine sound.

To complement the observations and interviews in the evaluations a SUS survey was conducted. The survey was used in both the first and second evaluations, thus the first SUS result could be used as reference to the second result. It was a clear way to see that the concept has been improved, and that the drivers preferred the improved concept.
Chapter 9

Conclusions

The conclusions that the thesis resulted in are described in this section.

The thesis covers a large research spectrum, consisting of autonomous vehicles, user-friendly products and human machine interaction. Consequently the thesis has merely scratched the surface of the fields. Automation is an area which is very current since more and more vehicle suppliers are implementing safety features in their products. Consequently, automation features are becoming a standard in the car industry, which increases the relevance of implementing it in the truck industry as well. With increased automation comes the need to achieve well thought out interaction for the user. This opens up for further study and development, it is the beginning of new and exciting areas for BTP to continue working with.

The thesis has identified different ways of assisting the truck driver. In the situation when the driver changes travelling direction to adjust his position to the racking shelves, or after collecting a pallet, a safety system provides feedback regarding if anyone is near so that accidents are avoided. Additionally, a display feature allows the driver to engage an Autonomous Positioning of the truck to the racking shelves. Both safety and productivity is thus enhanced. A conceptual interface allows communication between the driver and the truck: sounds are heard and symbols are shown on the display to warn of danger, and the driver can control truck functions through this same display. Since the conceptual interface has been evaluated and improved in iterative evaluations with several drivers and other participants, the feedback received in the concept can be deemed intuitive.

The concept’s Add-on design can be implemented on trucks currently in production, and the Innovation design can be integrated in a next generation market offering. The concept’s auditory part is identical in both the Add-on and the Innovation design. The display interface (the visual part of the concept) may be different for the Add-on and Innovation design since it might be difficult to implement all features that will be included in future Reach truck into existing ones.
9.1 Conclusions of the Formulated Questions

Below are the questions described together with the conclusions formed of each of them.

Q1 In which situation is a driver assist appropriate to implement?

The result and discussion from the filtering, workshop and interview shows the situation that it is most appropriate to implement a driver assist on: when the truck driver has problem adjusting the truck relative to the pallet. As a consequence of being positioned crookedly, there is a need for the driver to quickly change travelling direction in order to adjust the truck. Since this situation requires the driver to focus in both the fork and the drive wheel directions, there is a need of a driver assist for the situation to be safe while maintaining high productivity.

Q2 What type of information should be communicated to the driver?

The concept development and verification show that for the selected situation the truck driver needs information of objects that are in potential danger of being hit by the truck. If the object is semi-close it is enough with warning so that the driver becomes aware and can take action. However, if the object is very close the truck needs to stop to maintain safety, and the driver then needs information of why the truck has stopped. In addition, the driver needs information of when the Autonomous Positioning is activated and deactivated. Additionally the route that the truck will take needs to be presented to the driver.

Q3 In what manner is it suitable that the system and driver interact?

It is suitable for the system to notify the driver by a directional auditory signal in order to encourage the driver to turn his head towards the object that is in risk of collision. In addition, interaction occurs when a symbol appears on the display, which warns that there is an object close to the truck. If the driver does not react to the feedback and the distance between the truck and the object in risk decreases, the system simply takes control of the truck and stops it. The truck will remain stopped until the object is no longer in the risk zone, then the driver can continue driving. To activate the Autonomous Positioning the driver presses a touch button on the display. The Autonomous Positioning will deactivate itself automatically when the positioning is finished but the driver can cancel it by using a touch button on the display or by using the brake pedal.

Q4 To what extent should the driver be able to choose if a system is in control or not?

The driver cannot choose to deactivate the system, but the system does not always interfere. The Automatic Safety Stop is only in control when the risk of collision is too imminent for the driver to be able to react. If the driver reacts to the warning signals that appear before the risk is too large, the safety
system does not take control and brake. In addition, the driver can decide whether he wants a system to position the truck autonomously. The driver can choose to deactivate the Autonomous Positioning whenever he wants to. It is important that the driver maintains some controlling function, lest he becomes under-stimulated. In regards to the Autonomous Positioning, the driver has supervisory control, and if he reacts to the warning signals he maintains manual control. In the case of imminent danger however, the Automatic Safety Stop has to take full automatic control and stop the truck.

Q5 How should the concept be designed to suit both an existing and a future truck type, respectively?

An Add-on design is developed for the existing trucks and an Innovation design for the future truck types. The speakers for the auditory feedback are mounted in the headrest both for the future trucks and the existing, hence the design is the same for both. For implementing the system into an existing truck the backrest, which includes the headrest, has to be replaced with one in which the speakers are mounted, thus the chairs have to be compatible. For existing reach truck models that will be produced henceforth, having the feedback solution involves fitting the truck with the associated seat and horizontal e-bar. Regarding the visual feedback the features in the display may differ for the future and existing trucks. For the future trucks the symbols will be implemented in the display that is currently under development by BTP, thus other features will also be included in the display. For the existing trucks the display will be retrofitted, and only include the symbols and buttons for this feature, hence the existing displays will remain for other features and information.

Conclusively, the concept enhances the safety as neither personnel nor trucks are in risk of collision. The productivity is increased as pallets with freight are not damaged and because the Autonomous Positioning enables the driver to align effortlessly to the pallets.
Chapter 10

Future Studies

Input received in the second evaluation concerning larger changes or features that require further evaluations are recommended for future studies. In addition, aspects that the thesis authors have identified and recommend for further studies are included in this chapter.

Considerable feedback was received in the evaluations. However, several of these aspects were not supported enough to improve, since they were strongly connected to the fact that the actual system does not exist. Examples of these aspects are whether to implement an additional sound for when the truck has stopped, make the positioning arrow animated or bigger, make the buttons look more pressable or to use physical buttons instead. The same goes for detail about the Autonomous Positioning, where the entire procedure needs to be evaluated when the All-knowing System exists or with technical equipment which enables someone to manoeuvre the truck from outside of the truck. Then it will be possible to decide details regarding whether the driver should accelerate or not during the positioning. The same reasoning applies to the safety pedal, and if braking to exit is a working function. All of these are small details that need to be further investigated and evaluated in their proper context in a later phase of the development. This is something to keep in mind when developing the concept further but there are more important aspects and parts to focus on before.

First of all a system to achieve control of the truck needs to be developed, then more evaluations can be performed, preferably in the production. This will help determine details like selecting a proper volume level for the display and speakers, and how the drivers react to autonomous positioning and abrupt safety stops. For further academical investigations, it might be relevant to investigate more in detail how the semi-autonomous trucks will affect the driver. Is it even possible to let the driver take responsibility for a few tasks or is it more safe to either have fully autonomous or manually driven trucks. Will the driver get used to the truck handling all difficult tasks and only performing easier ones manually? Will this result in less motivated and incapacitated drivers who cannot even perform the simplest tasks in the end?

To harmonise the solutions, further investigations of how to implement the
system to other truck types are needed. Although not a part of the thesis, for TMHE to be able to market the new system to customers, both the Add-on and Innovation designs need to be implementable on all varieties of trucks (not just reach trucks) that the customer may purchase or already have. This is mainly due to the issue of safety: if a driver gets used to the safety system and then uses a different truck, incidents may ensue. The solution developed in the thesis is implementable for most trucks where the driver sits, with some adjustments. However, a future area of study for THME is how to implement the safety system on smaller trucks where the driver stands or walks beside the truck.

In the first phase of the thesis, situations in the production and warehouse were investigated. The most urgent situation was identified and the solution was developed to solve it. However, further studies could be performed to see if the solution is implementable on more situations. It would likely be suitable in other situations when the driver changes travelling direction, such as after collecting or placing a pallet. A part of the developed solution is warning the driver when another truck is in the risk zone. This truck also needs some sort of feedback, so an area of study could be if or how to notify the driver of the second truck. Regarding the zones, further studies have to be performed to decide how large it is appropriate that each zone is. However, the zones should be dependent on what type of object it is and what speed and direction the object has. Further calculations and tests have to be performed by BTP to decide this.

Studies of the economical aspects remain to be performed. It is necessary to research whether the Innovation design is considered desirable and reasonably priced by the customers, as evaluations have only been performed with the drivers. Additionally, studies regarding if the Add-on design is sufficiently affordable to be purchased by future customers are necessary.

Automation and human machine interaction are both massive areas and plenty of studies could be performed here. Paired with the task of providing feedback solutions implementable on TMHE:s entire product offering, existing as well as future, requires structure and dedication. By dividing the areas into different research questions, progress could be performed to lead to new and important knowledge for the company. In future studies, the authors recommend more defined study areas. Future research could be done in designing a safety system: study the existing product offering, identify similarities and design a cohesive solution that works for all trucks. The automation aspect also offers opportunities: here further research of LOA could advantageously be performed, to learn more of what tasks are suitable to have automated and which are not. Another area is the All-knowing System, whose design provides limitations and opportunities alike. Further research of what the system needs to do could be performed, and after developing it see what it is capable of. The area of perception and cognitive ergonomics is of interest to the authors, and hope is that the developed solution has inspired to future studies in these areas at TMHE.
Bibliography


[48] Marc Stickdorn and Jacob Schneider. *This is service design thinking*. John Wiley and Sons, 2011.


Appendix A

Checklist Filtering

A checklist was developed where observed incidents or movements were listed as checklist parameters. While reviewing the observation films, a mark was placed when a checklist parameter occurred in the situation, but also where a parameter ought to have occurred (see Table A.1). The reason for this is that it is equally serious not to fulfil a parameter in certain situations, as it is to fulfil them in others. An example is that the drivers ought to look in the warehouse mirror before entering an intersection with obscure view, which is as serious as a driver leaning out of his truck in another situation and risk getting hit. As all parameters are not relevant for all situations, a blank space was left for when the checklist parameter was irrelevant for the current situation. The number of marks were then summarised.
Table A.1: Checklist Filtering, where blue marks high-scoring situations, green marks interesting situations, “x” marks parameters that occurred, and “o” parameters that ought to have occurred.

The ten most high-scoring situations were selected (marked with blue in Table A.1). Additionally, ten situations that caught the researchers’ interest were selected (marked with green in Table A.1). They were deemed relevant despite not getting “top scores” in regards to the checklist parameters. The reason was that they had different components such as positioning, aligning and inefficiency, which did not translate as well through the checklist parameters. A total of 20 situations were selected from the filtering, these situations are described in full in Table A.2 and Table A.3.
Table A.2: Description of situations selected in Checklist Filtering (part 1/2).

<table>
<thead>
<tr>
<th>Situation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q6</td>
<td>A truck driver has put down his pallet and then goes back to the pickup place. Enter the x-intersection and makes U-turn, a kickbike is driving towards the x-intersection at the same time, the kickbike slows down and turns left directly after the truck makes a U-turn. Mooting pedestrian when the truck returns to get more freight and oncoming truck and freight/EU-pallet is blocking the passageway which makes it narrow. (Electric counterbalanced truck, kickbike, pedestrian)</td>
</tr>
<tr>
<td>Q6</td>
<td>Truck entering the intersection with paper/information sheet in the drivers left hand, driver might focus too much on the paper and less on the surroundings which makes him less observant (Reach truck)</td>
</tr>
<tr>
<td>T7</td>
<td>Crowded storage area and passageway, one EU-pallet with freight sticking out in the middle of the passageway. Two personnel who moves around and slow freight. One truck passes by the narrow passageway and at the same time another truck reverse. Risk of collision/accident. (Powered stacker)</td>
</tr>
<tr>
<td>AC2</td>
<td>A powered stacker is backing up into an aisle, past an order picking truck. The second truck is aware of the first’s movements and is waiting to back out from the storage racks where he is picking up a pallet. However a third truck (a reach truck) is approaching from behind the second truck’s back. The second truck hastily goes forward again while lifting the forks to side into the pallet tunnels. Timing is of essence in this situation.</td>
</tr>
<tr>
<td>AR8</td>
<td>Three trucks are approaching, all going in the same direction. They are all reversing, with pallets and freight on the forks. The speed of the last truck is lowered due to preceding trucks. (All powered stackers)</td>
</tr>
<tr>
<td>AC9</td>
<td>A CB truck is waiting for the door to open. A powered stacker approaches and stops to wait behind him to the left (ie in opposing lane) as the destination of this truck is the storage racks to the left of the door. As the door opens, another powered stacker enters from outside which causes the first powered stacker to back up to let him pass. Meanwhile a driver of a third powered stacker is parked by the stationary computer (behind the first powered stacker) and the driver is (assumedly) receiving order information. He then walks across the passageway behind the first powered stacker, and is almost hit as the driver of this truck reverses away from the second truck. Following this incident the drivers of the CB and the third stacker shuffle to each other. The driver on foot emerges from the storage racks on the other side of the passageway and talks to the driver of the first stacker.</td>
</tr>
<tr>
<td>AJ10</td>
<td>In an aisle a driver has but down two pallets, he wants to transport both of them. He picks up the first one and positions it on top of the other a bit fast/sloppy, so it doesn’t go on straight. He then picks up the one on the bottom and the top one is adjusted by driving forward with speed and pushing it into the correct position.</td>
</tr>
<tr>
<td>AM10</td>
<td>A truck driver (reach truck reflex) reversing down an aisle, making a 90 degree turn, picking up a pallet and reversing off while lower the forks.</td>
</tr>
<tr>
<td>AN10</td>
<td>A truck driver drives around a corner (that is to his back). The aisle that he enters is however busy as two other truck are there. When he sees them he stops and waits, then drives out again. One of the trucks already in the aisle positions his pallets and exists past the first truck. The first driver stretches his neck/turms his back to see into the aisle, as he drives into it again. Then slowly goes past the other truck that was still in the aisle. (Reflex reach trucks)</td>
</tr>
<tr>
<td>AP10</td>
<td>Two truck drivers meet at a x-intersection. By pointing with his finger one of them shows which way he is going, enabling them both to drive past each other simultaneously. (Reflex reach truck and static power stacker)</td>
</tr>
</tbody>
</table>
Table A.3: Description of situations selected in Checklist Filtering (part 2/2).

<table>
<thead>
<tr>
<th>Description of situations</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>AQ</td>
<td>Plats 10, film GP010293, Time 03:05-03:38. Similar: AO.</td>
</tr>
<tr>
<td></td>
<td>A reach truck driver is reversing down an aisle and making a 90 degree turn while looking at something in his hand (phone or order list perhaps? To see how many pallets to pick up?) He then stops the truck in the intersection and fiddles with the radio (top left in the truck) while also looking in his hand. He then drives forward to pick up the pallets, has to reverse as he drives in a bit askew, angle his neck to see the floor in front of the truck, then picks them up, reverses back and stops. While he is stopped a power stacker goes past him - the driver of this truck nods to the first driver as he passes.</td>
</tr>
<tr>
<td>AV</td>
<td>Plats 10, film S1100003, Time 00:00-00:30</td>
</tr>
<tr>
<td></td>
<td>A truck driver (reach truck) places pallets and then reverses into busy/narrow x-intersection. Here there are two other trucks (reach truck and tow truck with train behind) as well as an operator walking. The first driver stops his truck and waits. The walking operator hands a paper to the first driver, then walks back to his truck. The second reach truck goes across, a bit hesitantly as to not hit the one walking. Behind him the walking operator follows in his reach truck (while fiddling with radio) and passes the first truck. Then the tow truck train goes across the intersection.</td>
</tr>
<tr>
<td>AX</td>
<td>Plats øvrigt, film S110029</td>
</tr>
<tr>
<td></td>
<td>Places pallet in storage racks. Reverses. Very narrow when reversing, little room for maneuvering. (Reach truck)</td>
</tr>
<tr>
<td>BC</td>
<td>Plats 9, film S1090018, Time 00:00-00:38</td>
</tr>
<tr>
<td></td>
<td>Queue in narrow driving passage, a parked truck at the right, a EU-pallet to the right, and a trolley to the right, which the two trucks passes by. A meeting truck with another truck behind, waits for the two trucks. The first two trucks turns right in next T-intersection. A meeting pedestrian. Crowded passage. The pedestrian meets other personnel and stops to talk and blocks the passage for the two trucks queuing behind them. (2xReach trucks, 2xPower stacker trucks (Staxco))</td>
</tr>
<tr>
<td>BF</td>
<td>Plats 9, film S109023, Time 00:00-00:03</td>
</tr>
<tr>
<td></td>
<td>Reverse without looking, reverse into an intersection without looking. (Powered stacker trucks staxio)</td>
</tr>
<tr>
<td>BI</td>
<td>Plats 3, film GOPR0288, Time 04:14-04:22</td>
</tr>
<tr>
<td></td>
<td>Truck is moving towards a T-intersection with obscure view, driving in the middle of the passageway (partly on the wrong lane), while the truck driver moves forward he raises the truck cabin when entering/turning in the intersection. This makes the view even more obscure. Risk of collision in case another truck closing up in front of him. (Order picking trucks Opus?)</td>
</tr>
<tr>
<td>BK</td>
<td>Plats 2, film GOPR0287, Time 00:53-01:29</td>
</tr>
<tr>
<td></td>
<td>Manned Truck &quot;parked&quot; has stopped just around the corner before intersection in the wrong lane, meeting truck has to round the truck in order to pass. Traffic jam further on the passageway, trucks who stopped to pick up order and one who has parked his truck, which makes the work inefficient caused by occupied lane/passageway. (Order picking trucks)</td>
</tr>
<tr>
<td>BM</td>
<td>Plats 2, film GOPR0287, Time 02:26-03:14</td>
</tr>
<tr>
<td></td>
<td>Truck has picked up EU-pallet and reverses to put it next to another EU-pallet with freight placed on the short side of the racking. Truck from short side has to wait for the other truck, personnel from the first truck parks the truck next to the EU-pallets and steps out to fix the freight. Traffic jam behind, other truck also &quot;parked&quot; stopped to read order, a fourth truck enters the traffic jam, drives around the parked trucks. After the fourth truck passed the second can pass by as well. (Order picking trucks opus)</td>
</tr>
<tr>
<td></td>
<td>Truck driver is rising the forks in order to place the EU-pallet right in the racking shelf, he has to raise them quite high and has some problem viewing if he reach the correct height, he hit the shelf and has to reverse and try again after adjusting the angle. (film 2: not that much problem with adjusting the EU-pallet) (Powered stacker truck klon)</td>
</tr>
<tr>
<td>BT</td>
<td>Plats 1, film GOPR0284, Time 13:32-14:12</td>
</tr>
<tr>
<td></td>
<td>Queue (in T-intersection) into one-way aisle, low productivity. Two trucks are able to pass the queue, and passes by with quite high speed. Traffic jam in intersection, personnel steps out of truck, crowded. (Order picking trucks, power stacker truck staxio)</td>
</tr>
<tr>
<td>BV</td>
<td>Plats 1, film GOPR0294, Time 16:29-16:42</td>
</tr>
<tr>
<td></td>
<td>A truck driver drives forward and suddenly stops, he has another truck behind him, which has to slow down (lower his support fence) and swerve in order to avoid crashing/hitting the truck in front, to pass the truck safely.</td>
</tr>
</tbody>
</table>
The situations that were chosen through the Checklist Filtering, were developed into shorter and more applicable situations. These descriptions were more to the point and more equal to each other concerning the level of detail. When rephrasing the 20 situations into shorter versions, a few were divided into two separate situations. Thus, 25 to-the-point situations resulted (see Table A.4). Situation 26-29 were added after insights from the Try It Yourself method.

Table A.4: Resulting situations after shortening the Checklist Filtering situations and performing Try It Yourself.

<table>
<thead>
<tr>
<th>Situation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Situation 1</td>
<td>Queue into narrow aisle</td>
</tr>
<tr>
<td>Situation 2</td>
<td>Personnel stops of of truck to fix freight</td>
</tr>
<tr>
<td>Situation 3</td>
<td>Personnel talk to each other and block passageway for two trucks</td>
</tr>
<tr>
<td>Situation 4</td>
<td>Communication stopped truck folks when other truck passing</td>
</tr>
<tr>
<td>Situation 5</td>
<td>Drive passed parked manned truck while fiddling with radio</td>
</tr>
<tr>
<td>Situation 6</td>
<td>Freight truck out and blocks/narrows passageway</td>
</tr>
<tr>
<td>Situation 7</td>
<td>First truck in a queue of two suddenly stops without looking, other truck must swerve</td>
</tr>
<tr>
<td>Situation 8</td>
<td>Haste driving forward while lifting forks to slide into the pallet tunnels</td>
</tr>
<tr>
<td>Situation 9</td>
<td>Makes U-turn in X-intersection with personnel near</td>
</tr>
<tr>
<td>Situation 10</td>
<td>Obscure view when entering intersection in wrong lane</td>
</tr>
<tr>
<td>Situation 11</td>
<td>Obscure view when making turn into aisle, has to back out again</td>
</tr>
<tr>
<td>Situation 12</td>
<td>Parked truck before intersection in wrong lane</td>
</tr>
<tr>
<td>Situation 13</td>
<td>Parks truck to read order near crowded intersection</td>
</tr>
<tr>
<td>Situation 14</td>
<td>Positioning a pallet on top of another, pallet on top has skewed position</td>
</tr>
<tr>
<td>Situation 15</td>
<td>Changing driving direction to adjust position, while focusing on pallet</td>
</tr>
<tr>
<td>Situation 16</td>
<td>Problem positioning pallet on high height, problem viewing</td>
</tr>
<tr>
<td>Situation 17</td>
<td>Stops in intersection and blocks intersection</td>
</tr>
<tr>
<td>Situation 18</td>
<td>Truck driver walks over to other truck and hands over a paper</td>
</tr>
<tr>
<td>Situation 19</td>
<td>Truck entering intersection while focusing on paper</td>
</tr>
<tr>
<td>Situation 20</td>
<td>Truck reverses in crowded situations without looking</td>
</tr>
<tr>
<td>Situation 21</td>
<td>Truck reverses in narrow passageway without looking</td>
</tr>
<tr>
<td>Situation 22</td>
<td>Trucks going in the same direction, the speed of the last is limited by the first</td>
</tr>
<tr>
<td>Situation 23</td>
<td>Trucks meet in intersection, pointing with finger to show travelling direction</td>
</tr>
<tr>
<td>Situation 24</td>
<td>Very narrow when reversing and turning out from storage racks</td>
</tr>
<tr>
<td>Situation 25</td>
<td>Places pallets on floor beneath storage racks</td>
</tr>
<tr>
<td>Situation 26</td>
<td>Uses sideshift to position pallet</td>
</tr>
<tr>
<td>Situation 27</td>
<td>Forgets to lift forks before putting down pallet in storage racks</td>
</tr>
<tr>
<td>Situation 28</td>
<td>Difficulty to estimate weight and centre of gravity of the freight</td>
</tr>
<tr>
<td>Situation 29</td>
<td>Problem positioning truck, hit storage racks</td>
</tr>
</tbody>
</table>

These 29 situations were then moved forward for a second filtering using Kansei words in the Kansei Filtering.
Appendix B

Kansei Filtering

The many Kansei words were clustered together into a hierarchical structure, with the words most relevant to the Driver Assist concept at the highest level. The seven words in the highest level function as categories for the 24 second highest level Kansei words (that can be seen in the pale green column), see Table B.1. For a consistent word interpretation, the meanings of the second level Kansei words were defined (white column).
Some of the words are defined from the warehouse manager’s perspective, and others from the drivers’ perspective. When evaluating the situations, the Safety, Feeling, Acting, Productivity and Desirable categories were seen from the manager’s view (in the list called “spectator”); Communication and Driver Perception is seen from the drivers’.

A Kansei semantic differential scale was used to filter the 29 situations resulting
from the Checklist Filtering, down to the most problematic situations in order to find the one most in need of a Driver Assist. The Kansei words were placed in the Kansei semantic differential scale, where a grade between 1-5 was put for how well a situation fulfilled the second highest level Kansei words. A lower number means it has a negative affect, for example 1 is Not safe, 3 is in the middle, and 5 is Safe. In the white rows in Table B.2 it can be seen how numbers are placed for Situation 1-9 for a few of the second level Kansei words. If the Kansei word is not applicable for the situation, a 0 is put, and then excluded from the summation. After a situation has been given a grade for all Kansei words in the matrix, the average number is calculated.

Table B.2: Example of how situations were graded in Kansei Filtering.

<table>
<thead>
<tr>
<th>Weight</th>
<th>Safety</th>
<th>Feeling</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reliable</td>
<td>Foreseeing</td>
</tr>
<tr>
<td>Group</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Situation 1</td>
<td>2.502350427</td>
<td>4</td>
</tr>
<tr>
<td>Situation 2</td>
<td>2.56974559</td>
<td>0</td>
</tr>
<tr>
<td>Situation 3</td>
<td>2.343668744</td>
<td>0</td>
</tr>
<tr>
<td>Situation 4</td>
<td>3.27062271</td>
<td>3</td>
</tr>
<tr>
<td>Situation 5</td>
<td>1.655974559</td>
<td>1</td>
</tr>
<tr>
<td>Situation 6</td>
<td>1.927472227</td>
<td>1</td>
</tr>
<tr>
<td>Situation 7</td>
<td>2.183150183</td>
<td>2</td>
</tr>
<tr>
<td>Situation 8</td>
<td>2.477064103</td>
<td>2</td>
</tr>
<tr>
<td>Situation 9</td>
<td>2.009157509</td>
<td>1</td>
</tr>
</tbody>
</table>

The relative importance of the highest level Kansei words were rated with numbers from 1-3, where 1 is the most important (see the second row in Figure B.2). This was done so that the Kansei word most relevant to the thesis would give the largest impact on the calculated “average”. Additionally, the relative importance within the categories, thus between the second highest level Kansei words, was ranked from 1-3 (see the forth row in Figure B.2). For example, within the category of Safety (where Safety is the highest level Kansei word) the second level words Reliable and Safe were considered most important and received a 1, Foreseeing was considered second most important and received a 2, whereas Steady was considered least important, thus receiving a 3. This way, the second level words most important to the thesis got a larger influence.

The resulting numbers that each situation received was used to select the situation with the highest potential for improvement (see the green column in Figure B.3). A lower number means both that the situation has bad connotations (graded closer to 1 on the 1-5 Kansei semantic scale) and that the importance was great (ranked closer to 1 on the 1-3 importance scale).
Table B.3: The result from the Kansei filtering. Bold situations are those with highest potential of improvements, hence the top ten situations.

<table>
<thead>
<tr>
<th>Situation</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Situation 1</td>
<td>2.502350427</td>
</tr>
<tr>
<td>Situation 2</td>
<td>2.68974359</td>
</tr>
<tr>
<td>Situation 3</td>
<td>2.343580744</td>
</tr>
<tr>
<td>Situation 4</td>
<td>3.271692271</td>
</tr>
<tr>
<td>Situation 5</td>
<td>1.858974359</td>
</tr>
<tr>
<td>Situation 6</td>
<td>1.927472527</td>
</tr>
<tr>
<td>Situation 7</td>
<td>2.183150183</td>
</tr>
<tr>
<td>Situation 8</td>
<td>2.477594103</td>
</tr>
<tr>
<td>Situation 9</td>
<td>2.009157609</td>
</tr>
<tr>
<td>Situation 10</td>
<td>1.498168498</td>
</tr>
<tr>
<td>Situation 11</td>
<td>3.541698507</td>
</tr>
<tr>
<td>Situation 12</td>
<td>2.231694982</td>
</tr>
<tr>
<td>Situation 13</td>
<td>2.063849743</td>
</tr>
<tr>
<td>Situation 14</td>
<td>2.113553114</td>
</tr>
<tr>
<td>Situation 15</td>
<td>1.483974359</td>
</tr>
<tr>
<td>Situation 16</td>
<td>1.768156288</td>
</tr>
<tr>
<td>Situation 17</td>
<td>1.705799231</td>
</tr>
<tr>
<td>Situation 18</td>
<td>1.551923977</td>
</tr>
<tr>
<td>Situation 19</td>
<td>1.088880342</td>
</tr>
<tr>
<td>Situation 20</td>
<td>1.356403256</td>
</tr>
<tr>
<td>Situation 21</td>
<td>1.639102686</td>
</tr>
<tr>
<td>Situation 22</td>
<td>2.002136752</td>
</tr>
<tr>
<td>Situation 23</td>
<td>2.217594718</td>
</tr>
<tr>
<td>Situation 24</td>
<td>1.991452991</td>
</tr>
<tr>
<td>Situation 25</td>
<td>2.230311356</td>
</tr>
<tr>
<td>Situation 26</td>
<td>2.716575092</td>
</tr>
<tr>
<td>Situation 27</td>
<td>1.302584103</td>
</tr>
<tr>
<td>Situation 28</td>
<td>1.465201485</td>
</tr>
<tr>
<td>Situation 29</td>
<td>1.261538452</td>
</tr>
</tbody>
</table>
Appendix C

Interview

The interview was performed with two truck drivers, one female and one male, that had been employed in the TMHE warehouse for one and two years, respectively. Both drivers were in their forties, and neither had driven trucks before they started working here. They both drive many types of trucks, as they have a rotating schedule: reach truck, powered stackers and ergomovers. The male also drove counterbalanced trucks, but only a little.

Driver Comments

Below are presented different comments, opinions and explanations that the drivers had regarding the situations they were presented with and as answers to questions they were asked.

Before turning in an intersection with obscure view: stops the truck until she has a clear view, do not trust right hand rule. Uses the warehouse mirrors, but they are dirty and blurry, she do not trust them as trucks are visible but personnel walking or on kickbike are difficult to detect. The device called SpotMe is useful but it blinks for a long time and only detects people walking on one side of the aisle (and trucks). In the production and warehouse, it is people walking or on kickbike that are the most dangerous, because they think they are visible when they are not.

When putting down pallets on high height, there are some difficulties: The pallet over or next to your pallet’s spot might be placed too carelessly so it may fall down when the new pallet is placed. If the pallet you are collecting is broken, the freight may fall down when it is lifted. When lifting freight high up the mounted fork camera is useful. There are preset heights in some trucks that are helpful and should be in all trucks.

Regarding driving in the drive wheel direction without turning to look: it happens daily and it is very serious. Kickbikers and pedestrians are difficult to discover. Some are counting on that the truck driver stops to let them pass and think that they are visible when really the driver has to turn his/her head back and forth and do not see them. One of the interviewed drivers has been hit by a
kickbike that drove into her, but she had her feet inside the driver’s platform and did not get hurt.

The drivers note that it is worse if something happens unexpectedly or is someone appears unexpectedly, than driving in an area where you know there are a lot of people about. If there are a lot of people you look more carefully and tell them to move out of the way if you need them to. When driving in the drive wheel direction there is a lot to focus on: the pallet in front, that you have the right tilt and are adjusted so the forks align with the pallet tunnels and are in the right height, at the same time as checking that no one appears from behind your back or from the sides. If someone is in the way you honk at them and sign that you need to get passed or that they should move.

The drivers do not hit the storage racks with the forks, but sometimes with the body of the trucks, or the fork lift frame because the driver focuses high up on the lifted forks/freight. Most often, it is not the storage racks that are hit but the yellow protecting fence in the corners of the storage racks, when the drivers are preparing to get a pallet.

Regarding driving in line, it is unpleasant if the truck in front of you suddenly stops or brakes. The drivers’ solution is that if someone drives to closely behind you, slow down which forces the one behind to slow down, then it is less scary to brake.

The drivers stop if they need to check where they should go, to look at the order paper or instructions. They have a notice board where information of where we are going, or where the freight will be received, so usually we do not use order papers. There are some drivers that are using their cellphones while driving, but not for work. If they have to deliver information to another driver they will not stop at the corner of an intersection, they will stop on a straight stretch instead. Then walk over to talk or if they need to hand something over (neither of the interviewed drivers has had to have order information delivered like this).

Regarding the tilt function of the forks: it is easy to forget to tilt back and have the forks straight when leaving pallets in the storage racks. However, since if you have heavy cargo you take it easy, nothing bad can happen. It might break if it is dropped but no one would get hurt. There is an indicator (a green light) that shows if the forks are 0-tilted. One of the trucks apparently changes the tilt automatically, which they find annoying and which makes them unsure of the tilt in all the other trucks. One of the trucks has no indicator for tilt at all which makes it really difficult to know if the forks are straight. There is also a display that shows sideshift.

Driving trucks is difficult in the beginning with so many trucks and fast tempo. Getting straight with the forks and putting a pallet on another pallet was difficult. Also it was scary to sit in the Reflex the first times when the seat tilted, but after doing it a couple of times you got used to it, and now it is essential. There is a function that shows how heavy the freight is, but only after you lift it. The pallet handling is stressful and they have a number of pallets they should move within a certain time limit. They unload from a conveyor belt, which has an uneven workload and they never know how many pallets are coming. The pallets also arrive in the wrong order so they have to sort them. They are not supposed to
place the pallet on the floor, but if people are in the way they have to. Also, they cannot leave to use the restroom as you do not know when the next group of pallets will arrive.

Regarding the narrow aisles: it is difficult to get in the right position right away. If the drivers does not, then he or she has to back all the way out and start over (cannot just switch travelling direction and adjust). The aisles are too narrow as the technicians only calculated on floor width and forgot that the blue protecting fence and the pallets stick out up to 1 dm on each side, so the ailses are 2 dm too narrow. If more than one truck needs to go into the same aisle, they stop before entering and ask the other driver how far in he/she is going. The one going further drives in first. Conclusively, the drivers comment that the reach truck Reflex is the most fun truck to drive.
Appendix D

Competitor Analysis

How competitors, mainly from the car industry, solve the positioning situation, can be seen in Figure D.1.
Figure D.1: Dashboard icons used in vehicles for parking assistance.

Different symbols used by the car industry to give feedback to the driver are displayed in Figure D.2.
Figure D.2: Dashboard symbols and buttons relating to start and stop of parking manoeuvres.
Appendix E

Function Concept Paper

Sketches of each concept were inserted into a Function Concept Paper (FCP), where all concepts were described so that they could be understood by others and to clarify their content for the authors. Then the concepts were graded on how well they fulfilled the list of requirements according to the authors. This list consists of Necessary, Desirable and Kansei requirements. First, it was made sure if the concepts fulfilled the Necessary requirements. As all concept fulfilled these, all were continued on to further scoring. However, not all concepts fulfilled all Desirable requirements, which was noted by the authors.

The concepts were then scored after how well they fulfilled the Kansei requirements (see Table E.1). In the first column is the list of requirements, divided into Necessary, Desirable and Kansei requirements. In the second column is the importance of each requirement: must or should, and the Kansei requirements are ranked and normed between themselves. In the third column it can be seen how the selected situation ”Changing driving direction to adjust position, while focusing on pallet” responded to the requirements. In the forth, the different concepts are graded for how they fulfil the requirements. As can be seen in Table E.1, some Kansei words identified for the situation filtering did not apply for the concept grading, thus these cells were left blank. The Kansei grading for the identified situation can be seen in the column ”Situation”; at the bottom of the column is the total score, and below this (in grey italicised text) the score that the situation would have received if the same words had been blank as are blank for the concepts.

The concepts were graded in the same manner as in the Kansei Filtering: given a number between 1 to 5, where the 1 means the concept fulfils the word description poorly and 5 that in fulfils it well. At the bottom of each concept column, the total Kansei score can be seen.
Table E.1: The table shows how well the concept fulfilled the requirements, and the best scored concept is highlighted with green.
A Pro-Con Analysis was performed on the concepts, as this is an important part of the FCP. The Pro-Con Analysis was carried out to verify if the highest scoring concept also had the highest potential according to Pro-Con Analysis. As several concepts received similar scores in the list of requirements, this was carried out as a selection method. An example of the Pros and Cons for different concepts can be seen in Figure E.1.

In Figure E.1, four of the highest scoring concepts are illustrated. Concept 3 (top left) consists of directed sound from the headrest that warns of an object appearing from left or right behind the driver. This concept includes symbols that are shown on a display (person, truck or pallet) and differentiates if the objects are still or moving. The zones for the warnings are dependent on the direction of the approaching object rather than on how close it is. Concept 6 (top right) have two warning zones, and different responses if the object is semi-close or really close. The warning sounds are different depending on which zone the object is in. Miniature symbols are shown if something is semi-close, whereas the truck takes control of the truck if something is very close. Then, a symbol is shown to notify the driver that autonomous control has engaged. Concept 8 (bottom left) goes deeper into the automatic positioning: the steering wheel makes a click, and the display shows the projected path that the truck will take. Concept 13 (bottom left) shows different symbols, in combination with text, to warn of objects close-by. The warning sound is different for each object: an engine sound for truck, a human sound for personnel, and a ”wooden” sound for pallet.
Figure E.1: Concept examples, including descriptions and Pro-Con Analyses.
Initially, 13 concepts were included in the FCP. After having analysed why these concepts received high scores, and more Pros than Cons, a 14th concept was constructed out of the best ideas. This concept was then graded in the same manner as the others, but naturally ended up with a higher total score. Thus, this concept was selected to develop further. The selected concept (Concept 14) can be seen in Figure E.2, complete with description and Pro-Con Analysis.
Figure E.2: Chosen Concept, including description and Pro-Con Analysis.

**Concept Description**

When the driver is positioned crookedly towards the pallet, and uses the switch to alter direction, the system checks what is around the truck. *

If something is semiclose in area 1, the driver receives a warning. This warning consists of sound from behind the driver's neck, from the side that the object is located on. This makes the driver turn his/her head in the right direction. The sound is different for different types of objects (trucks, people, walking or pallets). The display also gives information, by showing a symbol of the object (possibly in relation to the truck's position).

If something is very close in area 2, the system takes control of the truck. It stops until it is safe to drive and then positions the truck autonomously. To signal autonomous driving, the “engine sound” changes. Simultaneously, the display makes a short blink and shows “Autonomous Driving” plus a symbol of the planned positioning on the display. When changing to autonomous drive, the display also produces a sound to call the driver’s attention towards it. When the object is out of the way and the positioning is done, the system releases control. The display blinks, makes a sound, and shows “Self Driving” shortly before switching back to its normal screen. The “engine sound” is also changed back to the normal sound. **

* the system checks continuously but delivers information to the driver when the switch is used to alter direction (when the truck is crookedly placed in front of the pallet).

** the driver should also be able to choose Autonomous Drive when he/she wants the system to position the truck instead of doing it him/herself.

**Pros and Cons (+/-)**

- the sound directs the attention for where the driver should look
- the display shows positions of surrounding objects
- low learning curve
- shows trajectory that the vehicle will take.
- clear feedback when the system releases control of the steering
- logical sounds that differentiate types of objects
- multiple feedback (sound, flashing light and symbol on display)
- risk of too much feedback if situation occurs frequently
- risk of directing the attention away from the surroundings and towards the display
- risk of being messy with different types of feedback and sounds
Appendix F

Pre Evaluation Symbols

In the pre evaluation, three different colour alternatives were evaluated for the five symbols (person, truck, pallet, autonomous driving and self driving). These can be seen in Figure F.1.

Figure F.1: The three different colour designs for each of the symbols: contours, grey and black, and black.
Appendix G

First Evaluation with Drivers

The first prototype evaluation with drivers was conducted at three different times, with two drivers at each time, who conducted the evaluation together. The drivers represented various departments of production: High-Level Warehouse, Goods Receiving and the Lab (night drivers).

Drivers from High-Level Warehouse

Driver 1: Male, 39 years old. Has driven trucks for 15 years. The reach truck is his primary truck that he drives almost always.

Driver 2: Male, 32 years old. Has driven trucks for 12 years. The reach truck is his primary truck that he drives almost always.

Observation, High-Level Warehouse Drivers

The drivers do not react much to the feedback during the first round. The first driver does not acknowledge noticing symbols on the display, whereas the second sees and understands them. Regarding sound, which they do not know is part of the evaluation, the volume is possibly too low.

The drivers stated that sound feedback is good as a Warning for something - it takes time to first look in the right direction and then look at the screen/display. They are used to look in a display that is mounted differently from ours (on vertical or horizontal e-bar, so that the driver can look straight ahead instead of down; one of the truck drivers points out that it is better for the neck).

None of the drivers find it difficult to notice that the sound differs (number of clicks). The drivers also hears that the sound comes from different directions. Sound is good because it cannot be ignored or overlooked, also it does not interfere with where you need to look. One driver would prefer to have the same warning sound for all warnings, as he will stop no matter the object. Otherwise it would be too many sounds to remember.
The warning sound is too indistinct blend in, a snap or click might be a wrong type of sound. The first driver states that a beep is better than a click-sound, as it is easier to hear. It is hard to differentiate the surrounding speaker sounds from the warning sounds in the truck - in reality you learn to recognise the sounds your truck makes, states one driver. Low or muffled sound disappears. It could be good with a longer sound so it becomes easier to recognise. The second driver prefers a higher “click”-sound rather than a beep, as this would be annoying if heard often. Three clicks as a warning sound is preferable to one click, as the sound for pallet was hard to hear. He understood, quicker than Driver 1, that the sounds represented different objects (person, truck or pallet) and thought this was good.

During the tests, the second driver hears the sounds and then looks at the display, thus reacting correctly. However, he does not turn his head. Driver two said that he likes the sound and symbol combination, but that it would be nicer if the symbol appears after the sound. This could be interpreted as that the symbol has a too short duration, if you turn your head towards the sound. A delay of the symbol is not recommended due to deaf people also needing a warning.

The drivers comment that there is a risk of hearing the sounds a lot, as many people are moving about and you collect a lot of pallets.

Regarding autonomous control and driver control, both drivers correctly understands what is happening. They said “now the truck drives itself and I just accelerate, and now that the sound stops I am driving again”. One of them states that the “pling”-sound is enough and the engine sound is unnecessary.

Discussion, High-Level Warehouse Drivers

Driver 2 mentioned that it would be good if there is a possibility to change the settings depending on where in the warehouse/production you are. If there are a lot of people or trucks, it could be annoying with auditory feedback. If it is possible to turn it off, people would. Adaptable after the drivers’ needs. Another alternative is that you can decide to only warn about persons or trucks or pallets.

The drivers discussed that if they get used to one click for pallet and three clicks for persons, and then one time do not hear all the clicks, this would mean they will misjudge the danger level. This is a reason that one signal for all warnings is better. Or that there are two distinctly different signals (one for persons and one for everything else).

Ear plugs are recommended in the warehouse but the drivers do not use them, whereas headphones for music are forbidden. They do not want auditory feedback from headphones, as they often need to communicate with other drivers.

The click-sound is too similar to the surrounding noise. The drivers want either a stronger sound or a different type of sound. The placement is okay, they like that the speakers are not placed above their heads but rather next to the head. The sound coming from the display was a bit hard to hear.

The drivers discussed that one two or three clicks could be used to signal how far away the danger is, rather than represent person, truck or pallet. This is similar to how it is at railroad crossings. One click is however easy to miss. If we want
to signal different types of objects, a totally different sound should be used for person, so it cannot be missed.

The display placement is also discussed. Driver 1 would prefer if the display is up to the left on the vertical e-bar. He does not look at the display by his right-hand fingers. Driver 2 prefers the display by the fingers or straight ahead where the horizontal e-bar is, or in between the e-bar and the current display position. They conclude that it would be good to have individual customisation of the display’s position.

The situation of persons going past a truck “really quick, it’ll be alright” happens very often and persons are difficult for the drivers to hear. The drivers estimated that almost hitting someone is a daily occurrence.

The most difficult procedure in driving a reach truck is to see how to aim and align correctly with the pallet.

Regarding the autonomous drive, the drivers believe they would not chose to use it as they think it would be faster to do it yourself. However they both mention that parallel parking (reversing sensor) and cruise control are commonly used in cars for similar situations.

Both drivers said the size of the icons was good, but that it was unclear that they were warning signals. This could be clarified either by using a warning triangle around the icon, or by writing “warning” above it. It is not needed to show the icons in relation to the truck, it is better to check the rearview mirror. The autonomous and driver control icons are good as they have both image and text.

Drivers from Goods Receiving

Driver 1: Male, 54 years old. Has driven trucks for 27 years. The reach truck is his primary truck that he drives almost always.

Driver 2: Male, 37 years old. Has driven trucks for 15 years. Drives reach trucks about three times a week.

Observation, Goods Receiving Drivers

Both drivers interpreted the symbols correctly and reacted to the directed sound (left vs right, as well as the ones from the display). The second driver thought the truck symbol meant he had hit something, rather than being a warning of a truck.

The first driver did not understand what autonomous control was, and thought this had something to do with automated truck trains outside his own truck. The second driver understood that it meant that something in his truck was now automated, but thought it was the forks or the fork mast rather than the whole truck. He then compares the function with automatic car parking.

The second driver thinks it is beneficial with a warning of when someone is coming close to the truck. He also mentioned that if the system delivers a warning all the time, after a while the truck driver will ignore the feedback. According to the second driver the people walking in the warehouse does not fully understand that they are the ones who will get hurt if the truck driver is running into them. He also mentioned that before, a couple of years ago, a computer was mounted on
the E-bar, and he believed it would be better to place the display on the E-bar. He also stated that this concept would be great for a CB truck that drives in the loading or unloading hall or when driving in a yard. Another thing he mentioned was that it is not necessary in our concept to distinguish the warning depending on if it is a person or a truck.

The first driver pointed out that stronger sounds would be preferable. The first driver does not think that the situation when a truck driver has to correct the truck position (using travel direction switch) occurs that frequently. He also mentioned that the automatic driving function possibly would be annoying, but can be beneficial for beginners. However a risk is that they will depend too much on the system, never learn to do this procedure since they never get to practice it. The first driver mentioned that if you hear the sound and turn your head the symbol will be superfluous/unnecessary. A risk with the concept is consist of too many different sounds and symbols/pictures, so that it will be difficult to differentiate the signals/feedback. Second driver pointed out that he believed it was good with the directed sounds (left/right), but it might be good enough with one type of sound. He also said that it was good that the sounds came from the display. He pointed out that the the symbol representing a person looked like a person with a helmet.

It is common that office staff passes by behind a truck unobserved since they are difficult to spot for the truck driver, and if he do not notice them, there is a high risk of a collision/incident. It is quite common that trucks that passes by another trucks honk to signal that he is behind. (1st driver) The first driver stated that the sound for truck/people/pallet is similar to the ticket-clip used on trains. He also pointed out that it is a lot of people, kickbikers and trucks moving around and that the sound that we presented is not distinctive enough. He mentioned that it could be good to use a light signal instead, since he thought it will evoke the truck driver’s attention better.

Discussion, Goods Receiving Drivers

There is usually a rearview mirror that enables you to see everything behind you, but there was no one in the truck that was used in the evaluation since it is a cheaper one/budget model.

A question that was brought up was if the automatic drive will “align with the storage rack or with the pallet?”

The drivers was pleased with the placement of the sound from behind their head/neck, and thought it was good, since it will make them turn their head towards the object, if the sounds do not occur too often. They mentioned that it would be beneficial if it is possible to adjust them a little. One of the truck drivers mentioned that this personal adjustment could connected to each truck drivers personal code that activates the truck.

Regarding the sounds, they mentioned that it is better to use one warning signal instead of several and a suggestion is to use a “pling” like the one used on the display, a signal that differentiate enough from the surrounding noise, so that they understand that it is a warning signal. They said that it is not possible to
use ear protection when you drive a truck. To the radio that is placed in the truck it is possible to connect your cellphone, and listen to auditory book.

They questioned why it is necessary to separate what object you have behind you. They mentioned that as a truck driver you always have your left hand on the steering wheel knob and the right hand is often placed next to or touching the fork controls. At most time, the right hand is placed on the steering wheel knob but one of them stated that “sometime I only use one of my fingers to steer”.

To symbolise a warning of an object it would be better to draw a warning triangle around the symbol of people/truck/pallet. Regarding the autonomous drive, they mentioned that they liked that it was a describing text next to the symbols for autonomous control and driver control. They think that it is a bit annoying that the symbol representing a person is wearing a helmet. They mentioned that the view in the reach truck is ok, and that there would not be that much time to look in the display, which is the reason why the information in the display should be minimised. It is better to keep it simple for this truck model (Reach truck). that is why they pointed out that. They said that it will be too much information if we include the truck position compared to the object, and it will be too much information to handle.

They liked that the sound was directed (left/right). It would probably be good enough with the sound but since one of their colleagues is deaf it would be beneficial with another feedback in addition to sound, one of their suggestions was to use light as the other feedback signal. The symbols could maybe be flashing so that the truck driver will observe them. They stated that it was important to change the clicking sound, to another one that distinguish more compared to the surrounding noise.

Drivers from the Lab

Driver 1: Male, 43 years old. Has driven trucks for over 10 years. Drives reach trucks about two to five times a month. Test truck prototypes regularly.

Driver 2: Male, 30 years old. Has driven trucks for 4 years. Drives reach trucks periodically, with a couple of months in between. Test truck prototypes regularly.

Observation, Lab Drivers

Both drivers quickly realise that the sounds come from left and right, and that this must signify something. Driver 1 correctly believes that it means the object he should notice is to that direction. Driver 2 connects the sound to the symbol and realises they have something to do with each other, but not what. He turns in the direction of the sound.

During the first round, Driver 1 comments that as the symbols are grey, they must be informative rather than warnings. Thus he believes that the right hand click sound for pallet is to notify him that the pallet he should collect is to his right. Both drivers realise that the symbol for pallet is a pallet, the person means person, and the truck symbol is for another truck. Regarding autonomous control, Driver 1 understands the symbol and text, in combination with the sound, and
believes that if he presses the accelerator the truck will position itself, without him steering. Driver 2 compares it to autopilot. Both of them also understands the symbol and sound for when control is regained by the driver.

During the second round, Driver 1 realises that the symbol for person means that a person is somewhere but does not connect it to the direction of the sound. He turns in the correct direction when the click-sound for pallet is played. He connects this to the pallet symbol, but draws the conclusion that he is correctly positioned towards the pallet. When autonomous drive is shown, he wants to switch travelling direction and control acceleration himself. He wonders how it works where the truck first goes in the drive wheel direction and then aligns to the pallet by going in the fork direction - does he have to switch travelling direction or does it do it for him? Driver 2 comments that as a driver, he would prefer to have full control of the truck. He connects the directional sound to the symbol and correctly guesses that the object is in the direction the sound comes from.

Driver 1 prefers the click sound to beeps and honks, as these sounds are both common and annoying. He thinks directional sound is very helpful. Due to the background noise he feels he would wear earmuffs (possibly the kind allows voices from the surrounding to be heard). He sometimes listens to audiobooks, and then it would be annoying with a disruptive sound. Others might listen to music. He believes it would be neat with haptic feedback in the steering wheel knob, synced with the click sound. He says that while driving, his left hand is always on the steering wheel knob and his right hand is always on the plate by the finger levers on the right hand module. Driver 2 feels that the click sound is neither too low nor too high, and that it is not annoying. Both drivers prefers auditory (possibly together with haptic) feedback that does not require you to look at the display.

During round three, the faster round, driver 1 comments that by using click sounds you force the driver to focus, which could be strenuous. A click sound could sound similar to noises made by the truck or in the production. A more distinct or synthetic sound that is not currently a part of the truck environment, might be beneficial and more clear. During this round, driver 1 connects the icon to the directional sound and realises its purpose. He likes the “pling” sound that the display makes as this sound does not naturally exist in the truck environment. He comments that the engine does not make much sound when you collect pallets, as you stand still, thus a change of the engine sound might not be noticed or necessary. Driver 2 understands that the sounds dictate in which direction the object is, when the object is a person or a truck, but when it is a pallet he is unsure if it warns about a pallet in a certain direction or gives information about where the pallet he will collect is. He also hears that the number of clicks and the speed of them is different: three faster clicks is for person, two for truck and one for pallet. He likes that the engine sound changes during autonomous drive, and also likes the “pling” sound. He comments that it would be beneficial if the driver could control the sound level.
Discussion, Lab Drivers

Driver 2 comments that the click sounds are beneficial because they are different from the music sounds and warehouse sounds. However, when Driver 1 says that the clicks are similar to noises the truck makes, he agrees. Both agree that the speakers’ positions next to the head makes you feel and hear the sound, which is good. Both agree that the “pling” sound from the display was more artificial but still not annoying and therefore preferable.

The drivers do not believe it necessary to have different warning sounds for person, truck and pallet. However, one of them is terrified of hitting a person, and perhaps want the “warning about person”-sound to be separate and more distinct. They comment that it is very rare that a pallet is placed in the risk zone, and thus this symbol might not be shown a lot.

Regarding the Autonomous Control, they comment that it would be nice if it was a choice, rather than something that kicks in when you drive in wrong and something is close-by. A risk is that you start to trust the system too much. If it was possible to turn parts of the feedback off, the drivers believe many would.

When the pallet is on the ground, it is common to “push it” onto the forks, in this situation the driver does not come in straight to the pallet. In current trucks, he also feels that what is on the screen does not always correspond with the surroundings. It is important that the driver can trust the feedback. They do not want a concept that is similar to “pick-by-voice” in Parts, where the drivers get instructions in their headphones but it is very difficult to hear what the person is saying and frustrating with such a repetitive sound. Driver 2 feels that this concept would work better in terminals or in places where less people are moving about compared to TMHE’s production and warehouse. Both drivers have worked at Väderstaverken and believe this concept would work well there because the aisles are much narrower and there is less people moving about. At Vädestaverken, it is possible to position the pallets very crookedly in relation to the pallet below or above, something that is not possible in the TMHE production. This is also a reason why this concept would work well there (the situation of having to reposition occurs often).

The drivers comment that the grey border around the symbols is not enough of a warning, more distinct colors such as red, orange or yellow would be better. Perhaps a triangle symbol would be helpful. The symbol for person can be interpreted as the driver himself. Text is helpful on the “Autonomous Control” and “Driver Control” symbols, and not necessary on the others. The font is clear. The drivers prefer auditory feedback as you do not have to direct your gaze away from the work in the same way. Driver 1 comments that a light flash positioned by the directional speakers could be helpful.

They believe the feedback is clear enough. One driver says that he uses the rearview mirror and would not turn his head to look behind him. The other does not fully trust the mirror and feels it is helpful to know which side to turn his head. The drivers also comment that in reality they would have been told exactly what the symbols and sounds mean, and then it would be even easier to hear, see and understand their purpose and functions.
Appendix H

Second Evaluation with Drivers

The second evaluation was carried out with five of the drivers that took part in the first evaluation: two from the High-Level Warehouse, two from Goods Receiving and one from the Lab.

Driver 1, High-Level Warehouse

Here is presented insights from the observation and comments that came up during discussion.

Observation, Driver 1

He liked the sounds and mentioned that it was good with a repeating sound (that the same sound came twice). He also mentioned that the stop sign was clear/understandable.

He pointed out that he thought it was more serious to hit a person than something material which could be replaced, and therefore he would like the sound for a person to be different compared with the other ones for pallet and truck. Regarding the AUTO button he identified it quite fast, but it would be preferable if it looked more pressable.

Discussion, Driver 1

He compared the sounds from the first iteration with the second one (today) and he believed that the new sounds was better and that they are easier to notice for the truck driver. According to the driver it would be good if the sounds was adjustable for different truck drivers. It would be good to be able to make the sounds louder if you have problem hearing, or are wearing earmuffs. It would also be good to be able to lower the sound in busy environments where you expect people to be, and already know you have to be careful. It was easy to hear that
the sounds were coming from left versus right. He did not think about that the sound for the display was different from the sound from the headrest. It would not be annoying at all to hear the sound multiple times in a day. However if it was heard several times when you are in the same spot it would be. A longer sound (repeated) is preferable for when it is a person, compared to a pallet (toot-toot toot-toot toot-toot instead of toot-toot). If a too short signal is used it is easier to ignore it, which was the reason why he thought it was better with a longer one for a person.

The symbols are easily understandable. The grey overlay on the display when the symbols appeared was beneficial, as they focus your attention on the warning. Five seconds is long enough to see the symbol. He mentioned that the symbol for the fork angle is shown in the display, and that this was something that he had asked for earlier. Regarding the symbols in the display with warning triangle or stop sign, he did not think that they would be confused with other similar warning and stop symbols.

Autonomous control is comfortable, and perhaps would be used often by new reach truck drivers. He would probably only use it when he is annoyed with his own driving - sometime then and again. While driving he did not notice the return symbol, since he was too focused on driving the truck. The return symbol for exiting autonomous control was considered fairly intuitive, but perhaps “Cancel” or similar could be used. The symbol should appear already when the big AUTO-symbol is shown.

Driver 2, Goods Receiving

Here is presented insights from the observation and comments that came up during discussion.

Observation, Driver 2

He pointed out that it should be possible to terminate the Autonomous driving if something does not work, or you just want to have driver control, but it would be easier to just press brake pedal. He compared it to a car’s cruise control. During Autonomous control, he feels he should need to have his foot on the safety pedal, as well as be able to brake (thus cancelling Auto), but not control speed. He mentioned that a situation when several trucks are near each other in the warehouse since they are working close to each other (narrow racking shelves), and because of this it is possible that the sounds would appear too frequently. If listening to radio while driving, he would prefer if the radio sound was lowered when the headrest warning sounds rather that if it was muted. When starting Auto, he first looked at the Driver Control-symbol next to the clock, and then pressed the AUTO-button (perhaps the AUTO-button need to look even more like a button or they need to look separate in some other way).
Discussion, Driver 2

He prefers the new sound to the previous sounds and believe the new ones would draw the drivers attention better. Regarding volume control, he wants it to “just work” and be preset to a good level, since they do not have personal trucks. However, he believes it would be beneficial for people with bad hearing if the sound can be made louder for them, perhaps connected to their log-in code. He likes the sounds (both from the headrest and from the display) as they do not sound like anything else in the production/warehouse, and feels they are not annoying as they are “soft” sounds rather than sharp. He comments that the headrest sound maybe should be different for warning and stop, but is not sure what he prefers. Regarding the stop sound, he also pointed out that it might not be necessary with a different sound since you will be aware of it since the truck has stopped.

Regarding the display, the meaning of the symbols next to the clock are not entirely clear. He likes the grey overlay behind the large warning and stop-symbols, as they give you a clear focus. When pressing Auto, he needs more/faster feedback that the button is “clicked”. He feels he would use the Auto-function on occasion, mostly when he is tired. The driver control symbol was a bit clearer with text on (like it was in the previous evaluation), but he understood it now too. It just takes longer or you need it to be shown the first time. If using text he would prefer if it was written in swedish. Same with the Auto-symbol.

Driver 3, the Lab

Here is presented insights from the observation and comments that came up during discussion.

Observation, Driver 3

During the Auto-drive, he would like to accelerate using his foot, but otherwise the truck should control it all. He commented that it is “worth as much as gold” to not have to adjust perfectly towards the pallet tunnels, as the adjustment is slightly different for different trucks. For example, it is easier to adjust with a counterbalanced truck, therefore you might get in wrong towards the pallets tunnels when driving a reach truck.

He commented that he likes the sound, as it is soft and not annoying at all. It does not sound like anything else in the production or warehouse. The sound could be even louder though. He hears it every time and can tell if it is from left or right. Although he hears the sound he does not look left/right, he says that in reality he might have but now he knows no one is behind him.

Discussion, Driver 3

Regarding the symbols, he feels the second symbol for autonomous control, where the arrow shows the path the truck will drive, is enough, and the big AUTO-symbol is unnecessary and also somewhat similar to the driver control symbol. He would also prefer if the arrow was animated, or bigger. The buttons look like you can
push them, and he understood that the AUTO button was to start autonomous drive. He would prefer a physical button over a display button, because touch pads can get dirty and then they do not work well. Also you can not feel the button on a display, you have to look. During auto-drive, he would like to control the speed with the accelerator pedal. He believes that if you use the auto function depends on how good you are. It would definitely be interesting to try it. He mentioned that he might use this Auto feature, depending on how well it would work, if it will be faster to positioning the truck about 20 degrees askew and then let the auto do the rest of the positioning, that would be smooth.

The symbols for warning and stop is a bit too similar as well (note from author: in the evaluation the truck did not stop when the stop symbol showed up, which may have affected the result as in a real situation this additional feedback of stopping would have impact on what the driver notices). The driver feels that text accompanying the symbols is not necessary. He suggests a distinctier “road sign” look of the symbols. When asked if a yellow warning triangle looks similar to anything else in the trucks, he explains that currently there is a yellow sign with an M on it is certain trucks, that means you can override the system. There is also a yellow triangle that means possibility of zone limitations. On the reach truck, there is a yellow triangle with a black exclamation mark, that means emergency drive.

The sound is distinct and good, you can hear it in a loud environment. It is better now with the same sound for all warnings. He does not want to adjust the volume of it, as he feels there is a risk of turning it off. It is better if it is not controlled by the driver or possibly if it has pre-set levels and you could only choose between them. He feels that the sound would not even be annoying if he heard it several times a day. When the truck stops, he feels the sound from the headrest should be modified. Although he also is unsure of if a sound is necessary. As the truck will stop, he would look around him as well as towards the display to find out what happened.

The display sound is a bit boring he says. He would also like it to come from the headrest (note from author: this however would defeat the purpose of signalling of danger behind the driver from the headrest, as the display sound is to notify the driver that information is shown on the display which is unrelated to dangers). Another idea he had was to use one kind of signal when the auto starts (fade in) and another similar (fade out). The display sound could be either a bit louder or using a higher key (two octaves higher or so).

Driver 4, Goods Receiving

Here is presented insights from the observation and comments that came up during discussion.

Observation, Driver 4

He mentioned that as a truck driver you are aware of fix objects in your surroundings and did not believe that there are any risks with these kind of objects.
Because of that he did not think it is necessary with a warning or stop for a pallet, since you are aware of those anyway. He also mentioned that it is common that you take an entire pallet stack and then you have to put down the pallet stack on the floor in order to just take the one on top. The problem that he referred to in this situation is that the warning signals would appear all the time in these kind of situations, if the system is warning for pallet and fix objects as well. For movable objects such as kickbikers, trucks or pedestrians the warning system is appropriate to use.

He did not have any problem hearing from what direction the sound came from, but he pointed out several times that the sound has to be more distinct to be distinguished from the surrounding noise. For example when driving in a welding area, where the surrounding noise is louder than usual, he believed that it would be appropriate to also have a light signal. The light signal could also be good for drivers that are using earmuffs.

He mentioned that there are risks with implementing this kind of system, and that the truck drivers will rely on the system too much, and he is questioning what will happen if the system fail some day. Regarding this he also mentioned that there is a generation difference (referred to younger truck drivers) today, and that those truck drivers use their cell phones during truck driving even though it is not allowed and that the risk with implementing a new display is that they will pay too much attention to, and rely on, the display and less on the surroundings which could cause even more accidents. According to him accidents occur because truck drivers use their cell phones or are using earplugs/headphones while driving and that there is high working load. He believes that if this system will be implemented it is better to keep it simple since otherwise it could be too much information for the truck drivers to handle, and that is not appropriate since they already have a lot to think about.

He believes that the system could be appropriate in smaller warehouses and when driving on a yard. Regarding the yard he pointed out that people is moving around in another way there and that they believe that the truck driver are aware of them even though that is not the case. Regarding return button in the the auto driving feature, he believes it would be better if the feature is canceled by using the brake pedal. He does not want to control the acceleration, the truck should drive itself and then give back the control to the driver when he presses the brake pedal.

Discussion, Driver 4

He mentioned again that it would be good to also implement a light signal. Although he also mentioned that drivers tend to tape over light signals and cut cords of annoying safety features. Thus, he did not think the drivers should be able to adjust the volume of the sounds. He pointed out that there is a risk that the drivers will be stressed if the system is beeping all the time, he think that will cause a stressful situation for them, and that it is better to minimise the stress. Only one sound should be used, the same sound for both objects (person and truck). He also mentioned that we should think about the frequency of the sounds
so that they do not appear too often. He believes that it is too many symbols, and that it is better to use just the human or truck symbol (skip the warning/stop symbol). Regarding auto he believes it is good enough with text and a symbol and that we should skip the sound (people think there is too much noise already). He preferred the driver control symbol as it was during this evaluation: without text. An improvement that he asked for was to implement a LED on each side of the display in order to show from which direction the object is coming.

Driver 5, High-Level Warehouse

Here is presented insights from the observation and comments that came up during discussion.

Observation, Driver 5

He stopped the truck immediately after he heard the warning signal from the headrest. He mentioned that it was easy to hear from what direction the sound came from, and he was able to hear the sound although the surrounding noise (production noise) was playing. He also mentioned that the new sound located in the headrest was better than the ones that was presented during the last prototype evaluation. He did not believe that this sound would be irritating to hear frequently since it was a softer sound, and that it was distinctive enough compared to the surrounding noise. He immediately noticed that the warning and stop symbols looked different from each other and understood what they meant. Regarding the Auto feature and how to deactivate it, he compared it to another automation feature that is possible to use in the reach trucks, and pointed out that that feature was deactivated using the C-button (cancel) that is placed near the old display. However after some consideration he believes that the return-button that we “developed” would be as good as the other one, but that it would be preferable to deactivate autonomous control by using the brake pedal.

Discussion, Driver 5

He mentioned that the sound was comfortable and not shrill, and that the placement of the sound was good since it is so close to the ear. Thanks to the placement he believed that personnel listening to the radio, which is included in some of the reach trucks, would still be able to hear the warning signals without difficulty. A benefit with the concept is that since the speakers are mounted in the headrest, truck drivers which are shorter would hear the signals as clearly as taller ones since the distance between the driver and the speakers is the same no matter of the chair position. A problem with the warning signal is still the truck drivers that are using their own in ear headphones which many do although it is forbidden. A solution could be for the drivers to plug in their headphones in the trucks AUX and then have their music played in the headrest, and then overridden when the warnings sound. Regarding the sound from the display, he mentioned that it was difficult to hear, as the volume was too low. He had some ideas regarding the
display sound, if that sound also could be played from the headrest. He said that if it was louder it would work well.

Regarding the usage of the display, he mentioned that he would not pay attention to the display if he was able to see the risk object when turning his neck, but if unable to see it he would look at the display to check what object caused the warning signal. He also mentioned that this could be a habit thing, after a while you might get used to look at the display. He pointed out that the difference between the stop symbol and the warning symbol was different enough (the triangle and octagonal traffic sign shapes, as well as the colours used). Regarding to use text in addition to the symbols he mentioned that it is never bad, and that it could be beneficial in the beginning, perhaps the first time you use the system. If using a text it should be preferable if it was in your own language (Swedish) because of older personnel who barely know any English. Still he pointed out that some personnel are foreign and for them it might be preferable with another language. Although “AUTO” was okay to use for the autonomous driving, for both Swedish and foreign drivers.

Regarding the AUTO feature, he still believes that he would not use the feature since it will be faster to do the adjustment by himself. However for beginners it is a good feature, for example if you have stand in personnel (just for shorter time periods) it will be very efficient time-wise with this system, since to adjust the forks correctly to the pallet tunnels is one of the most difficult procedures when driving a reach truck. The auto drive might also teach beginners how the best path looks and thus how they ought to drive in towards the pallet tunnels.
Appendix I

Flow of the Autonomous Positioning

The following figure shows how the display interface changes during the Autonomous Positioning (see Figure I.1). When no specific functions are activated the home screen is shown on the display. If the driver wants to activate the Autonomous Positioning he clicks on the AUTO-button, and the display shows a larger symbol of the AUTO-button for a short time (2 seconds). In addition, a notification sound appears from the display to notify the driver that the Autonomous Positioning is activated. The projected path that the truck will take is then shown, until the truck is done with the positioning. The driver can choose to cancel the positioning by clicking on the return button in the bottom right corner. When the control is regained by the driver, a driver control symbol and a notification sound is played to notify the driver that he has regained control of the truck.
Figure 1.1: a) Home screen. b) The AUTO-button is clicked. c) The truck goes into AUTO-mode. d) The projected path is shown until the truck is positioned, the driver can abort by clicking on the return button. e) The driver regains control.
Appendix J

Resulting Kansei Score

After further developing and verifying the concept with developers at BTP and drivers, a final Kansei score for the result was calculated by the authors, see Figure J.1. The grading for the identified situation can be seen in the column "Situation"; at the bottom of the column is the total score, and below this (in grey italicised text) is the score that the situation would have received if the same words had been blank as are blank for the concept. The resulting concept is scored in the column "Result". As can be seen, the resulting Kansei score is 4,242 (or 4.889 if the Kansei words that do not apply are excluded).
### Resulting Kansei Score

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</tbody>
</table>

Figure J.1: Here the Kansei scores of the original situation and the resulting concept are compared. As seen, the concept has greatly improved the Kansei.
Appendix K

Resulting Illustrations

Two illustrations were made of the final concept design: one for the warning and stop system, and one for the Autonomous Positioning. An illustration for the warning and safety system can be seen in Figure K.1. In the illustration it is called EIA, which stands for Effective Interceding Action.
Figure K.1: Final concept illustration: Effective Interceding Action.
The illustration for the Autonomous Positioning can be seen in Figure K.2.

Figure K.2: Final concept illustration: Autonomous Positioning.