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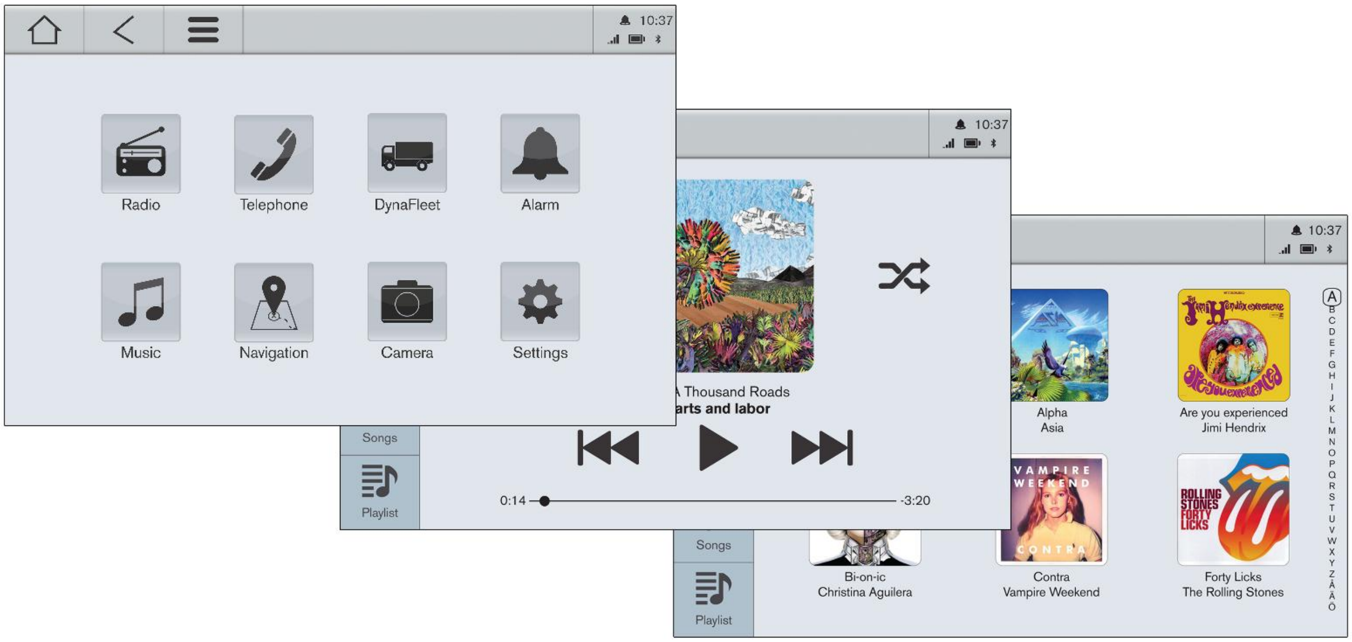


# Investigation and design of future touch interfaces in trucks

*Bachelor's thesis in Engineering, Industrial Design*

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Gothenburg, Sweden 2014

# Investigation and design of future touch interfaces in trucks

# Utredning och utformning av framtida touch-gränssnitt i lastbilar

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**Cover**:
The cover shows the final concept for the touch-based user interface. For more information, see chapter 8. FINAL CONCEPT DEVELOPMENT.

**Publisher**:
Department of Product- and Production Development.
Göteborg, Sweden, 2014.

# FÖRORD

Detta arbete utfördes som examensarbete (15 hp), som en del av Designingenjörsprogrammet på Chalmers Tekniska Högskola, i samarbete med Volvo Group Truck Technologies. Arbetet genomfördes våren 2014.

Vi vill med detta förord tacka vår handledare Erik Ohlson och vår examinator Anna-Lisa Osvalder, som har bidragit med hjälp då det behövts. Dessutom vill vi även tacka Charlotta Roth och Björn Rehammar, som tillsammans med andra kollegor på Volvo, har tagit emot oss i företaget och varit hjälpsamma under hela våren.

# ABSTRACT

The purpose of this project was mainly to develop a touch based user interface, suitable for operations in the Volvo FH series. The project was carried out in Gothenburg, at Volvo Group Truck Technologies (Volvo GTT). The driving question of the project was to investigate whether it is possible to implement touch displays in the Volvo FH series, as well as providing Volvo GTT with design guidelines regarding touch screens in trucks.

In order to create a suitable interface several relevant theories as well as previous reports on the subject were summarized. Moreover, a variety of methods was used to achieve satisfactory results. Market research, benchmarking, system research and finally user studies were carried out, and the results were used as a foundation for the later concept development.

The project resulted in a final interface based on the previously gathered data, which ensured that the developed interface was well-suited for in-vehicle use. The project also delivered several guidelines to take into consideration when designing touch based interfaces for trucks.

The project further resulted in the recommendation that it was possible to implement touch displays in the Volvo FH series; if thoroughly considering safety aspects as well as offering both user value and usability to the drivers.

# TABLE OF CONTENTS

# LIST OF ABBREVIATIONS

CW = Cognitive Walkthrough
DID = Driver Information Display in the Volvo FH-model
ECW = Enhanced cognitive walkthrough
GUI = Graphical User Interface
HTA = Hierarchical task analysis
NHTSA = National Highway Traffic Safety Association
OS = Operating System
R&D = Research & Development
SID = Secondary information display in the Volvo FH-model
SWJ = Steering wheel joystick
SWS = Steering wheel system
UI = User Interface
Volvo FH = Volvo Front High (Largest model cf. FM= Front Medium and FL = Front Low)

# 1. INTRODUCTION

Looking back to the year of 2007, when one user-friendly touch phone was introduced on the market (iPhone Keynote Complete, 2007), it was unbelievable that touch technology was to revolutionize modern society in the ways it did. A few years after the introduction, every mobile phone producer were rivaling for market shares with their own equivalent products. Worth noticing is that touch technology and touch phones has existed before 2007, but its acceptance among society was postponed due to several reasons. One reason could be that initial touch phones were resistive instead of capacitive which made interaction more difficult.

The use of touch displays has gradually been accepted and integrated into modern vehicles, where applications of those displays have been everything from operating sound- and navigation systems to providing in-car phone calls. The integration of such technology has over recent years completely flourished in automotive industry, and with its potential, the customers of tomorrow seems to demand it in an even wider scale than before (Yi, 2013).

The Cab Interior division at Volvo Group Trucks Technology is responsible to develop new interiors and driver environments for Volvo Group's different truck brands and to maintain today's products that are already in production. Being a part of modern automotive industry, Volvo Trucks is investigating the potential of touch technology in the driver environment of trucks. Therefore a thorough investigation regarding this implementation will be carried out.

## 1.1 Aim and Purpose

The purpose of this project is to investigate if it is possible to create a touch interface that is intended to be used while driving a truck, and to develop a conceptual touch display interface for the Volvo FH truck. The fulfillment of these goals will act as a springboard for future Volvo Truck design guidelines and lay the foundation for further research and development.

At the end of the project Volvo Trucks will be provided with information about:

- If it is possible to implement touch displays in the Volvo FH-series, and how to succeed with this
- Benchmarking data about competitors' products in different fields
- Design guidelines for touch screens in trucks

## 1.2 Limitations

In order to meet the above stated purpose and goals, several limitations will have to be taken into account.

The final user interface will not be programmed; this will instead be done by Volvo professionals. Marketing and benchmarking will not be of primary concern. The focus will rather lie on the development of a conceptual user interface and a simple prototype, along with developing a list of design guidelines. Moreover, the user interface will mainly focus on controlling four functions that currently exists in the SID. These functions are stated below.

- Call a contact with the SID, when already having paired a smart phone via Bluetooth
- Make a phone call by entering a ten digit telephone number
- Tune radio and add favorite
- Play music via USB/iPod

Furthermore the environmental aspects will not be of major concern as the project will be on a more conceptual level. However, sustainability aspects will be considered briefly.

In order to achieve a satisfactory result in such a wide variation of topics and to regulate the projects goal to the available time, this project will strive to investigate far and wide rather than in-depth. The main focal point will be on the development of the design guidelines and the conceptual user interface, and therefore the use of previous research is needed. In addition, Volvo Typefaces and colors will be used together with a screen resolution of 1280 x 800 pixels (due to evaluation purposes) in the final interface.

## 1.3 Deliverables

The intention of this project is to answer the question: "*Is it and how is it possible to create a touch interface that is intended to be used while operating a truck?*".
This project will deliver:

- Material for benchmarking and market analysis
- An investigation of the current UI in the Volvo FH truck
- User studies conducted on subjects that are already familiar or associated with the Volvo FH truck
- A touch screen user interface concept suited for the Volvo FH truck
- Design guidelines for touch screens in trucks
- An evaluation of the results and used methods
- An oral presentation and a written report

## 1.4 Time plan

The time plan that was used in the project is presented in form of a Gantt-chart (see appendix, A1) together with an explanatory table (see appendix A2). The project consisted of five phases (as can be seen in Fig.1 below).

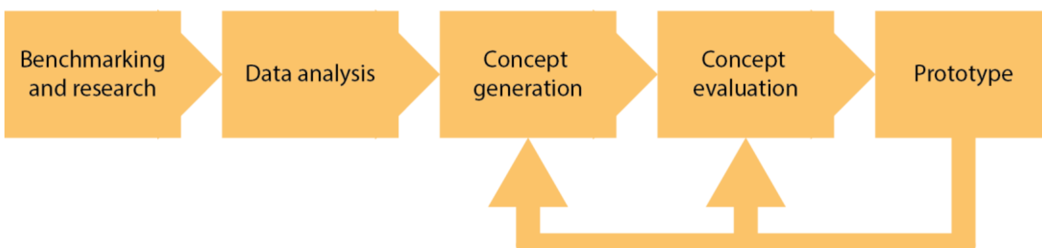


Figure 1: Work flow: the arrows symbolizes the iterative process

The first phase of the project was the *Benchmarking and research phase*, where data was acquired and market analyses were carried out. The second phase was the *Data analysis phase*, where the gathered data was analyzed. The third phase was the *Concept generation phase*, in which naturally, the concepts were generated. The developed concepts were finally evaluated in the *Concept evaluation phase* and simple prototypes were created in the *Prototype phase*. The two final phases were both iterative phases to ensure the best possible concept. Furthermore, continuous documentation was also carried out throughout the whole project. For further information and specific dates regarding milestones and completion of the different phases, please refer to the Gantt-chart (appendix A1).

## 1.5 Disposition

The next chapter of this report *(2. THEORETICAL BACKGROUND)* will examine relevant material from theories and other scientific reports which will lay the foundation for the areas that will be processed. In addition, this chapter will also contain factual information and sources for further reading regarding the science behind information processing and attention, interface design and touch technology in modern vehicles.

The chapter following the theoretical background (3. METHODS) will present the chosen methodology for the earlier described work process. Thereafter a chapter containing the results (4. RESULTS) will follow, where all results, except for the development of concepts and design guidelines, will be presented. The results will be disclosed in the same order as the methods chapter, meaning that the described method (for example 3.2) will be presented under the subsequent result chapter (which in the said example will be presented in 4.2.).

To summarize the theoretical background and the results chapter, design guidelines for touch screens (5. DESIGN GUIDELINES FOR TOUCH SCREENS IN TRUCKS) will follow after the results. Moreover chapters addressing the concept development phase (6. CONCEPT DEVELOPMENT) and the concept evaluation phase (7. CONCEPT EVALUATION) will follow after chapter 5. After the concept evaluation there will be a chapter presenting the final concept (8. FINAL CONCEPT DEVELOPMENT). Finally a discussion (9. DISCUSSION) followed by the final conclusions (10. CONCLUSION) will be presented.

# 2. THEORETICAL BACKGROUND

This chapter consists of the theories that are intended to be used as a way of evaluating and as a basis when later generating the “deliverables” (see chapter 1.3), especially focusing on the development of the touch based UI and the design guidelines for touch screens in trucks. Therefore, the theoretical background will firstly present the Volvo FH model (2.1), secondly examine *information processing and attention* (see 2.2), thirdly address *design guidelines* concerning GUIs (see 2.3), and lastly investigate *incentives for touch implementation in trucks* (see 2.4).

## 2.1 The Volvo FH model

The Volvo FH model (see Fig. 2 below) is the most powerful and among the top tier of trucks in the world. The FH 750 is currently the strongest truck in the world, with 750 horsepower and a total torque of 3550 Nm (Volvo, 2014a). Volvo has always been concerned about safety both for the driver and for others travelling the road. The Volvo FH is no exception to this line of thought, as security and Volvo safety features is prioritized highly.

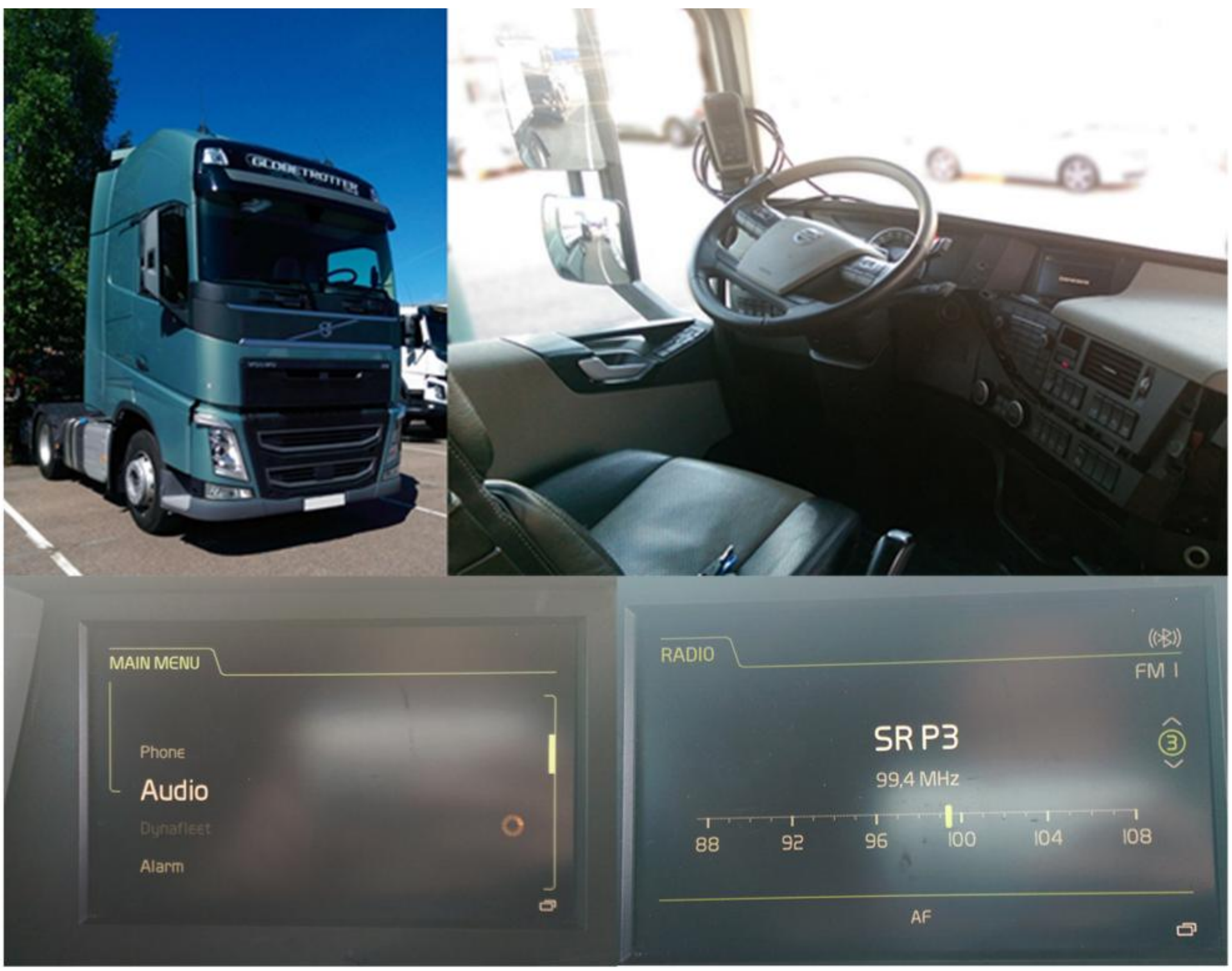


Figure 2: The Volvo FH and its interior environment

Furthermore, the FH-series is aiming to cut down fuel consumption while still accommodating the driver with a spacious cab interior. The FH features Volvo's appreciated I-shift system that automatically changes gear and is now also equipped with the ability to "remember" hills and slopes, thus optimizing the gear shifting the next time the truck encounters the same road conditions (Volvo, 2014b).

The cab interior has always been a focus for Volvo, since the drivers will spend a large amount of time inside the truck, wherefore this time should be as comfortable as possible. With features such as I-ParkCool (which keeps the cab cool, even when staying parked) and the large spacious cab, the driver should feel satisfied while inside the FH (Volvo, 2014c).

The Volvo FH has a Secondary Information Display (SID) which allows the user to access functions such as the radio and navigation system, or if synced via Bluetooth, the contacts in the users' phones, together with the possibility to make calls via the UI for the SID. In figure 4 on the previous page, example screen shots (the main menu and the radio interface) of the SID are displayed. The project will henceforth address the SID as a system, and thereafter the development of a new touch UI for some of the functions in the current SID.

## 2.2 Information processing and attention

The human processing of information can be described, in accordance to Wickens et al. (2004) by the model in Fig.3 below.

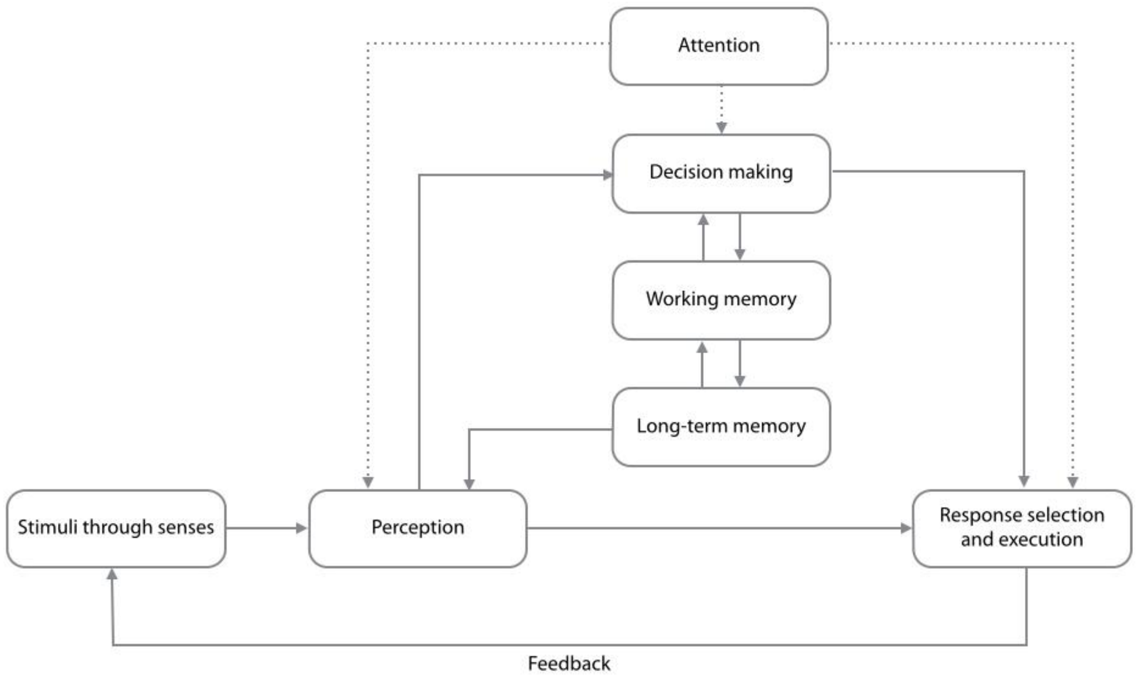


Figure 3: Model of information processing

First and foremost, information is received through human senses, for example via auditory, visual and tactical stimulus. Thereafter the stimulus is processed and perceived, initially by analyzing the actual stimulus. The perception of this information can occur in different ways or combinations of ways.

The stimulus can be perceived through *top-down processing*, where decisions and responses are made based on earlier experiences and knowledge of the specific situation or stimulus. In top-down processing, information is gathered from the long-term memory. The decision making and response can also be made through *bottom-up processing*, where the decisions are mainly based on the nature and quality of the sensed stimulus. When humans are becoming increasingly familiar with a specific situation, or task, the perception can become *unitized*, thus creating an automatic behavior where the processing proceeds to response selection and execution directly.

To be able to succeed with the perception of a specific situation, *attention* has to be allocated, either through *selective attention* or *divided attention.*

*Selective attention* can be defined as a way of allocating the attention, and concentrating the mental capacity on different sources of information or channels, for shorter periods of time (Osvalder & Ulfvengren, 2010). The selection of those channels is, according to Wickens et al. (2004) based on four elements. These elements are summarized below:

**Prominence of the stimulus**
Especially auditory, tactile and distinct stimulus can be seen as prominent stimulus. This can for example be observed in the so called "cocktail party phenomenon" (Osvalder & Ulfvengren, 2010). In this phenomenon a cocktail party with an ongoing normal conversation is envisioned, when suddenly the attention of the studied person is interrupted by someone (not attending to the conversation) mentioning said person's name.

**Expectations**
Earlier knowledge and top-down processing effects the choice of the attention channel. Scenarios including a person who is expecting to find specific information or input of stimulus are important factors to consider.

**Required effort of the stimulus**
If it requires a lot of effort to choose a specific channel, humans tend to avoid those channels.

**Quality of the stimulus**
If the quality of a stimulus is insufficient, or irrelevant to a person, that specific stimuli could easily be disregarded.

Another allocation of attention is instead *divided attention*. Osvalder & Ulfvengren (2010) describes this as the ability to consider and perceive stimulus from different channels at the same time. Divided attention is according to Osvalder & Ulfvengren mainly dependent of the following three factors.

**Resource demands**
When handling complex or demanding tasks, it is correspondingly hard to succeed with handling another task at the same time. In addition, divided attention can be more easily supported when one of the tasks are automated (Wickens et al., 2004).

**Resource similarity**
If the required mental resources are the same, divided attention can be difficult. For example, monitoring several dynamic information sources (via visual stimulus) can be hard.

**Task management**
If the time is allocated optimally, it can be possible to succeed with divided attention of multiple tasks.

## 2.3 Design of interfaces

Osvalder & Ulfvengren (2011) defines 13 basic design principles regarding visual interfaces that better supports attention, perception, memory and the mental models of users:

### Attention

**1. Minimize the effort to find information**

For example, frequently used information should be positioned in a logical and intuitive manner, preferably close to the user, and related objects should be grouped.

**2. Multiple information sources**

When presenting several information sources on a single screen it can be beneficial to group and colorize related information with the same color or using lines and arrows to define the related information sources. However the screen should not be clattered with information.

**3. Use a multimodal approach for interaction**

If several information sources are required on a screen, it can be advantageous to use a multimodal approach for interaction, meaning for example to complement visual stimulus with auditory- or haptic stimulus.

### Perception

**4. Displays should be easy to read**

A good ratio between the light/illumination, contrast and the viewing angle is required.

**5. Avoid using many levels when the user is intended to evaluate information**

An object on the screen should not be able to adopt more than five levels. For example, if the user of the interface is intended to evaluate the size or thickness of an object, and those variables can vary in more than five levels, it could be difficult for the user to process. A maximum of three levels is recommended.

**6. Avoid only top-down processing of information**

For the user to better perceive the provided information on a screen, information should be shown in accordance to the users' expectations, and when needed, the information should be clarified to better conform to bottom-up processing.

**7. Use redundant information**

If the user of the interface is provided with redundant information, misinterpretations can be avoided. For example objects or symbols could be complemented with text. A multimodal approach could also be preferable.

**8. Avoid similarities between objects**

Objects that are designed in different ways and/or constructed to be implemented differently should be clearly distinguished from each other. This especially applies when there is a risk that the user might misinterpret the information and/or the data that are linked to the objects.

## Memory

**9. Avoid sole use of user memory**

It is preferable to minimize the amount of information that the user is required to remember during a short period of time, or retrieve from the long-term memory. Information that can be comprehensively presented should be shown in the interface, based on the concept "Knowledge in the world". However a good system will provide possible ways for both the expert- and novice user. Therefore a good equilibrium between the concepts "Knowledge in the world" and "Knowledge of the user" is required for a well-designed interface.

**10. Provide the user with system status**

The interface design must minimize mental workload by presenting the user with adequate system status and feedback, both for real time events and future consequences of possible actions.

**11. Design with consistency**

Based on instincts or pre-learned patterns of behavior, a user can perform incompatible actions in an, for the user, entirely new interface. Therefore it is essential to create an interface that interacts well with, and corresponds with the user's pre-conceived expectations and requirements. Furthermore a consistency in the design pattern and the logical structure of the interface is crucial to make the user experience intuitive.

## Mental models

**12. Object in conformance with reality**

Objects in the interface, (such as icons and illustrations) should relate to realistic objects known to the user. However, the implication of this guideline should be in accordance with "illustrated realism", meaning the symbolic meaning of the objects should conform to the perceived reality of the user. This is partly culturally conditioned.

**13. Dynamic objects and information**

The dynamics of objects and information should conform to the user's mental model of said objects. For example when scrolling through a digital document on a tablet, the swipe movement for proceeding through the document should be upwards, thus corresponding to a notional rotational direction of a scrolling wheel.

Wickens et al. (2004) highlights a model originally created by Norman (1986), called the *Seven stages of actions*. The model consists of two "bridges": the *execution bridge* and the *evaluation bridge* (as can be seen in Fig.4 below)

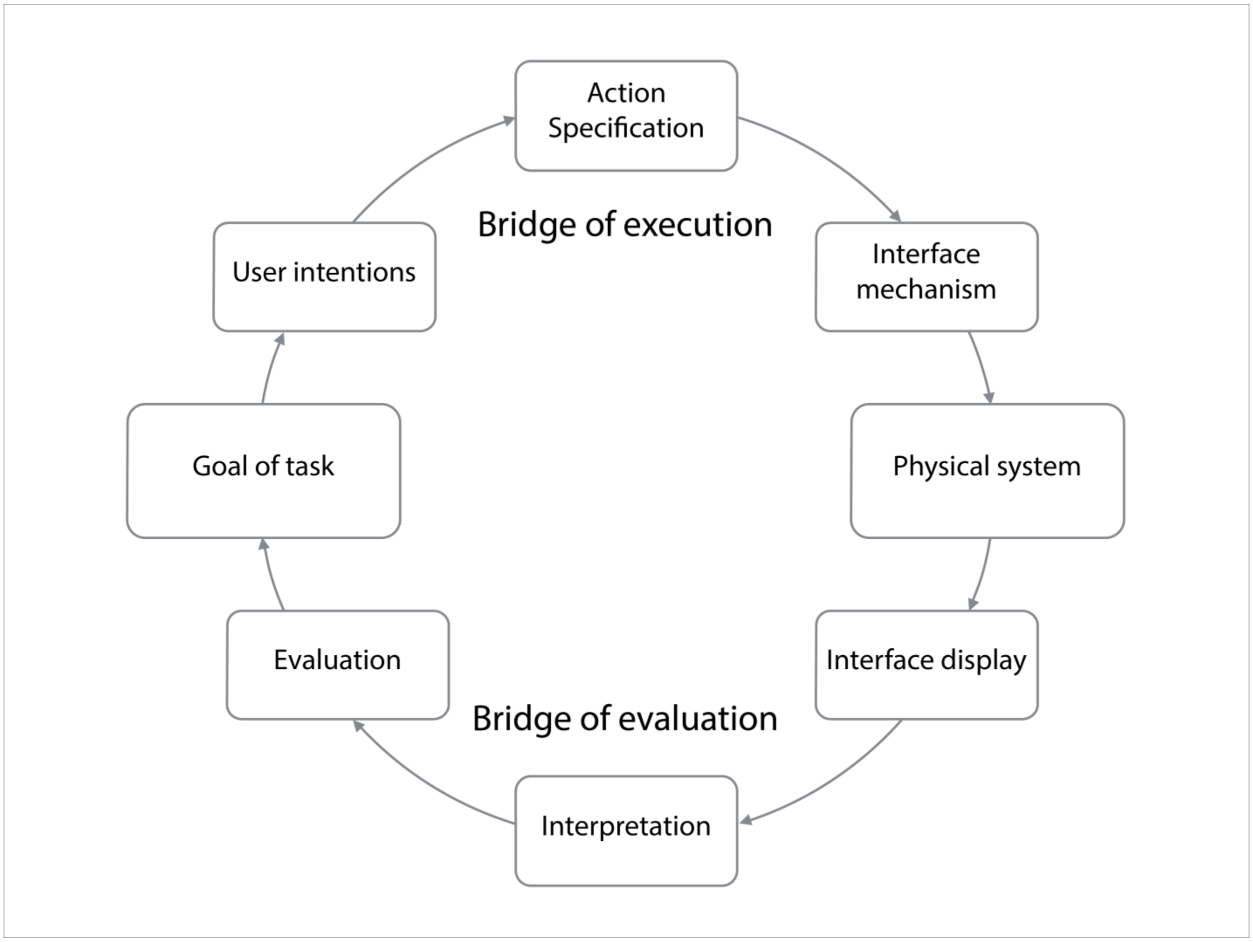

Figure 4: The seven stages of actions

Firstly the user intends to accomplish a certain goal or task. In order to do this, the user has to decide his/her incentive and intentions, specify the required actions to accomplish the goal and actually perform the intended actions in the interface. When doing this the user has to climb the *execution bridge* (which can be seen at the top of Fig. 4), which symbolically represents the non-conformance between the user's intentions and what actions the interface allows the user to perform.

When having performed the intended actions the user instead climbs the *evaluation bridge* (which can be seen at the bottom of Fig. 4), in which the user gets input from, for instance, a display, interprets that input and finally evaluates the initially intended goal. This bridge also symbolically represents the gap between what the user expects the system to do and what the system actually does.

Wickens et al. (2004) states that if an interface is designed with regard to all the *seven stages of actions*, where the goal is to make all steps intuitive and easy for the user, it is possible to minimize these non-conformances between the user and the interface. Wickens et al. (2004) further describes that the non-conformances can be dealt with by creating an effective mental model for the user. In order to accomplish this, an interface must be made predictable for the user, so that the users' intentions and actions match the outcome of that interface. Mayhew (1992) suggests that an effective mental model can for example be achieved by designing a UI with respect to one or several of the following conceptual models:

### Clarify or make hidden structures and processes visible

A system should provide the user with cues regarding how to perform a desired task.

### Design with consistency

By implementing design patterns and structures that are consistent throughout the whole interface it is credible that the users will create a strong mental model of that specific interface.

### Provide the user with feedback

It is vital that the users understand what consequences different actions has in an interface and therefore the system should provide sufficient information regarding the process or the status of the sequence.

### Design with metaphors

If an interface is designed with a metaphor, that is implementing elements or conventions from reality or a, for the user, well-known system, it could support the mental model of the user.

A study made by Nielsen (1994) investigated different proposed heuristics, or principles for interaction design, in an effort of matching the heuristics with real usability problems. The study culminated in new design principles. The principles applicable to design of touch UIs in trucks are summarized in accordance to Nielsen hereinafter.

### Visibility of system status

The user should be provided with appropriate, timely feedback and be informed about the system status regardless of what action is carried out. The system should also indicate task progression. Furthermore features, such as functions or visual indicators should not be hidden from the users.

### Match between system and real world

An interface should use the same language as the user as well as being constructed in such a way that it "understands" and follows cultural or real-world conventions, symbols and metaphors.

### User control and freedom

It should be made easy and possible to undo and redo actions. Construction of irreversible consequences or actions should be avoided when possible. Moreover exit actions should be distinguished from other actions and the users should be in control.

### Consistency and standards

UIs should be consistently designed throughout the entire interface, meaning that same objects should look the same and be expressed in the same manner. In addition, menus or information recurring on different screens should be shown at the same place and keys should also be designed consistently, focusing on creating a few generic commands for use throughout the whole interface.

### Error prevention

A proactive approach to errors should be used, and it is of importance to prevent errors from occurring at all. Furthermore it is vital to understand what mistakes the user can make when performing different actions.

### Recognition rather than recall

Possible actions should be made clear and all the user requires should be made generally accessible. Furthermore the memory load of the users' should be minimized and a "see-and-point" approach should be applied instead of a "remember-and-type" approach, meaning that it is inconvenient for users' having to remember too much.

### Flexibility and efficiency of use

If appropriate, shortcuts and individual user customization should be possible and the interaction with the system should be efficient, natural and logical.

The most recurring heuristic principles which can be found in Nielsen's study are the following: "Consistency", "Speak the user's language", "Show receipt of user's input", "Seeing/pointing vs. remembering/typing" and "Aesthetic integrity, keep design simple". These five heuristics can therefore be seen as especially important.

In addition to the above stated design principles and guidelines a guideline for the minimum typeface size, as a function of the distance away from the screen, would be advantageous. Wickens et al. (2004) describes this guideline as the "*James Bond rule"*, where the height of the text, divided by the distance away from the screen should be equal to or bigger than 0,007

## 2.4 Incentives for touch technology in trucks

The main focus regarding the integration of touch interfaces in trucks is to realize that safety always is to be considered as the primary objective. Kern & Schmidt (2009) states that task *driving* can be divided into three levels. The main or primary level in driving is simply to maneuver the vehicle and be in control over the driving environment.

The secondary level consists of tasks such as steering and notifying other drivers when for example changing the lane. Kern & Schmidt concludes that infotainment and other interaction in cars are to be seen as *tertiary tasks*, thus not being necessary for the task of driving. This indicates that it is vital that these tasks do not affect the attention significantly. Wickens et al. (2004) also notes that the predominantly most important factor that affects safety during driving are tasks that diverges the driver's visual attention away from the primary intended focal point during driving (which is referred to, and further described by Wickens et al., as the PVAL).

One of the main advantages of using touch screen interfaces in vehicles is the speed of which tasks can be carried out. A kinetic scrolling (i.e. scrolling with the help of a kinetic force in a manner that allows the user to scroll after the touching of the screen has stopped) is much faster than scrolling with the more traditional "one button press equals scrolling one step" (Burnett et al, 2011). However, with this increase of speed, which leads to a faster task completion time, a loss and decrease of accuracy seems like a valid trade-off, as hypothesized and concluded by Saariluoma and Kujala (2011) in their report *"Effects of menu structure and touch screen scrolling style on the variability of glance durations during in-vehicle visual search tasks"*.

Despite this trade-off, touch screens often bring the potential for a more diverse feature palette, which makes it an interesting option to make available in vehicles. Burnett et al. (2011) investigated the use of a rotary dialer, a touch screen and a touchpad to examine which of these devices are most suitable for use in a driving situation, where safety is critical. Burnet's et al. main focus however was to see which tasks a touchpad would be best suited for. Despite this focus, the research was seen as applicable for this report.

Burnett et al. (2011) tested several different tasks and measured the time it took to complete the tasks. The test subjects were also asked which device they felt most comfortable using and which device they thought was the safest during driving. The touch screen proved fastest in four of the seven tasks, and scored second in the remaining three; the rotary dialer was always the slowest. In the question "How comfortable did you find it to use the input device while driving (where 1 = very uncomfortable and 5 = very comfortable)?" the touchscreen scored a 4 median rating and the rotary dialer a 2,5. In the question "How safe did you find it to use the input device while driving (where 1 = very unsafe; and 5 = very safe)?" the touchscreen scored a mean value of 3 while the rotary dialer scored a mean value of 1,5.

Klauer et al. (2006) suggests that visual distractions are key components in many crashes and near-crash scenarios that take place. Since traffic and driver safety are core values and one of the top priorities for Volvo (AB Volvo, 2012), this is an important aspect to take in consideration. This together with the results from Burnett et al. (2011) study suggests that touchscreens in vehicles are possible. However the implementation of them must be done correctly, with a solid foundation in safety and security for both the user and the environment in which the user travels.

The National Highway Traffic Safety Administration (NHTSA, 2012) has presented several guidelines to ensure the safety and well-being of drivers and other in close vicinity to vehicles. These guidelines consist of several recommendations regarding glance time (i.e. the time it takes to "glance" at the infotainment module, or any other tertiary task, thus taking the eyes of the road) and distractions. Beneath follows a few, as stated by NHTSA.

- 85% of individual glance durations should be less than 2.0 seconds
- The mean of individual glance durations should be less than 2.0 seconds
- The sum of individual eye glance durations to complete a task should be less than or equal to 12.0 seconds

Taking these guidelines into consideration when designing a touch user interface would certainly help reducing the amount of time the eyes are off the road, thus making safety a paramount aspect. However, to evaluate a user interface in accordance with NHTSA's guidelines extensive research and testing will have to be instigated, which was seen as outside the scope and time period designated to this project.

Another important aspect to take in consideration is the recognition factor of a touch user interface. Surveys has concluded that approximately 22 % of all people globally now carry smartphones (Heggestuen, 2013), which is a percentage that is substantially higher in developed countries (mobiThinking, 2014). Furthermore, these are rapidly increasing numbers as new record sales from smartphone companies are reported annually (Reuters, 2014). This recognition factor of the user interface could potentially play a huge role as people are more likely to be familiar with the structure of things they already know (Mayhew, 1992). A curious case of this phenomenon is the QWERTY-keyboard layout. The original QWERTY-layout was set in such a way because of the mechanical limitations of the existing typewriters (Baker, 2010). However, even though these limitations do not exist anymore and that the world has progressed into using mostly computer keyboards (which theoretically could have any key layout that the user wishes for), the QWERTY-layout is still the most used today.

Despite that August Dvorak in the early 1930's pointed out several flaws with the QWERTY-layout and therefore created his own keyboard layout, which arguably was more efficient, the QWERTY-layout still continued to be the most used, since the users already were familiar with it (Baker, 2010). This further supports the claim that once people get used to handling systems or interfaces in one way, it is hard to change it; though not impossible which the introduction of touch interfaces in cellphones, and the markets rapid adaption to this introduction prove.

A problem with many existing infotainment systems in vehicles today is that they are cluttered with information and cramming too many objects onto a small screen. Another problem with the currently present infotainment modules in vehicles is that many manufacturers seem to want to reinvent the wheel, and thus not offering a natural user interface for the user (Diewald et al., 2011). Diewald et al. (2011) further states that *"natural user interface paradigms are still not standardized and, for that reason, people have to get used to each different system they use. It can be observed that most users are more familiar with the handling of their mobile devices, than with handling different in-vehicle infotainment systems. Especially while driving, it is important that the user can interact with the IVI [in-vehicle infotainment] without having to concentrate on the handling itself."* A natural and familiar way to interact with the IVI system is therefore desirable.

One of the advantages of a touch UI is the dynamic aspects of the system. The information is accessible when the user needs it and can be hidden away when not in use. An on-screen keyboard for example, can easily be summoned when the user need to type in text and otherwise remain out of sight, which frees up more of the screen. Steve Jobs famously promoted this idea when he first unveiled the iPhone in 2007 (iPhone keynote complete, 2007) and stated (paraphrased) that the *"problem with smartphones that have a dedicated keyboard is that the developer has locked in the functionality and has no way of adding more functions that require more (or less) keys."*

Moreover, another large convenience of a touch interface is the ability to update the system in the truck, for example by adding functionality (such as new buttons or menus) or fixing glitches. The developer could add a missing feature or add a new button if the users request it. This is much harder and considerably more expensive to do if new "hardware buttons" are required which would require submitting the truck to a workshop to have it upgraded. When using touch interfaces a software update could instead be applied quite easily.

Lastly, there is the matter of some applications and functions that natively works well with touch screens. An example of this would be Navigation. Navigation systems (GPS) have fully adapted the use of touch technology to the degree that it is seen as a very natural way to navigate the system successfully. With the ease of natural motions such as swiping, panning, pinching and zooming, navigation systems have fully utilized the means of touch technology. If instead trying to use a non-touch based navigation system, such a system with a keypad, this could be experienced as inefficient after having used a GPS with touch technology.

# 3. METHODS AND PROCEDURE

The methods chapter will be divided into eight different sub chapters, corresponding to the actual order in which the project was carried out. The following chapters will described the different methods in terms of how and why the chosen methods were used in the project.

## 3.1 Market research

In this chapter the methods that were used for market research are presented. The *PESTLE-analysis* (see 3.1.1) together with the *Power-interest grid* (see 3.1.2) constituted the methods used to analyze the *macro* environmental factors of the market. To further investigate the *micro* environmental factors of the market, a *Five forces* analysis (see 3.1.3) and a *Competitors analysis* (see. 3.1.4) was conducted. All the said methods were thereafter compiled into a *SWOT-analysi*s (see. 3.1.5). Furthermore, in 3.1.7, the *Sustainability considerations* applied to this project is briefly presented.

### 3.1.1 PESTLE-analysis

The letters in the word "PESTLE" represents Political, Economic, Social, Technology, Legal and Environmental factors (Chartered Institute of Personnel and Development, 2013) that might affect the product, the development/usage of it and the related organization. The PESTLE-analysis was used as a springboard to get a quick overview of a variety of different areas regarding touch technology and to lay the foundation for more in-depth research and methods. The method was conducted by doing basic research in the above stated fields and by examining how these fields related to touch technology in Trucks or Volvo Group Trucks in general. The method was chosen because of its wide scope and it was seen as an entryway to better understand the market prerequisites.

### 3.1.2 Power-interest grid

When having completed the PESTLE-analysis, data on an overall large scale was available. However, to narrow down the data to establish what areas to focus on, a power-interest grid was established. A power-interest grid is a stakeholder analysis, which is helpful when visualizing where power and interest among stakeholders are located (Norton, 2008).

A grid with two axes was drawn, where the y-axis symbolized the amount of power of the stakeholders, while the x-axis symbolized the interest of the stakeholders. The grid was split evenly into four quadrants: "Minimal effort", "Keep informed", "Keep satisfied" and" Key stakeholders". From previous data different factions were placed accordingly to which quadrant deemed adequate. For example, drivers wield a large amount power, but might not be extremely interested in a touch UI. However if the drivers do not like the touch UI it might bring consequences such as other brands being favored over Volvo; hence the drivers should be kept satisfied. When having visualized different stakeholders in these quadrants it was possible to allocate development resources accordingly.

### 3.1.3 Five Forces

To get more in-depth knowledge of the market conditions a Five Forces-analysis was conducted. The Five Forces-method is used to assess the market climate in an efficient manner by focusing on five different forces, namely what power different actors have (Porter, 2008).
The five different forces are Suppliers, Buyers, New entrants, Substitutes and Rivals. Furthermore, entry barriers and exit barriers of the market were taken into consideration.

In the Five Forces analysis the different forces or actors were graded in accordance to the amount of power they were considered to have and the grading were supported by explanations.

### 3.1.4 Competitor analysis

In addition to the five forces method (see 3.1.3 above) another competitor analysis was carried out to further comprehend and understand the competitors and the conditions on the market, as well as Volvo's, strengths and weaknesses. The competitor analysis was conducted by reading through various articles, reviews and factual texts to get a perspective both from a consumer point of view as well as a professional. A test of functions and the SIDs (or equivalent) of different truck brands, was also carried out. The data discovered was compiled into a table extending over several different aspects, such as interior, usability and technology.

**Journalistic study**
Since reviewers of trucks and automotive vehicles have a broad experience of driving conditions and what aspects of the truck to assess, reading through journalistic literature acted as guidance for the competitor analysis. Furthermore, since it would be impossible to personally investigate all of the competitors' models and trucks, reliance on other sources was a necessity. Different articles from a variety of magazines were chosen to enable a non-partial and objective perspective. The studied truck brands were Volvo, Mercedes, DAF, Scania and Man, since these are the main trucking manufacturers in Europe. The articles were finally summarized in a table, showing different categories of interest (driving experience, innovation, interior, usability and technology) for each of the truck brands, and conclusions were thereafter drawn.

**Test of interfaces in trucks**
In order to get a more hands-on perspective, physical investigations of different competitors' (the same competitors as described under "Journalistic study" above) trucks were also conducted. By visiting a facility in Torslanda, the investigations were made possible. The main focus in this study was to evaluate the competitors SID or equivalent to SID. Quick tests to try different functions were therefore carried out. The tested functions were for example *"Bluetooth pairing"* (when available), *"radio tuning and adding favorites"*. In addition, this investigation proved to further strengthen and validate the impressions stated by reviewers and drivers in different articles. This testing allowed for the creation of the positioning matrix (see 3.1.5 below).

### 3.1.5 Positioning matrix

Data that was collected about different competing brands was put together in a positing matrix (Axelsson & Agndal, 2012) in order to provide a visual overlook of the brands priorities regarding infotainment and dashboard maneuverability. The axes in the matrix were labeled *Usability* and *User value*. The different brands were placed along the axes, which ranged from low to high, in the stated categories listed in the previous sentence.

*Usability* in this context stands for how user friendly the different functions were considered to be and how much feedback the user receives from them. In a sentence, how easy and well designed the functions are.

*User value* stands for how much value the functions give the user, for example, a brand could have an excellent function in the SID that would tell the user to have a nice day every time the truck stops. This function could have excellent usability and design; however it would not provide the user with much real value. Well-designed useless functions are nevertheless useless.

The different brands (Volvo, Scania, Mercedes, MAN and DAF) were finally positioned in the grid to match the perceived overall usability and user value of the SID in the different brands.

### 3.1.6 Strengths, Weaknesses, Opportunities, Threats - SWOT-analysis

To compile the information gathered from previous market research, a SWOT-analysis (JRC European Commission, 2006) was deemed as appropriate. This analysis was done by listing the strengths, weaknesses, opportunities and threats, and thereafter categorizing them to be of *internal/external origin* and harmful/helpful.

Strengths and weaknesses, from an *internal* point of view correspond to those strengths or weaknesses that the product (the touch UI in a future Volvo Truck) would have on the market, while the *external* origin regarded what external (i.e. out of Volvos direct control) factors could do affect the product.

### 3.1.7 Sustainability considerations regarding touch technology

Furthermore, sustainability aspects of touch interfaces were regarded as a complement to the above market research methods. These aspects may be worth considering when further developing touch interfaces.

## 3.2 Benchmarking

With the purpose of investigating different UIs comprehensively, a variety of different touch UIs were examined. Devices specifically made for being handled on the road, such as GPS devices or Infotainment systems in cars were of particular interest. In addition to this, other devices, for instance smartphones and tablets, were also explored since these are common products of today that plays a critical role in future touch technology and user interface development.

The focus in the Benchmarking process was mainly to highlight particularly user friendly solutions to be used as references in the concept development phase, and secondary to describe complicated solutions in different interfaces.

### 3.2.1 GPS-devices

Many GPS devices are specifically designed with the intention of being used in a car or other motorized vehicles. It was therefore of interest to further investigate such devices to compare and examine what makes these devices different from the average smartphone or tablet.

The testing was carried out by visiting different electronic stores that had a vast amount of GPS devices and simply try the devices in the stores. The testing was filmed and often specific tasks, such as entering an address or changing settings, were performed. The tested GPS devices were the four following:

- Garmin Head-up
- Garmin Nuvi 2797 LMT
- TomTom Go 600 EU45 LMT
- Garmin Nuvi 3597LMT

### 3.2.2 Tablets and Smartphones

Since most people today are both experienced users of smartphones and tablets, it seemed important to also investigate such devices. The testing was done in the same manner as in *3.2.1 GPS-devices* with the exception that most people today carry around a smartphone in their pocket, so when the opportunity arose colleagues and other acquaintances phones were investigated. The following stated devices were tested.

**Smartphones**

- iPhone 5S
- HTC One M8
- HTC One M7
- Samsung Galaxy S3
- Samsung Galaxy S4
- Sony Xperia S

**Tablets**

- Lenovo Yoga Tablet
- Samsung Galaxy Tab 3
- Sony Xperia Tablet Z
- iPad Air
- iPad Mini

Other devices were also briefly interacted with but not tested in the same structured manner as the devices listed above.

### 3.2.3 Cars

Another object of interest was cars. Some cars today are equipped with a touch interface, often to different degrees, were Tesla for example has chosen to completely use touch for all controls.

The most important distinction to make between infotainment systems in trucks and cars however is that cars mostly are bought by private individuals whose prioritizing might differ from those of truck drivers/customers. A car can for instance be considered a status symbol, were a truck is mainly a logistics transportation device. It proved to be difficult to get an opportunity to try cars with these new technologies. It was therefore decided that the testing instead would occur strictly on a theoretical level, with no real interaction with the systems. With that said, the investigation was done by reading through articles, reviews and looking at videos of the cars. The investigated cars were the following four.

- Volvo XC90 - Apple CarPlay
- Tesla Model-S
- Mercedes C-class
- Google Car

### 3.2.4 New touch technologies

Apart from the previously stated benchmarking of touch technologies and devices, new experimental technologies were also investigated, with the intention to see if these new technologies could offer solutions to create a safe and functional touch UI for a truck. These technologies were found by reading through various technology blogs and other technology related news sources. Furthermore, some of these technologies were also proposed by colleagues and tutors. These new, more experimental technologies were considered as important to keep in mind for future development and projects that might be in need of creative solutions.

### 3.2.5 Other technologies

Technologies and solutions, such as head up displays, eye tracking and voice control, were also investigated with the intention of finding new creative solutions. Furthermore, these other technologies and solutions might prove resourceful in the future and were therefore deemed necessary to also consider.

## 3.3 System research

Before the conceptual phase could begin a thorough walkthrough of the existing systems, layouts and user interfaces had to be carried out. This walkthrough was made with a set of methods that will be described in this chapter.

### 3.3.1 Investigation of current layout

An important set piece in understanding the day to day basis of a truck driver was to get familiar with all of the different buttons, knobs and maneuvers that a truck driver uses on a daily basis. Therefore a mapping of the physical layout of the cab interior was deemed necessary. To do this mapping every button and function in the UI and in the cab interior had to be known, resulting in a lot of consulting with the driver's manual and a flash based program provided by Volvo (that contained a digitized copy of all the buttons and layouts). In this investigation it was also concluded which area that was considered suitable for adding a touch screen.

### 3.3.2 Current user interface in Volvo FH-series

In order to further familiarize with the existing user interface in the Volvo FH-model an explorative evaluation mostly by trial and error was executed. This explorative evaluation was done by performing different tasks in the UI and navigating the different functions and applications in the UI. The UI was thoroughly analyzed to make sure no vital functions were overlooked or neglected. This was an important step in identifying which functions existed and how they were used.

### 3.3.3 Hierarchical Task Analysis, HTA

A Hierarchical Task Analysis, a HTA, is method to describe and divide different tasks, e.g. "to tune the radio in a vehicle UI", into subtasks (functions*)* and subdivisions of the subtasks (operations) (Bohgard et al., 2011).

While investigating the current UI of the SID, it was discovered that some functions seemed to need a vast amount of steps to be done correctly. To map out exactly how these functions were carried out, to get a wider understanding of the UI itself, and to find possible unnecessary operations, several HTAs were executed. The created HTAs were also intended to be used as a basis for further analysis and ultimately for the evaluation of the final concept.

However a minor modification was made to the HTA methodology, to further explain the functionality. This was done by supplementing each user operation or action in the HTA with a "prompt box" describing the outcome of that specific operation. Furthermore, an "or"-symbol was added to clarify when the tasks could be approached and performed in various ways. This modified HTA methodology will hereafter be known as *Action/Promt based HTA*. To further understand the modification to the original methodology, please refer to the result of the HTAs (see 4.3.3)

The Action/Prompt based HTAs investigated the following functions/tasks in the SID:

- *Bluetooth pairing of Android and the truck*
- *Call contact in the SID with an Android smartphone (HTC ONE) with smartphone already paired*
- *Call contact in the SID with an iPhone (while another cell phone is connected)*
- *Make a phone call with Android Smartphone*
- *Make a phone call with iPhone already paired*
- *Tune radio and add favorite*

The Action/Prompt based HTAs were carried out by performing the tasks above and thereby becoming familiarized with the UI of the SID (as well as recording data of how many steps each function required). The notes were then digitized in a list format and made graphically visualized in Adobe Illustrator.

### 3.3.4 Heuristic Evaluation

Xerox has developed a method called "Heuristic Evaluation - A System Checklist" (Pierotti, n.d.). This method was applied to the project in order to extract information regarding different areas of the UI and the human-machine interaction of the system.

The method consists of a large checklist that enables the person analyzing to answer either "Yes", "No" or "N/A" (if the question is not applicable to the investigated interface) to a series of questions regarding the heuristics of the interface. There is also a section in the checklist where more specific comments and concerns (related to the individual questions) can be placed. The questions in the checklist are split in 13 different categories such as, *"Visibility of System Status", "Aesthetic and minimalist design" and "Privacy".*

The Heuristic Evaluation was chosen because it is an empirically tested method that has been used extensively by Xerox and other companies. The evaluation also offers a wide range of specifically targeted questions to enable improvements of the UI interaction.

The Heuristic Evaluation was conducted on site, using the interior interface of a Volvo FH-truck. The evaluation consisted of general testing of the truck's basic UI functions, thus providing data for the completion of the checklist. The checklist was later compiled into a written summary containing the most important conclusions and comments of the evaluation. Examples of the questions in the Heuristic Evaluation can be found in the appendix (A3).

### 3.3.5 Enhanced Cognitive Walkthrough, ECW

With the Action/Prompt based HTAs as a basis, an Enhanced Cognitive Walkthrough, ECW, was conducted. An ECW aims to identify existing usability problems in a UI (Bligård & Osvalder, 2013). The method is based on the *functions* and *operations* of a HTA, for each of which questions are answered regarding the usability. The questions in an ECW are divided into two different levels: a first level to analyze *functions* and a second level to analyze individual *operations* of a HTA.
The questions on the functional level are, according to Bligård & Osvalder:

1. Will the user know that the evaluated function is available?
   *Does the user expect, on the basis of previously given indications that the function exists in the machine?*
2. Will the user be able to notice that the function is available?
   *Does the machine give clues that show that the function exists?*
3. Will the user associate the clues with the function?
   *Can the user's expectations and the machine's indications coincide?*
4. Will the user get sufficient feedback when using the function?
   *Does the machine give information that the function has been chosen and to what position the user is in the interaction?*
5. Will the user get sufficient feedback to understand that the function has been fully performed?
   *Does the user understand, after the performed sequence of actions, that the right function has been performed?*

Through answering the questions above various usability problems on a functional level can be identified, which can then be categorized into different *problem types*. The problem types that were used are stated below:

- (U) User
- (H) Hidden
- (T) Text and icon
- (S) Sequence
- (F) Feedback
- (M) Missing function

For each of the usability problems, the problem *seriousness* was related on a scale between 1 and 5, to describe how likely it was for the user to succeed with the task. On this scale, the grading 1 corresponded to a poor chance of success while the grading 5 corresponded to a good chance of success.

Only the functional level was considered in the conducted ECW-analysis, mainly to get an understanding of which usability problems that existed in the system as a whole rather than examining problems with individual operations (such as button presses). This delimitation was done in order to streamline the analysis and to focus on what was considered important for the later development of a touch UI. An ECW was carried out for the following tasks:

- *Bluetooth pairing of Android and the truck*
- *Make a phone call with Android Smartphone*
- *Make a phone call with iPhone already paired*
- *Tune radio and add favorite*

The result of the two ECWs was compiled and structured in different tables for each investigated function. Lastly the results were compiled in a matrix to show where the largest problem areas resided. A summary of the analysis and an example showing how the method was applied can be found in the appendix (A4).

### 3.3.6 Predictive Use Error Analysis, PUEA

By using the results from the Action/Prompt based HTAs, Predictive Use Error Analyses, PUEAs, could be carried out. The PUEA methodology aims to assist when identifying and predicting possible user errors and uses a HTA as a springboard for this purpose (Bligård, 2012). Like ECW, this method provides the analysts with questions on a *functional* and an *operational* level of the HTA. These questions are presented, in accordance to Bligård, in Table 1 below:

Table 1: Questions in a PUEA

| **Level 1: Analysis of tasks/functions** | **Level 2: Analysis of operations** |
|---|---|
| What happens if the user performs an incomplete operation or omits an operation? | What can the user do wrongly in this operation? |
| What happens if the user performs an error in the sequence of operations? | What happens if the user performs the operation at the wrong time? |
| What happens if the user performs functions/tasks correctly but at the wrong time? | |

The above questions are intended to be a guideline when investigating possible user errors. According to Bligård the method proceeds by firstly relating each arisen error with an error type and error cause classification. The possible error types and causes can be found in Table 5.7-5.8 in the thesis *Predicting mismatches in user-artefact interaction - Development of an analytical methodology to support design work* (Bligård, 2012). Bligård further describes the steps of the methodology after having classified the errors into error types and causes. For each user error both a primary- and secondary consequence are to be investigated, followed by an investigation of how the error is detected, what steps are required for the error recovery, how well the user is protected from the primary and secondary consequences and lastly how the error is prevented or could be prevented.

In the appendix to Bligård's thesis the reader is also presented to example studies that use the PUEA methodology. In an example of a PUEA, where the studied product was kitesurfing equipment, the analysts succeeded, through the method, to identify 88 % of the user errors later observed in an observational study. PUEA can therefore be seen as a method to detect possible errors without having to extensively perform many usability studies on the subject. Nevertheless, by studying the tests in the appendix of the said thesis it appears that the best result of the method is obtained by combining it with other methods such as ECW, to cover other usability problems not detected in the PUEA.

However, in this analysis the three following steps were disregarded from the original methodology, due to them not being applicable, within reasonable circumstances, for the specific tasks involved in the study:

- The secondary consequences of the error (4)
- The detection of the error (5)
- The protection from the consequences of the error (7)

To clarify, the studies "reasonable circumstances" (mentioned above) does not include errors made during tasks that results in, for instance, fatal injury or serious harm to person, these secondary consequences deemed (in this particular case) too unlikely or too unpredictable to take into account.

A PUEA was carried out for two of the tasks in the ECW, namely:

- *Bluetooth pairing of Android and the truck*
- *Tune radio and add favorite*

The result of the analysis was later presented as two matrices in which relationships between problem types and causes were shown. Naturally the result also provided information of which user errors could occur, the most common user errors and causes together with possible ways of preventing the errors in the UI of the SID today. The result was also later used as input for the design guidelines for touch screens in trucks, see chapter 5.

## 3.4 User studies

To extract direct knowledge from the actual users several user studies were performed. Among them were interviews, observations, a test drive and ride-alongs. These methods were used to get the full scope of how the user interacts with the UI and the SID. Users often have problem expressing needs or wishes in a technical fashion, therefore observations, where the user is observed in the natural habitat of the task, can be very rewarding. Furthermore, more in-depth knowledge can be extracted from actually experiencing the situation and not only acquiring others experiences.

### 3.4.1 Interviews

In order to get input from the actual users of the SID and the complete UI of the FH-model, interviews were carried out. To get in-depth answers from the interviewees, and to be able to ask questions unrelated to the template questions of the study, the interview was semi structured in accordance to Case (1990) and contained probing when regarded necessary.

The interview was split into 5 different sections:
1. Initial questions and functionality
2. Placement and ergonomics of existing controls and screens
3. User procedures for accomplishing tasks
4. Implementation of touch technology
5. Other questions

The complete questionnaire with the sections above can be found in the appendix (A5)

The interviews were planned to function as a springboard for further analysis and was intended to generate answers regarding the usability and status of the current UI of the SID (and what the users considered to be necessary or desirable when implementing a touch based UI instead of the existing UI).

In the study two test drivers and two professional truck drivers acted as interviewees. The first two interviewees were chosen to obtain valuable data concerning the existing functionality of today's UI and their considerations regarding the implementation of touch technology. The latter two interviewees were of particular importance to get an understanding of the day to day work of a truck driver, which is also further explained in *3.4.2 Observations*. All four interviews were performed in the natural driving environment of a Volvo FH, and the answers to the questions were noted manually.

To get a better perspective of the users' opinions, and to better scientifically underpinning the study, notes from another interview- and observational study were taken into account. In this study eight professional test drivers were subjected to perform different tasks on a touch screen while driving a Volvo FH and were then addressed questions regarding their performance and other opinions.

When having taken into account the above described studies further interviews were considered unnecessary, thus the latter answers to the questions seemed to emerge in the same direction, with similar data, as the initial respondents to the interview. This delimitation can also be substantiated by the benefit-to-cost ratio as a function of the number of user tests (Wickens et al., 2004), where the highest benefit-to-cost ratio was found at 5 user tests. Provided the limited time span, 12 interviewees were regarded as adequate.

The results of the described two studies above were later compiled using an *Affinity diagram*, see 3.4.7.

### 3.4.2 Observations

Parallel to the interviews observational studies were also carried out. The observations were open, semi-structured and partly participatory, in accordance to Karlsson (2000). The studies were conducted by simply observing what the user actually did and how the user interacted with the system, on a day-to-day basis. In some cases follow-up questions, regarding the actions of the user, were asked in order to obtain further information.

Relevant observations along with the answers provided by the user were written down manually to record the information. The reason for the observational study was that users often do not reflect over their actions or may have difficulties expressing user needs in directly applicable technical terms (Karlsson, 2000). There is also worth taking into consideration that there is a possibility that users might claim something in theory but do something else in reality. Therefore observational studies can help to distinguish between the claims and real actions and give further in-depth data. Two observational studies were conducted, when riding along with two drivers.

### 3.4.3 Ride-alongs

To complete the observations and interviews ride-alongs with truck drivers were necessary. Two extensive ride-alongs were performed; they were orchestrated by contacting available drivers at different trucking companies and finding a suitable day for the ride-along.

The first ride-along was with a truck driver that drove for a logistics company, which delivered goods around the region. The total time spent with the first driver was an entire working day, lasting approximately 8 hours. The day of the ride-along was particularly lucky day since the driver had routes all over the west coast of Sweden and had to make several deliveries that consisted both of unloading and reloading of the cargo.

The second ride-along was with a gravel driver at an excavation site on Tjörn, under completely different conditions than the first ride-along, since this driver instead stayed at the excavation site during an entire day.

### 3.4.4 Test drive

In order to get a better picture and to understand limitations when designing a UI for a truck, different Volvo trucks were also driven.

By traveling to a Volvo facility it was possible to also experience the truck from behind the wheel rather than only sitting in the passenger seat. At this site several different Volvo trucks and models were tested, among them were Volvo FH-16, Volvo FM, Volvo FMX, Volvo FH-12 and Volvo FL. The trucks were driven on a sealed off track emulating real road conditions with slopes, turns and straights.

### 3.4.5 Affinity Diagram (KJ Method)

After the interviews, a way to sort through and categorize the information was in dire need. This could be accomplished by using an Affinity Diagram (ASQ, 2004). By writing down quotes, observations, statements and ideas (from the interviews) on post-it notes and placing them on a large open space, a way to visualizing the information was given. In addition to this a way to organize emerged. By grouping related or similar post-it notes and removing exact duplicates, certain categories could come into existence. The post-it notes were also moved between different categories until consensus was reached.

In some particular cases it was not possible to fit a post-it note into any of the formed categories. These post-its were regarded as "lone wolves" and were independent from the rest of the categories. The KJ method was especially useful since it enabled a large quantity of diverse information obtained from interviews to be organized in a structured and useful manner.

## 3.5 Design guidelines for touch screens in trucks

As a way of finally summarizing the result of all above methods, design guidelines for touch screens in trucks could be compiled, mainly by focusing on the theoretical background and the functional analysis, the result from the user studies and the concept evaluations. This was done by firstly dividing the requirements for touch screens in trucks into four categories to create a better overview:

1. Menu structure, tasks and navigation
2. Objects and Graphical elements
3. Typography colors and language
4. Physical requirements

## 3.6 Concept development

During the concept development several ideas began to take root. In order to achieve a satisfactory result some more steps were needed to be done before visualizing the concepts. Among these steps were to formulate a vision and a function analysis. The used tools for ideation were for example a KJ-method, an Ishikawa diagram, brainstorming and wire framing.

### 3.6.1 Vision

Initially during the concept development phase, a vision was formulated in order to set sail for the final concept and to focus the effort on what was considered most important to create a well-functioning touch UI for a truck. The vision was based on insight obtained from the market analysis and the theoretical background.

### 3.6.2 Function Analysis

To establish a solid foundation of user needs, and to map out functional criteria for touch interfaces, a function analysis was orchestrated. The analysis is used to create an abstract and broad problem specification, thus expanding the design solution space (Johannesson et al., 2004). The function analysis contained two categories, namely: *"Visual information"* and *"General functions for touch in trucks"*. The analysis consisted of a table containing four columns; one column for a verb, one for a noun, another for priority and finally one for comments.

An example of this layout follows in Table 2 below:

Table 2: Example of a function analysis

| Verb | Noun | Priority | Comment |
|---|---|---|---|
| Minimize | Distractions | Desirable | Don't look away from the road longer than recommended. |

The above described method was used in order to make a list of different needs for the users and to underpin information for the design guidelines. The categories mentioned above and the content of the functional analysis was based on the theoretical background and previous investigations (market analysis, benchmarking, system research and user studies).

### 3.6.3 KJ method for ideation

As a structured approach to continue with the concept development phase, a complementary KJ method, in accordance to the description in 3.4.6, was carried out. However this later KJ method was instead carried out by writing ideas (not from the interviews) on post-its.

### 3.6.4 Ishikawa diagram

To help further investigating the problem: *"It is difficult to succeed with divided attention"*, which was seen as an important issue that arose from the above described KJ method (3.5.3), an Ishikawa diagram was carried out. Ishikawa diagrams can be useful when examining possible causes of a specific problem (Bergman & Klefsjö, 2007). Four different problem categories were established, namely "Haptics", "Human capacity", "Environmental factors" and "UI-structure".

The Ishikawa method was used to help further understanding why divided attention while driving and focusing on the SID could potentially be dangerous if the UI is designed without safety in mind. The method was done by writing down various causes to the initially stated problem on post-it notes and then arranging these causes in the above mentioned categories.

### 3.6.5 Concept generation - Ideation and wire framing

The ideation process consisted mainly of brainstorming (Johannesson et. al, 2004), where sketches were made both on paper and on whiteboard. Concepts and ideas were also further developed using the 6-3-5 Brainwriting methodology (Johannesson et. al, 2004), with the exception that the group consisted only of two persons instead of six.

Thea above mentioned methods provided adequate and effective ways to visualize several concepts in a short period of time. When conceptualizing different concepts, these were first made by hand to express the idea or functionality of the interface. The concepts that seemed fruitful and realistic were thereafter digitized in Adobe Illustrator. This wire framing process was heavily focused on the layout and pure functionality of the different UIs. Therefore icons, color and typography were deemed secondary. In addition, most of the wireframes were black and white with replaceable icons (if the concept proved to have potential).

The developed wireframes were also used as means of making an interactive test with the help of Adobe InDesign and a Samsung Galaxy Tab 3 for evaluation purposes.

## 3.7 Concept evaluation

To adequately evaluate which concept that was considered most suitable for use (in the UI of the SID in the FH truck), several evaluation methods were used. First of all, different *pros and cons* (3.6.1) were examined to each of the concepts, and *feedback from a reference group* (3.6.2) was also obtained. Furthermore, a *usability test* (3.6.3) was conducted, followed by a *HTA evaluation* (3.6.4), before the final concept could be chosen in the *concept choice* (3.6.5).

### 3.7.1 Pros/Cons

All concepts were evaluated based on the design principles presented in the theoretical background, the functional analysis and reasonable conclusions. In order to do this, wireframes of every concept were put on a whiteboard, to get an understanding of the concepts as complete entities. Thereafter advantages and disadvantages were posted on the wireframes with sticky notes. These advantages and disadvantages were later summarized for all concepts.

### 3.7.2 Feedback from reference group

To obtain valuable input, senior colleagues at Volvo were consulted and asked to comment on each of the developed concepts.

### 3.7.3 Usability test

To further be able to evaluate the functionality of the developed concepts, a minor usability study was conducted. This was done by using two of the previously created wireframe concepts from Adobe Illustrator as design templates to create interactive files (Adobe DBS Folio-files) in Adobe InDesign. The created files allowed for simplified versions of the intended touch interactivities when loaded into an Android tablet (Samsung Galaxy Tab 3 10.1). Firstly the interactivity was explored and discussed simply by counting the amount of steps needed to perform various tasks in the two UIs and by continuing to investigate advantages and disadvantages.

Secondly the same tablet was mounted into the driver environment of a Volvo FH to test the interactivity in reality, on ordinary roads. This was studied by letting seven drivers from Volvo GTT perform a 20 minutes long usability test, while being video recorded. Initially, the users were asked to find different functions, such as the album view of the music player, in the two UIs. Thereafter the users were intended to perform a more specific task: "*Call a specified contact via scrolling through a contact list*". To assist the usability test, and to be able to take notes, a guide document was established. This document can be found in the appendix (A6). When the drivers were finished with the usability test of the UIs, more in-depth interviews were conducted. In these interviews, the users' opinions of the both concepts were examined.

Furthermore, a subjective prioritizing method was applied as part of the interviews, namely the $100 test (Karlsson, 2000). This test was applied by letting the users prioritize between the two concepts, by allowing the users to freely distribute 100 Swedish crones in tens, on the two concepts. The users were instructed to distribute with regard to functionality and the perceived potential of the concept.

The result of the usability test was later assayed and the $100 test was statistically evaluated by estimating a sample mean and a sample standard deviation (on the sample of seven drivers) (Montgomery & Runger, 2011). These estimations were used together with the "Central limit theorem" (Montgomery & Runger, 2011) to describe the samples with the normal distribution. Thereafter it was possible to calculate the probability that the concepts in a normally distributed population would obtain more than 5 of the distributed tens, for Icon Grid and Constant Menu respectively. The result of the statistical analysis was used as one foundation for the final concept choice.

### 3.7.4 HTA evaluation

In order to properly evaluate the final concept, one HTA analysis was conducted. The task in this analysis was *"Make a phone call with iPhone already paired"* which was also carried out earlier for the present SID (see 3.3.3 Hierarchical Task Analysis). This was made to see how many steps and what kind of simplifications that were made in the new concept.

### 3.7.5 Concept choice

The final concept was chosen from the data and result gathered from previous evaluation methods and earlier research. Thereafter, the chosen concept was further developed in the Final concept development (3.7).

## 3.8 Final concept development

After taking into consideration the result of the concept evaluation phase (see 3.6), final adjustments, such as modifications of icons, total structure and an example color scheme, were added to further improve the chosen concept.

# 4. RESULTS

After concluding the method chapter it is time to enter the results chapter and present all the results. The Results chapter will follow the same structure as the method chapter. Meaning that the market research will be presented first in 4.1, after that the benchmarking in 4.2, moving over to the system research in 4.3 and finally, the user studies result in 4.4.

## 4.1 Market research

The results of the market research will be presented in the *PESTLE-analysis* (4.1.1), which will consider macro environmental aspects of the market. Afterwards a *Power-interest grid* (4.1.2), will be established in order to validate which the key actors are and how to keep those satisfied. In addition to this the current business climate of entering the market of touch screens in trucks will be examined in the *Five Forces* chapter (4.1.3), and more in depth in the *Competitor analysis* (4.1.4). Furthermore, in the competitor analysis other manufacturers SID solutions will also be investigated. A visual representation of the results from the competitor analysis will be presented in the *Positioning matrix* (4.1.5), along with a recommendation for how Volvo should react. Finally a *SWOT-analysis* (4.1.6) will conclude the strengths and weakness of the product (a touch interface SID) along with opportunities and threats from external origin, and *Sustainability considerations* (4.1.7) will be presented.

### 4.1.1 PESTLE-analysis

The PESTLE-analysis (see Fig. 5 below) showed that there were many key factors in the economic, social, technology and environmental columns. The political and legal columns mostly consisted of what if-scenarios and if the current status quo would be radically changed, e.g. stopping the export of indium, that is an important material for manufacturing screens of all types. The legal column was heavily leaned towards guidelines and standards, such as NHTSA's guidelines for glance time (NHTSA, 2012) and other important factors to keep in mind for safety reasons.

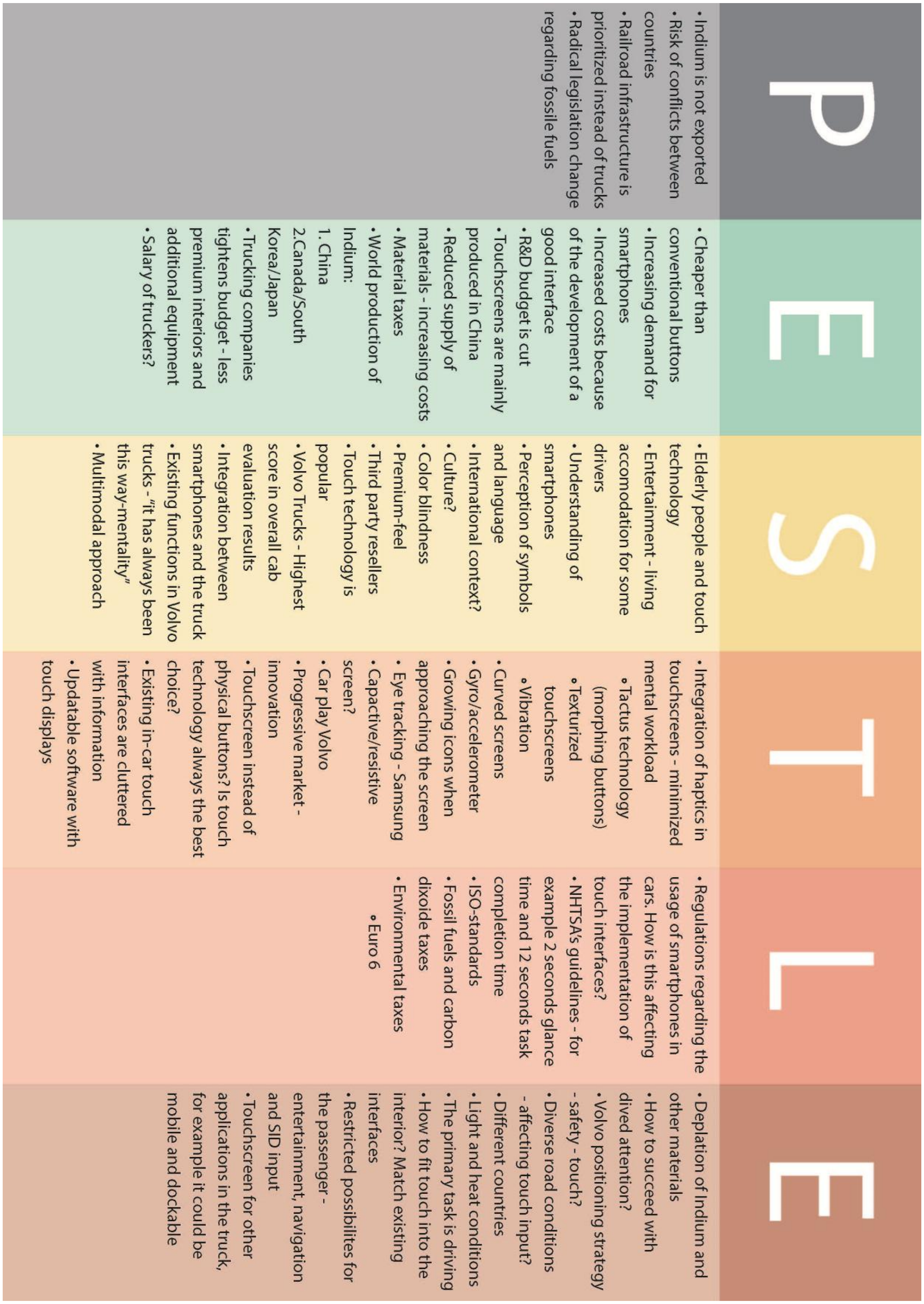


Figure 5: PESTLE-analysis

The economic factors that weighed heavily were that touch buttons are now starting to becoming cheaper to manufacture than conventional buttons, in addition to this the touch buttons have a dynamic range that conventional buttons simply does not have. However, customer satisfaction with the touch interface is crucial for a successful transition from conventional buttons; this will require research and development, which is costly. If the economy were to suffer a crisis, R&D budget would surely have to be put on the backburner along with trucking and logistics companies' incitement to invest in new state-of-the-art touch technology in trucks.

Factors in the social column were much about how culture can affect the decoding of symbols, language and layout. It was also important to take into consideration that touch technology is very popular today, with smartphones and tablets selling in record breaking numbers (mobiThinking, 2014), however, despite this older drivers might not be as familiar with the technology as the younger generation. Moreover, the drivers that have adapted to smartphones and touch technologies often express a desire to have their smartphones better integrated into the SID. Entertainment aspects are also important since some drivers spend a lot of time on the road and are practically living in their cabs for sometimes days or even weeks at a time.

Technology factors were mostly about new touch technologies. *"How can haptics be better integrated into touchscreens?"* - Perhaps with the use of new technology such as texturized touchscreens, morphing buttons or vibrations (more about these technologies in 4.2.4). The dynamic abilities that touchscreens allow are influential when designing a great interface, the touchscreen could include a gyro or accelerometer that would allow the screen to change regarding of stimuli from the outside world. Eye tracking such as Samsung has integrated in its Galaxy-line that makes the screen "aware" of when it is being looked at could also be technologies to continue to investigate (Samsung, n.d.). Finally, it is important to ponder over if touchscreens always are the best choice for any given situation; perhaps physical buttons have advantages over touchscreens in some situations.

In the environmental category it was chosen to focus rather on the environment the truck and touchscreen will be present in than macro environmental factors. What factors play a role in able to succeed with divided attention? How does this work with Volvo's established safety image? Other question and results that emerged were how touch can be affected by different environments such as diverse road conditions, light conditions and temperature differences. Important yet again is to mention that the primary task is driving and interaction with the SID is always secondary while on the road. Maybe some functions of the SID should be disabled while on the move to encourage safety and minimize mental workload. Another idea that emerged was that the touchscreen could be mobile and moveable so that entertainment features could be enjoyed during breaks and down hours.

The important conclusion from the PESTLE-analysis is that it generated a lot of ideas regarding touch technologies and opened up for new questions while it also helped grouping the questions to different categories. The full PESTLE-analysis can be viewed in the Appendix (A7)

### 4.1.2 Power-interest grid

Coming from the information established in the PESTLE-analysis several different actors were indirectly investigated, however these needed to be grouped and directly sorted into various categories of how important they were, to know which ones to focus on.

Government and competitors were sorted into the Minimal effort category; the reasoning behind this was that these are passive actors. These organs act from their own agenda and will continue to exist and interact with Volvo, no matter what Volvo does. From the PESTLE-analysis it was concluded that governmental organs would have to make radical changes to wield a huge impact. Volvo is also by many considered among the best at cab interior and infotainment; the competitors are watching Volvo and waiting to see how Volvo will react to touch technologies (more about this in in 4.1.4 Competitor analysis).

Important actors to keep satisfied are drivers of the trucks and the media. These are factions that wield a high amount of power but might not be very interested. A driver can still continue his job whether the truck has a touch SID installed or not, however if the touch SID turns out to offer good user-value and usability for the drivers, Volvo's selling power could increase. The media is also a passive actor, they will not be influential to the development but their reviews and articles about Volvo could provide a very good boost. On the other hand, bad PR could also lead to disinclination towards the new SID and have a damaging impact on Volvo's image.

Moving on, actors to keep informed would be partners, Volvo Cars and brands in the Volvo group falls under this category as well as manufacturers and research institutions. Keeping an active communication dialog with the group and Volvo Cars is beneficial for both parties since the technology might be applicable in both trucks and cars. Manufacturers can provide experience and know-how regarding what might work and in which quantities they will be able to produce. Price point can also be bargained more effectively by having active exchange of information with manufacturers (Jonsson & Mattsson, 2011). Research institutions are naturally curious of new technology and potential breakthrough so sharing information with such actors could also be potentially beneficial for both parties; this could also lead to good PR.

The key stakeholders will be the customers and Volvo AB. These actors wield both high amounts of interest and power. If the customers are unhappy, fewer trucks will be sold; this is bad for business and must be avoided at all costs. If Volvo AB is unhappy, budget could be cut, which would result in less R&D and less resources to focus on the SID and touch technology.
Keeping these two parties happy are a major concern and priority. The Power-interest grid can be seen in Fig. 6 below.

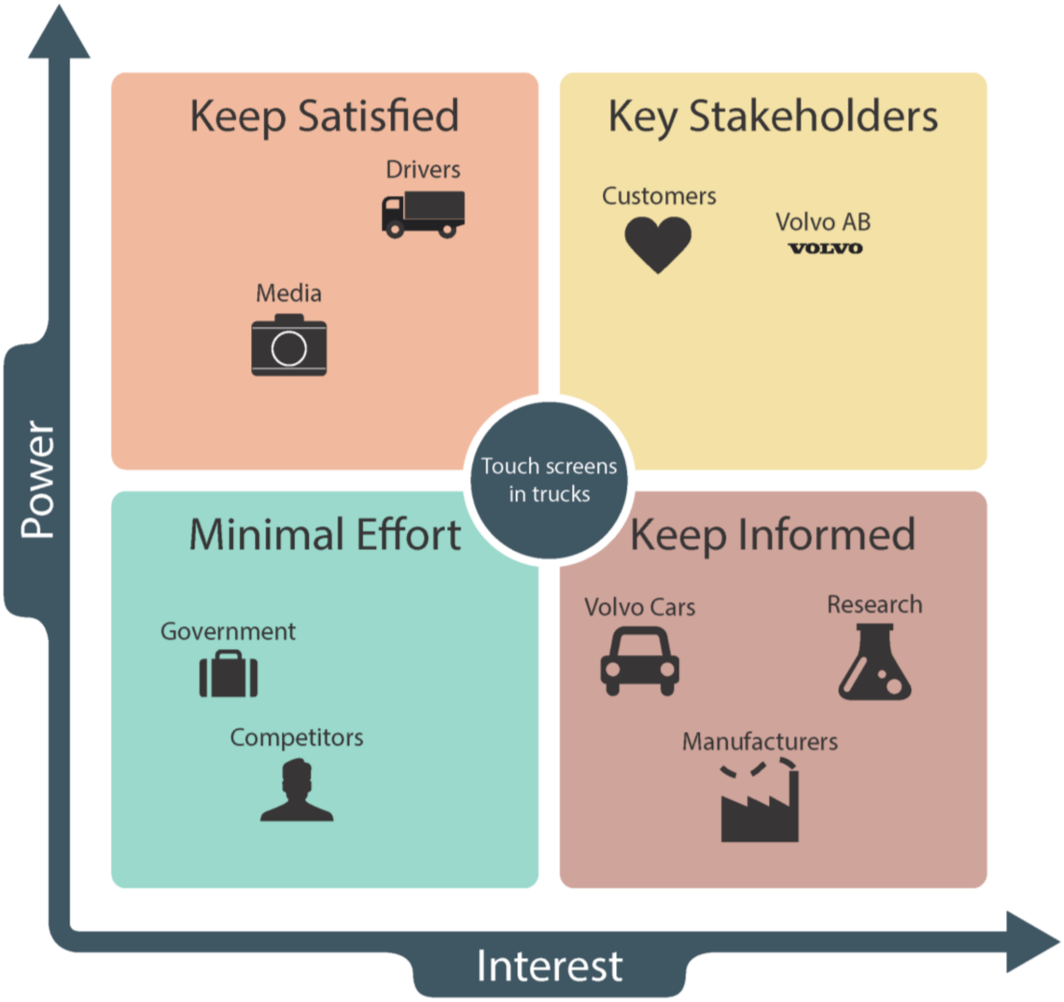


Figure 6: The Power-interest grid

### 4.1.3 Five Forces

The Five Forces model in its whole can be seen on the following page (see Fig. 7)
Firstly, the entry barriers mostly consisted of possible patent intrusions and how to avoid these, new patent may have to be sought and incorporated before starting manufacturing on a large scale. There is also the problem that competitors may follow and possibly copy parts of the UI, thus cutting their own R&D costs, however without risk there can be no innovation. Moreover, Volvo's safety image is well-rooted and it is important that this new touch UI is in accordance with this image; the development of a safe UI however will most likely be costly.

The suppliers power was estimated as low, since manufacturing of touch screens are well known production techniques. However, there is the fact that some suppliers could be more suitable than others since they possibly could possess better know-how and experience. In addition, reports are saying that the indium required to make screens is starting to run low (Hartley, 2010), this could potentially give the suppliers more power over time.

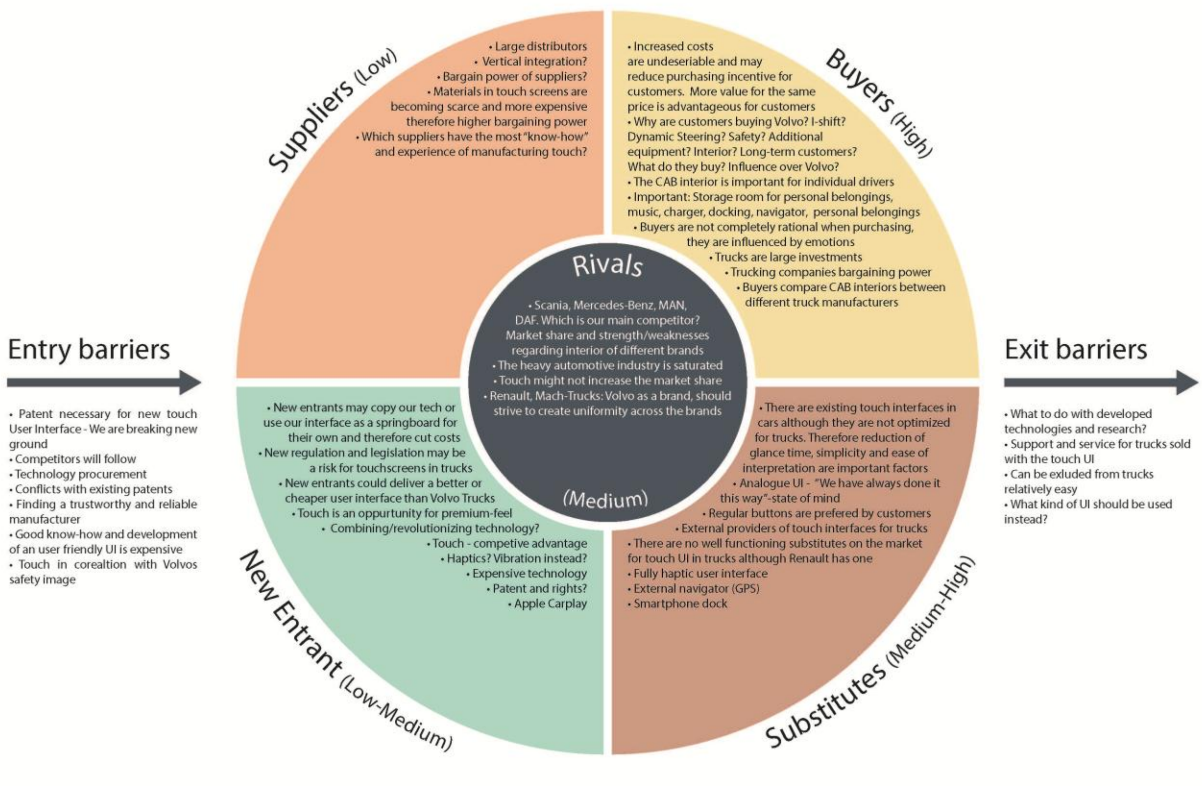


Figure 7: Five Forces-analysis

The New Entrants category was valued in power from low-to-medium. There is the possibility that new entrants could copy Volvo's UI and sell it at a lower cost. However, this would be grounds for legal action, but this could prove to be a long and drawn out process and the new entrant would be able to sell the UI until the legal process is done. Moreover, governments may pass new laws that prohibit the use of touch screens in vehicles, which would be of serious concern if Volvo just has released a truck with a touch screen UI; although, this seems like an unlikely turn of events at the moment, according to Edelstein (2012).

Additionally, new entrants could revolutionize the market by introducing new technology or solutions that work better, this may include combining of existing technology or various haptic input solutions better suited for in-vehicle use. However, development of such technologies would be costly. Solutions such as Google Car or Apple Carplay may also make customers demand this sort of UI, since both Google and Apple have a very large loyal customer base and a developed eco-system and UI hierarchy for smartphones and tablets. In addition, this could make users except no substitute to Google/Apple and the new entrant who first allows these UIs in their vehicles could gain market shares.

Substitutes were assessed in the level of medium-high in the matter of power. Substitutes may include factors such as customers preferring conventional buttons over a touch UI. Substitutes may also appear as users only using their smartphones or external GPS devices in their vehicle and thus ignoring the in-vehicle infotainment system altogether. Substitutes were regarded as a potential serious threat and therefore an extensive benchmarking process were instigated. The result from this benchmarking is found in chapter *"4.2 Benchmarking"*.

The Buyers category was rated as high in the means of power. No matter how well the other factors are handled and how good the UI may be from technical standpoints, if the buyers do not like it and do not purchase it, the UI will be seen as a commercial failure. Increased costs are undesirable from a buyer's perspective and may reduce purchasing incentive. A potential buyer would prefer more value for the same price. Moreover, the question that needs answering is *"why are buyers choosing Volvo, and how would a touch UI affect their incentive to purchase?"* This question will be further evaluated in later chapters. The cab interior is also very important for individual drivers, since they tend to spend a long amount of time in these confined spaces and for some drivers, the cab is basically their home. These trucks are large investments for both trucking companies and individual drivers, it is important that they feel satisfied with their truck. Another important aspect to keep in mind is that buyers tend to not be completely rational when purchasing products, buyers are also influenced by emotions (Murray, 2013).

The rivals category was regarded as medium in the amount of power. It was needed to better establish which manufacturer that was Volvo's main competitor. Scania, Mercedes-Benz, MAN or DAF, this will be further examined in "*4.1.4 Competitor analysis"* and *"4.1.5 Positioning matrix"*. There is also the factor that a touch UI might not help increase market share or give an edge against rivals, other factors than a touch UI may be valued much higher by buyers.

Exit barriers that would occur from trying to exit the business after entering it would be question such as, *"what to do with the already developed technologies?"* and what kind of UI that should be used instead, a conventional button UI or another solution? There is also the fact that Volvo need to be able to provide support for the trucks they have sold, even if they discontinued the line. However, a touch UI could be excluded from a truck without too much difficulty since it is not the most vital part of the truck. A visual version of the Five forces model can be found in the appendix (A8).

### 4.1.4 Competitor analysis

The competitor analysis resulted in a large table, (pictured below in Table 3) along with comments about each of the main competition vehicles from the different manufacturers. Moreover, results gathered from trying the different vehicles SID (or equivalent) will be presented below in "*Test of interfaces in trucks*".

**Journalistic study**

A summary of the journalistic study is shown in the table below. Beneath the table a descriptive text, for each of the individual truck brands, is presented.

Table 3: Competitor analysis

| | **Volvo FH** | **Mercedes Actros** | **DAF XF** | **Scania R** | **MAN TGX** |
|---|---|---|---|---|---|
| **Driving experience** | Great steering and road behavior – best driving comfort and total driving score | Well-functioning automatic systems | Good brakes and driving comfort | Great comfort while driving, good drivability and steering | Good driving position, well-functioning brakes, bad comfort, steering and gear changing |
| **Innovation** | I-shift and I-see | Predictive Powertrain Control, EcoRoll, PowerShift 3 | EcoRoll, fast shift between the highest gears. | Active Prediction and EcoRoll | Man TipMatic |
| **Interior** | Largest storage, practical and spacious, great finish | Largest cab and floor height, huge living space, large storage, high quality materials and finish | Large storage compartments | Not much storage, "the dark-colored dashboard eats up cab space" | Biggest total volume, but least storage space |
| **Usability** | Well organized interior and good road behavior, good controls | "Incredibly well thought out dashboard" | Easy to find the right switches because of effective grouping | Lowest floor height - best entry of all the tested trucks | Best visibility, lights, mirrors, safety belts and features |
| **Technology** | Neck-tilt, ACC | Highest torque rating, best fuel figures, good engine brake | Fastest average speed and highest performance in the test | Well-functioning ACC | Best driveline performance |

**Volvo FH**

Norvinge (2012a) points out that the I-shift together with the ACC (adaptive cruise control) and the driver seat makes the driving experience comfortable. These three features are also pointed out by Giles (2011), Lindstrand (2013) and Van der Meer (2014). In the same test drive article by van der Meer, the presented results shows that the FH got the best driving comfort- and total driving experience-score. The fact that the system adapts to and changes in accordance to different cues provided by the driving environment and the user was also mentioned (Giles, 2011)

The Volvo FH was seen as spacious, with a good finish (Van der Meer, 2014). The FH-model provides, according to van der Meer adequate storage compartments. Moreover, the neck-tilt feature was appreciated (Lindstrand, 2013). Lastly Lindstrand (2013) gave the FH-model credit for the intuitive controls on the steering wheel.

**Mercedes Actros**

Mercedes was the first truck brand to meet the demands of EURO6 (Åkeri och Entreprenad, 2011a), and with the Actros model, Mercedes further succeeded with lowering the fuel consumption (Åkeri och Entreprenad, 2011b). In accordance to Prime Mover Magazine (2011a) and Van der Meer (2014) the Actros has well-functioning automated systems, for example the Active Brake Assist System, which provides the user with automatic brakes, when in need. Prime Mover Magazine (2011a) further notes that the steering and drivability of the Actros is great.

The living and working environment was seen as spacious (Prime Mover Magazine, 2011a) and the storage was seen as sufficient (van der Meer, 2014). Moreover, Van der Meer considered the overall finish to be excellent, with good materials. Prime Mover Magazine (2011a) gave credit for the proximity control and the lane assist.

**DAF XF**

The driving comfort was according to both Van der Meer (2014) and Prime Mover Magazine (2012) good, and the truck performed well in the test by Van der Meer. Prime Mover Magazine further stated in the article *DAF XF105* (2012) that it was (paraphrased) *"easy to hold a normal conversation in the DAF XF cabin without being disturbed by the engine sound*". Furthermore, Van der Meer described the shift between the highest gears as fast, the storage compartments as sufficient and that the grouping of the switches, in the driving environment of a DAF, was well thought out.

According to Prime Mover Magazine (2011c) the *"cab design is the result of constant discussions with drivers to get the picture of what they need in a long distance truck to achieve comfort , productivity and safety".* Prime Mover Magazine (2011c) further stated that some of the automated safety systems, such as the ACC, lane departure- and collision warnings increased driver security significantly. Lastly, Norvinge (2012b) stated in the article *DAF introducerar en ny XF* that DAF also had released a "*Super Space Cab*" version of the XF model, which in accordance to Norvinge was the cab with the biggest volume.

**Scania R**

In the test drive article written by Van der Meer (2014) it was concluded that the Scania R had great driving comfort, together with a good drivability. In the article *Scania R 730* (Prime Mover Magazine, 2011b) the author investigated the capability of the automatic systems for cruise control and downhill retardation in an R-model, and concluded that the systems were well suited for demanding routes in Australia. An example of these capabilities, presented in the article, was that the R-model enabled the user to climb and descend a great hill with heavy load, just by using some buttons.

However, Van der Meer (2014) considered that neither the storage, nor the space, was sufficient and further stated that (paraphrased) "*the dark-colored dashboard eats up cab space".*

**MAN TGX**

In the test drive article written by Van der Meer (2014) the MAN TXG was regarded as the safest vehicle with the best driveline, whereas the truck, for example, had best visibility, lights, mirrors and safety belts. However, the TXG model got least overall scores in the test.

When analyzing the different articles and the above result, it is possible to conclude that all of the five competing trucks have been focusing on creating automated systems to create a better driving day-to-day working environment for the actual drivers, to lower the fuel consumption in accordance to regulations of the European Union and to further improve safety. However, the customers of tomorrow could desire other qualities than what until now has been competitive means in the trucking industry.

**Test of interfaces in trucks**

The main competitors to the Volvo FH all include some kind of infotainment system that the user may interact with to various degrees. These UIs and systems were investigated and the results are presented below.

**DAF XF**

The DAF XF did not offer much usability or user-value. When the system was tested, the only function that responded was the radio. In fact, the entire system seemed to be controlled from the radio display (see Fig. 8).


Figure 8: DAF's radio UI

There was some kind of SWS and the iconography indicated that phone calls should be a possible function (see Fig. 9 below), however, the system offered no cues on how to accomplish this and the function remained untested.


Figure 9: DAF's SWS

**MAN TGX**

The MAN TGX proved to be a considerable step up from DAF in both user value and usability. The SID equivalent was located next to the speedometer, the same place as the DID is located in Volvo FH (see Fig 10). MAN TGX also had plenty of SWS buttons, which provided the user with the chance to interact with the system. The system allowed the user to pair a phone via Bluetooth; when this was tested it worked with both an iPhone and an Android phone. The system could also display recently called numbers and an options for contacts was provided. However, when attempting to enter contacts a loading screen was shown but nothing seemed to happen, after waiting approximately 90 seconds and the system still only displayed a loading screen the attempt was forfeited. The display was a small rectangular shaped display with low resolution. The iconography and system consisted mostly of simple icons and lines of text; the system was simple but functional.


Figure 10: MAN's UI

**Mercedes-Benz Actros**

The Actros featured a nearly square shaped screen. The resolution was quite low but higher than the MAN TGX. The system provided the user with a black and white screen (see Fig. 11). Maneuvering in the system was accomplished by using the rotary dialers and alphanumeric keypad. There were also some additional buttons for phone options as well as "Return" and "OK". The "OK" functionality was hidden however, the user had to press down the rotary dialer to accomplish this command; the command was in fact only discovered after several minutes of interaction with the system and by a method of trial-and-error.

However, the user was provided with more functionality than both DAF and MAN. The system featured both streaming of music via Bluetooth, phone functionality, radio with a favorite system and settings. The UI was also more complex than previously investigated UIs, with several levels of functionality. The user was able to switch between the main functions by pressing the left and right arrows, then different views and settings within the displayed function could be viewed by pressing the up and down arrows. This was not instantly clear since the only indication of several views of the same function was a very small rectangular icon, only a few pixels large, which indicated what view the user was currently in. Navigation via spinning the rotary dialer also felt unnatural since it had to be spun "the wrong way" to go up or down in lists, which contributed to further confusion for the user.


Figure 11: Mercedes' UI

**Scania**

Scania featured a touch screen UI, with the highest resolution of all the tested UIs and what seemed to be a screen fully capable of displaying several colors (this is uncertain since only green and shades of gray was displayed however). The user could interact with the system both via conventional buttons and via touching the display. The system provided the user with hardware buttons to functions like Radio, Map and Setup for fast navigation. What was quite confusing however was that what first appeared to be a home screen, which displayed all the available functions neatly, actually turned out to be a configuration menu (see Fig. 12). The UI also featured a taskbar in which the time along with information about which function the user was currently in. If a phone was paired via Bluetooth, reception and a Bluetooth symbol was also displayed.


Figure 12: Scania's configuration menu

The UI featured some unique functions such as when searching for a contact in the phone the UI automatically suggested which contact the user might be looking for based on the amount of letters typed (see Fig. 13).

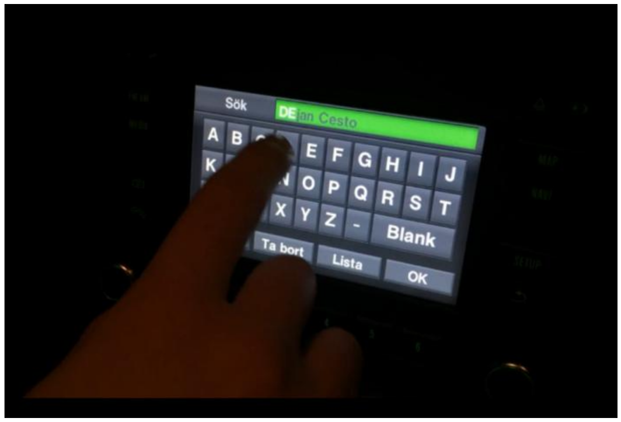

Figure 13: The user has written the letters D and E and the system is trying to auto-complete the name.

The UI felt unresponsive and "sluggish" sometimes, if compared to, for example, a standard smartphone UI the Scania UI felt very slow. It also felt like Scania had not taken the touch technology to its full potential and sometimes made some confusing or frustrating design choices. An example of this would be the small buttons and large empty spaces in the UI, also while scrolling, the system did not respond to the input of the scroll action until the user let go of the scroll. This caused the entire list to unexpectedly "jump" down lists, which was confusing.

The system would have benefitted from being more fluent and responsive.

### 4.1.5 Positioning matrix

After completing the competitor analysis, enough information was gathered to conclude the positioning matrix (see Fig. 14). DAF and MAN that offered very little in the way of both usability and user value were placed in the lower west corner. It was clear that an infotainment system was not a priority for these companies, which made them easy to place in the matrix.

Mercedes-Benz while offering more functions and a graphical interface, scored poorly in usability; this as a result of the low resolution of the display, small size and lack of color. Furthermore, navigating the menus were a chore since it felt forced and unnatural. All these factors together resulted in Mercedes getting positioned quite low on the usability axis.

Scania actually offered a touch interface, with more functions and user-value than both Mercedes-Benz and Volvo. However, the usability of this interface could be vastly improved. The interface also supported conventional button navigation and became confusing as towards where in the interface structure you were currently located. Bluetooth settings were another major flaw, both an Android phone and an iPhone were subjected to trying to pair with the interface, however only the iPhone could make a successful pairing.

Volvo's interface despite its flaws proved to be quite well regarded in both user-value and especially in usability. Some functions were missing that other manufacturers (Mercedes and Scania) possessed, however the functions that Volvo's interface did include were often better executed than the competitors. Volvo's interface will be further examined and accounted for in *"4.3 System research"*.

Volvo should however strive to keep this position as number one in the infotainment spectrum and should therefore keep improving both usability and user-value (as seen in Fig. 14).

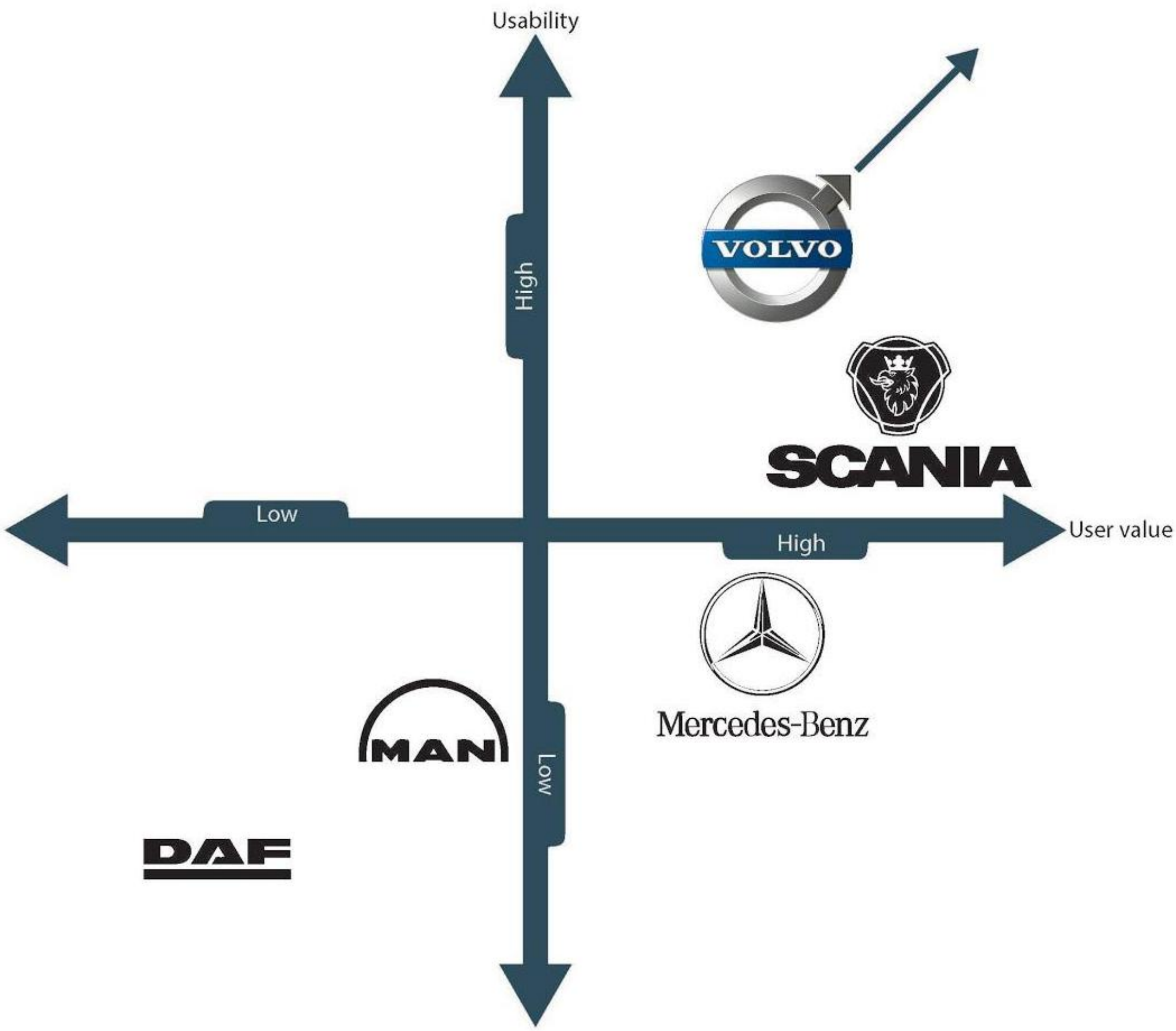


Figure 14: The Positioning matrix

### 4.1.6 Strengths, Weaknesses, Opportunities, Threats - SWOT-analysis

The SWOT-analysis was a summary of the result from the previous market research studies (see Fig. 15 below) It was a helpful and easy way to visualize and categorize different aspects of the product (a touch UI).

The main strengths were that Volvo would be the first premium truck with also a premium touch interface. This leap to touch technology would also help to further differentiate from other manufacturers. The touch interface would also lead to a more dynamic and update friendly user interface, since functions could be added via over-the-air-updates. Icons, languages and colors could be changed to match the cultural context of different countries.

The UI would also be able to change colors or typeface size in order to better support elderly or color-blind people. The ability for better smartphone support is also a large strength since most people today do not go anywhere without their phone. Touchscreens are also growing increasingly inexpensive to manufacture, opening up for cutting costs and extending revenue. However, it is Important that the UI is intuitive and simple, so it can instantly work for anyone, anywhere.

Furthermore, weaknesses that were assessed were if the UI would fail to comply with NHTSA's guidelines or in any other way be considered inappropriate for in-vehicle use. The physical layout of the cab would have to be redesign to be more ergonomically sustainable for the user if touch was implemented. In addition, the development of a well-functioning UI would be costly. Another weakness would be if the new UI conflicted with existing patents and became the smoking gun in a legal battle. In conclusion, most of the weaknesses would only come into existence if the UI was not developed with these weaknesses kept in mind in order to avoid them.

Opportunities on the market were considered the use of new technology in an efficient way, such as the implementation of perhaps curved screens to reduce screen reflections or eye-tracking systems. App integration was another opportunity, most people today are familiar with apps like Google Maps or Spotify, implementation of such applications could prove a selling point. Having a well-designed touch UI over a traditional button input with dubious menu structure could also very well prove a selling point for buyers.

The Volvo brand is also a very strong incentive to buy a truck, their cabs are rated among the best in the business, providing their users with a more modern and functional UI would surely help increase this standing even further. Another opportunity is that there is no manufacturer that has successfully implemented touch in a way that boosts both usability and user-value, Volvo being the first to do so is an opportunity waiting to be realized.

External threats included subjects such as NHTSA changing their guidelines or their stance to touch interfaces in the car. Other regulation and legislation by independent governments and countries is also a possible threat. There is also the fact that buyers and drivers may prefer an analog interface. There is also the everlasting concern that indium will run out and touchscreens may become scarce or more expensive to develop. An extreme case is also if international relations would destabilize and cause for stricter export/import laws. Other threats would be if users prefer other touch UIs such as Apple Carplay or third-party developed solutions (e.g. GPS-devices or tablets).

In conclusion, the SWOT acted much as a visual summary of previous result structured in an easy-to-oversee manner. Strengths lay to a large part in the dynamic interface that touch technologies enable, moreover that people like and are familiar with them. Weaknesses lay in failure to develop an UI that does not keep safety regulations and patents in mind. Opportunities are much based in the fact that new ground is breaking and the use of Volvo's well established brand. Threats are taking substitute solutions and manufacturing concerns into account.

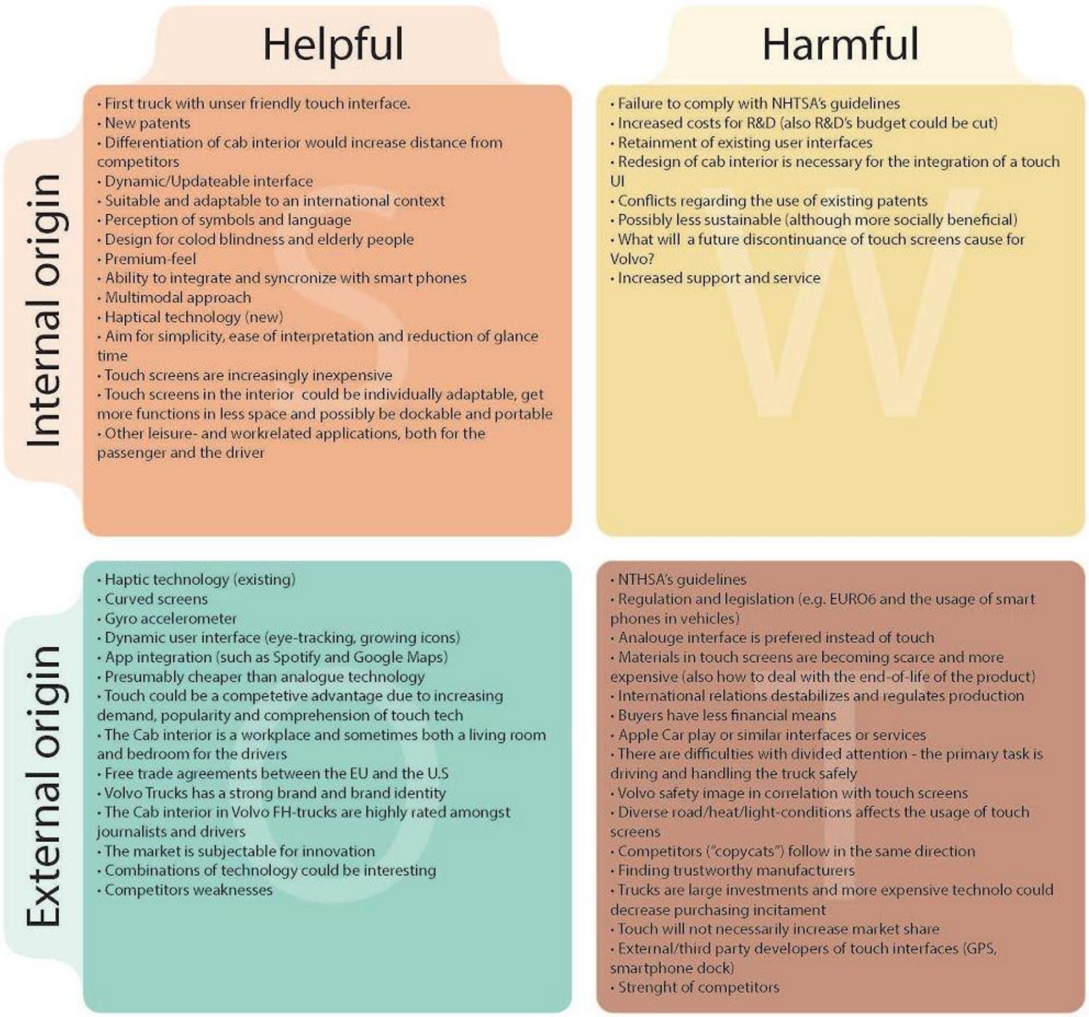


Figure 15: The SWOT-analysis

### 4.1.7 Sustainability considerations regarding touch screens

In the chapter "*4.1.3 Five Forces*", it was stated that the supply of Indium (which is a common material in touch screens) was running low, which is something that is important to take into consideration when discussing sustainability issues of touch screens. If this is not resolved by finding a way of efficiently recycling Indium, with the purpose of reproducing new touch screens, it could potentially pose as a threat.

When considering the economic aspects of touch technology, it would seem that touch technology is becoming increasingly inexpensive, and in some cases touch screens might even be less expensive than conventional controls in vehicles. If analyzing this in contrary to the above paragraph regarding Indium shortage, no logical pattern can be observed. Therefore, if the supply of Indium actually were to end, it could occur suddenly without prior notice. It is therefore of importance to keep track of the Indium supplies in the world.

When instead considering the potential usage phase of touch screens in trucks, many social benefits can be found. For example, if implementing touch screens, operations or tasks can be made easier than with a conventional screen, and there are many more potential and possible functionalities in a touch based interface compared to the conventional one. Furthermore, the touch screen can be made dockable, which would enable the users to utilize the interface in a completely new manner. Moreover, social media or music applications such as Spotify would be easier to implement, which further adds to the social benefits of touch screens in trucks. The social sustainability considerations are important in a truck, especially when regarding the truck as a home.

## 4.2 Benchmarking

The benchmarking resulted in a large amount of data about different touch or vehicle related devices. A variety of devices were examined in several different fields and the interesting solutions and what made the different UIs well-functioning or not so well-function will also be commented upon and presented in this chapter. First out is an examination of different "*GPS-devices*", following that are "*Tablets and smartphones*", moving forward there will be a special chapter devoted to how different car manufacturers have handled touch technology. Lastly new touch technologies alongside with other interesting technologies will be investigated.

### 4.2.1 GPS-devices

**Garmin Nuvi 2797 LMT**

The Garmin Nuvi 2797 had a 7" display in a rectangular shape, resistive screen bundled with large clear buttons along with a sort of home screen which the user could return to by pressing the back button for a sufficient amount of times. The back button always remained in the same place, except for on the home screen. The home screen provided extra-large buttons for the main tasks, "Where?" and "Show map". Smaller icons were located at the bottom of the screen, giving the user the ability to access "applications", "Volume" and "settings". When pressing an icon, the next screen showed icons in a grid style, not dissimilar of those popular in smartphone operating systems. Every time a button was pressed a small sound was also heard, signaling that the device had recognized the input. Along with that the icons when pressed also lit up with a large square box around them, showing the touchable space for that particular icon.

Overall this GPS device proved functional and offered good usability. The menu structures felt logical and familiar since they emulated the grid style icon view that exists in smartphones.
Another great functionality that the Nuvi 2797 provided were that when typing on the on-screen keyboard, searching for an address the keyboard automatically grayed out the keys were no matching addresses were to be found which, provided this functionality works flawlessly, that the user will never experience aggravating miss presses and "no matches"-searches (see Fig. 16 below).

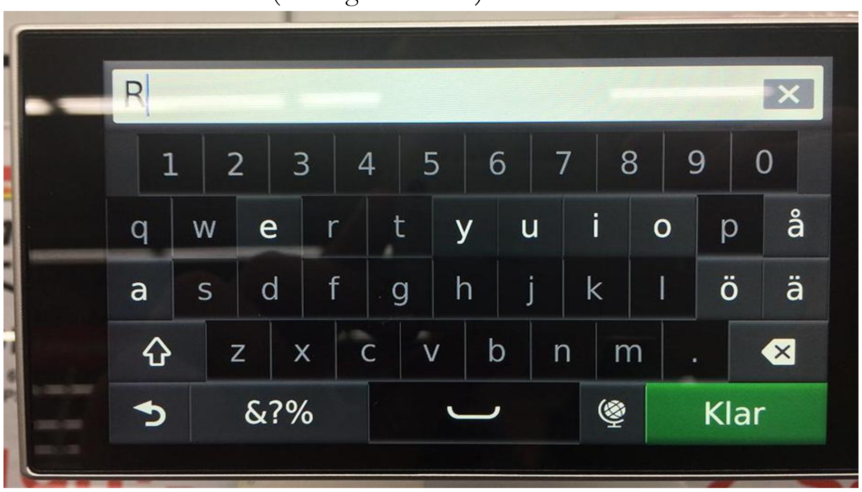


Figure 16: The keyboard excluding letters that will result in no matches

**TomTom Go 600 EU45 LMT**

This device had a 6" screen which was much glossier than the one on the Garmin Nuvi 2797. The interface felt more illogical than previously tested devices, probably because the icons were not as clear and much smaller. To bring up the menu from the map view the user had to press a very small round icon in the shape of three dots in the left bottom corner. This in turn brought up a sort of overlay menu that was horizontally scrollable since all the icons did not fit on the same page. The map view was still active in the background, simply faded with black and some opacity. This overlay menu overall felt more "sluggish" and did not respond quite as good as the Garmin Nuvi 2797.

Another curious design choice was the on-screen keyboard provided by the TomTom. The buttons were rounded and not connected with each other, the top buttons were also more drop-shaped except for the last letter "å" on the top row, and this was left round as the other rows of buttons (see Fig. 17 below). Typing on this keyboard felt more cumbersome than such a simple task should feel. The overall impression from the TomTom Go 600 was not that it was particularly bad, just that it could have been a lot better with other design choices.

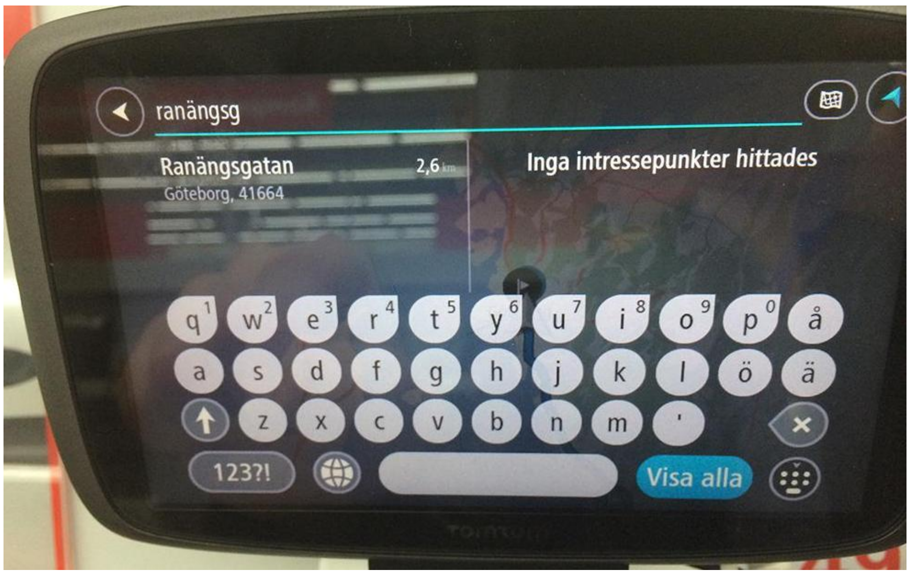

Figure 17: TomTom's keyboard

**Garmin Head-up**

This device was interesting since it provided the user with a head-up display that was projected upon a plastic like surface and giving the user directions via this interface. The device also enabled the user with the ability to connect their smartphone via Bluetooth and an app. However, this functionality was not tested. The Garmin Head-up served as an inspiration for possible solutions along with proving how smartphones could be integrated into the driving experience. But the device itself provided little in the matter of touch input and user interface.

**Garmin Nuvi 3597LMT**

The Garmin Nuvi 3597 featured a 5" screen that was among the same level of glossiness as the TomTom Go 600. This device had the same UI as the Garmin Nuvi 2797, only on a smaller screen.

The smaller screen sized made the icons and touchable surface harder to press correctly, however the UI was still very responsive and the structure was as clear as on the 2797.
In conclusion this device felt as it was developed for users that desired the same functionality as the Nuvi 2797 but were intimidated by its size or felt a 5” display would be more portable.

### 4.2.2 Tablets and Smartphones

Since the smartphones consist of either Android based OSs or iOS not all the examined smartphones will be accounted for in the same manner as “*4.2.1 GPS-Devices*” with an analysis of every device. Instead the main OSs will be examined and if there is a special feature available in some specific device it will be brought up.

**iOS:**
iOS is the name for the operating system that runs on Apple’s devices. It has been around since the first release of the iPhone in 2007 and is currently in its seventh iteration, named iOS 7.
The OS mainly consists of icons in rows, although some new features recently have been added, such as the ability to pull down the upper status bar to display various notifications from different apps that allow this feature. From this pull-down menu there is also the possibility to view calendar events for the day and see missed notifications. Furthermore the user may also swipe in the same manner as with the status bar but instead from the bottom of the screen. This will bring up the “Control center” which features a variety of easy toggle functions, such as “airplane mode”, “Wi-Fi”, brightness and music controls etc. (see Fig. 18 below). Apple has also added the ability to unlock the phone via fingerprint, in the iPhone 5S, thus enabling the user to skip the lock screen and jump right into the home screen.

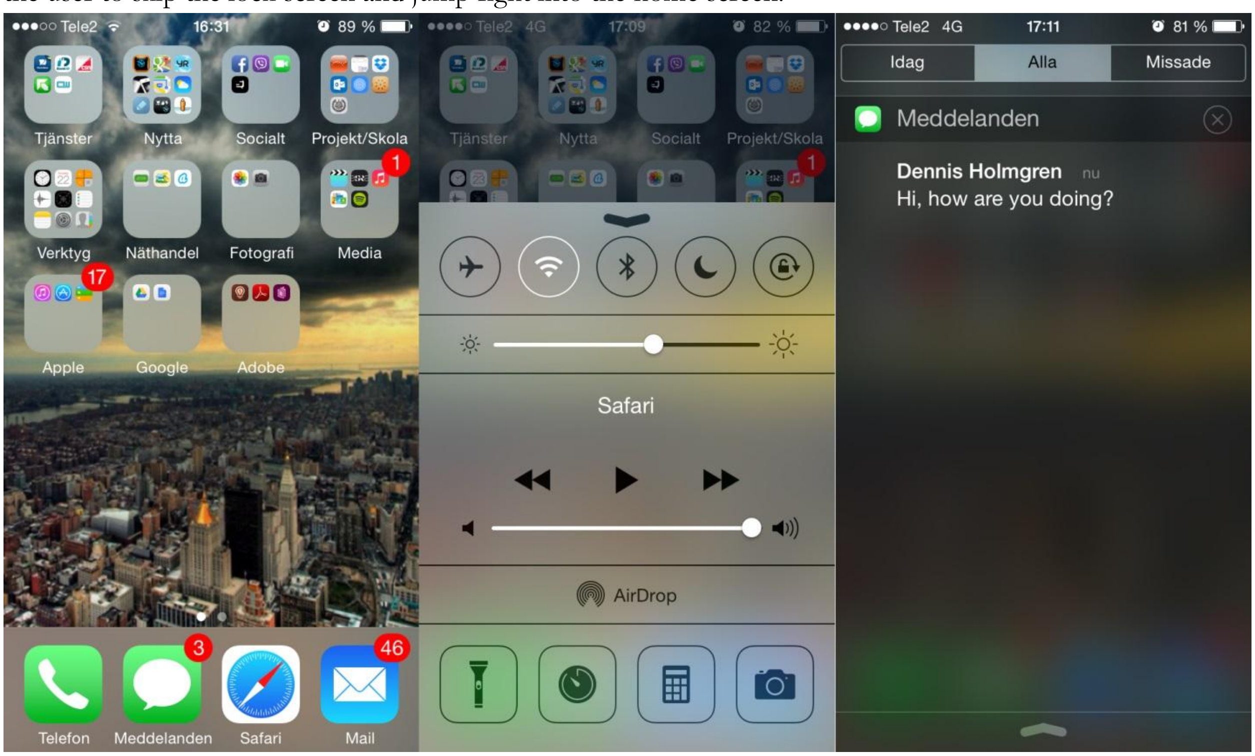


Figure 18: iOS, Standard view, Control center and Notification center

**Android:**
Android was developed as an open source OS supported by Google. Its initial release was in 2008 and its latest version is 4.4 KitKat. A large difference from iOS is that Android is not manufacture exclusive; instead Google encourages manufacturers and developers to develop for Android and put it on their own devices. This has led to that there is currently a large variation of Android based phones and tablets from different manufacturers, among them Samsung, HTC, Sony, LG and the list goes on. A large differentiation however are that all of the listed manufacturers have their own developers and put "skins" on top of standard Android. For the untrained eye a phone from LG and a phone from Samsung may look so diverse that it is hard to believe they are at their core running the same OS.

The advantage of this is however that all these devices are connected to the same app structure and can access the Google Play store. Some basic functionality also remains the same whichever flair of Android the user may be operating. Among them is the pull-down notification field which works much like on iOS, however widget based applications may also reside here, such as battery graphs, the user is also free the download apps from the Google Play store that will place themselves in the notification bar. This also brings us to the next point, widgets. Android has from early version offered the ability to add widgets onto the home screen. These widgets may be calendars, stock indications, battery info, quick toggle settings etc. These widgets are also resizable and movable, offering the user quick access directly from their home screens (see Fig. 19 below).

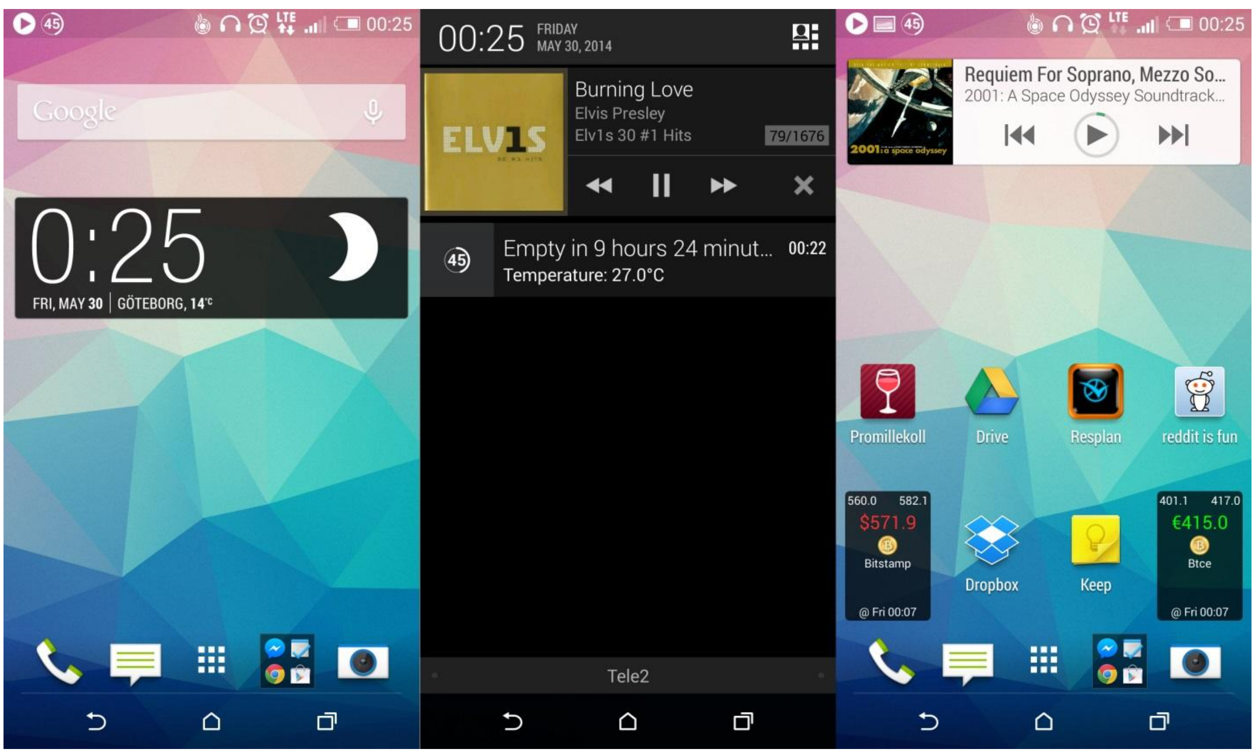

Figure 19: Android, Standard view, Notification field and a screen with lots of widgets

Another difference between Android and iOS is that Android offers the user a lot more customizability. The user is free to access the file system, switch out the keyboard and even the main launcher can be changed and customized.

Many manufacturers have also experimented with adding additional functionality to the Android OS. Samsung has offered many "eye-tracking" abilities, among them functionality such as that the screen brightness does not fade as long as the user is looking at the screen, or the ability to scroll in lists with their eyes (Samsung, n.d.).

HTC recently added functionality that allows the user to wake their phone from sleep by double tapping the screen, or simply swiping either up, down, left or right for quick access, for example swiping up brings the user directly into their latest used app (HTC, 2014).

**Tablets:**
Tablets have made a quick entrance to the market and customers have embraced these products. The benefit of the extra screen space makes room for interesting design solutions to optimize this extra screen real estate. The major operating systems here are Android and iOS as well; however some features differ from their smartphone counterparts.

While examining the iPads it was concluded that in many of the cases Apple's design solution had just been to "enlarged" iOS from the iPhone. This resulted in that the "Control center" for example, had very small buttons and did not utilize the screen space to its full potential. The icons on the home screens are also sorted in the same rows as on the iPhone. While the resolution is higher on the new iPad Air (Apple, 2014) than the iPhone 5S the icons rendered on the screen are roughly the same size. Apple simply increased the space between the icons on the iPad rather than making the icons substantially larger. All the iPads featured, just like the iPhones, a physical button which would bring the user to the home screen. Furthermore, a landscape mode for the home screen also existed; the user could also orient the device "upside down", i.e. spinning the device 180 degrees in portrait mode and the home screen would show that way. These were features not included in the iPhone version of iOS.

When instead considering Android tablets the same climate as for smartphones exists, thus meaning that manufacturers put their own flair on top of standard Android leading to some variations between the tablets.

Lenovo's tablet "Yoga" featured an extendable stand on the back of the tablet. Software wise Lenovo had split the taskbar functionality, meaning that if the user pulled down the taskbar on the left side of the screen the notification field would be revealed, while if the user did the same action on the right side of the screen a quick access field with toggles for Wi-Fi, Bluetooth and settings etc. would be revealed. The tablet carried no physical buttons, only software buttons which relocated depending on which way the user oriented the device.

Samsung had a variety of tablets, varying in both screen size and price class. Most notably was that the standard viewing mode for these tablets were landscape. The Samsung tablets featured a physical home button and two soft-touch buttons, one on each side of the home button. These were buttons for "back" and "settings". The UI also encouraged the user to enable widgets which could be resized and customized. With such a large screen, widgets were a good use of crossing usability with user value. Pulling down the status bar also revealed the notification field bundled with some quick toggles for Wi-Fi as well as direct access to adjusting the brightness and volume level.

Overall Apple's tablet while offering a good user experience felt lacking as they very much were just enlarged versions of their smartphone counterpart. Android, while not perfect, offered both more customizability and better use of the screen space. Worth mentioning however are that some of the low-end Android tablets offer lacking build quality and are often equipped with insufficient hardware, making them sluggish and sometimes infuriating to use. Apple on the other hand offered well-built devices that functioned as advertised (although sometimes with the occasional crash or glitch, no system is perfect after all).

### 4.2.3 Cars

The car industry today offer many different ways of interacting with infotainment systems, the investigated solutions found in this chapter offer four different ways of interacting. An application based system via smartphone, a fully touchscreen UI and a touchpad bundled with a rotary dialer as well as an announced but not yet shown interface.

**Apple Carplay**
Apple has together with car manufacturers, one of them being Volvo Cars, announced that they will be offering a new service called Apple Carplay which will allow the user to plug in their iPhone 5 (or newer) into selected models of cars from supported manufacturers (Apple, 2014). This will bring up a new UI specifically tailored by Apple for interactions in the car via touch. The UI will look similar to their iOS counterpart but with larger icons and fewer apps. Phone, text messages, navigation and music player are some of the apps that will be available however. Apple Carplay will be introduced in Volvo XC90 (Volvo Cars, 2014).

**Tesla Model S**
Tesla Motors, the electric car company, has chosen to make all their input systems fully touch based by offering a 17" capacitive display in their Model S. All interaction with the car's system from the climate control to changing radio station is made through this display. At the top of the display a status bar is presented, which displays information such as temperature, a small clock and if a phone is Bluetooth-paired, reception. Beneath this menu is a line of icons such as Media and Navigation. Tesla also provides the user with a fully usable web browser. After this comes what takes up the lion share of the screen real estate, the content. Depending on which functionality the user has started, the information of that function will be displayed here. Tesla allows the user to multitask functions by having to functions sharing the screen. These functions can be rearranged or if the user desires, one function, such as navigation, can take up the entirety of the screen. Finally, at the bottom are buttons for climate control, volume etc. that are visible at all time (Tesla Motors, 2014). Switching to a fully touch based system might be viewed as a risky move, however according to reviewers, this system works great (Laird, 2013; Brownlee, 2014).

**Mercedes C-class**
Mercedes-Benz has recently released a new C-class car, C 180, which has a ~8" infotainment display (Mercedes-Benz, 2014). Mercedes-Benz has long favored the use of rotary dialers over other technologies such as touch screens. However in their latest addition to the C-class they have included a touchpad with multi-touch which is capable of recognizing commands and also handwriting. The touchpad is capable of providing haptic feedback to the use. The system is able to read the inputted data aloud to help the user keep his eyes on the road. Mercedes-Benz however still gives the user a choice to use the rotary dialer if that input method would be preferred, and has to support this included a technology which allows the touchpad to determine whether the user is trying to put in command via the touchpad or is simply resting his hand on it (Mercedes-Benz, 2014).

**Google Car**
Google has long been working on various implementations of vehicle technology, for instance by experimenting with self-driving cars (Fisher, 2013). Google has also announced something called the Open Automotive Alliance. This alliance consists of several car manufacturers alongside with graphics manufacturer NVidia and is devoted to bringing the Android platform to cars, starting in 2014 (Open Automotive Alliance, 2014). However, no visual material has been presented as of how this will work or look yet, but it is worth keeping under supervision, especially now that Apple has released their solution.

In conclusion, the car industry is offering some intriguing choices and solutions and further investigation and interaction is recommended to extract more information.

### 4.2.4 New touch technologies

The following technologies are conceptualized or newly developed technologies that have not yet been fully commercialized, they are however worth noting and keeping under supervision, since they potentially could yield fruitful or new solutions. This section will be kept brief, for more in-depth information about the technologies, kindly consult the references.

**3D touchscreen with tactile feedback**
Microsoft has been developing a new 3D touchscreen that provides the user with tactile feedback. It works by having a robotic arm behind the screen and when the user touches the screen the arm pushes back with a small amount of force, generating tactile feedback. While pushing forward the object the robotic arm moves backwards in a controlled and smooth manner while the screen is rendering the object in perspective, so it appears as if the user pushes forward, the objects come closer, hence the “3D-effect” (Kelion, 2013).

**Morphable touch screens**
A thrilling new technology that is currently being developed is the ability for a touch screen to have “morphable” buttons that can come out in the shape of keys for the keyboard, thus giving the user better tactile feedback and emulating the feeling of pressing a real button rather than a flat surface. When the buttons are not used the screen simply looks like a regular flat screen. The buttons can morph out in different shapes and positions on the touchscreen (Tactus technology, 2014). This technology would allow for more tactile reliant input and less visual, thus potentially having benefits for use in-vehicle.

**Adaptive touchscreen**
This technology builds upon the idea that once the user approaches the screen with his finger the icon grows. This is done in order to minimize errors and reduce the amount of misclicks (Bachfischer et al, 2008). This could also have direct application for touchscreens in vehicles since the user needs to keep their eyes on the road and this technology would potentially result in higher accuracy for trying to press icons on the touchscreen without looking.

**Local Vibrations**
Most smartphones and touchscreens have vibration and haptic feedback built in, that responds when the user use the device. However this vibration is a full body vibration and only one vibration is allowed at each time. New technology in the development stage would allow for local vibrations, meaning a specific vibration where the user touches the device and also multi-vibrations to give more accurate tactile feedback (Ramstein & Liaukeviciute, 2014).

### 4.2.5 Other technologies

The following descriptions are brief mentions and investigations about technologies that may prove useful in an in-vehicle environment. For further reading, please consult the citations.

**Neonode solutions**

Neonode is a newly established Swedish company that offers new technologies they call zForce, which is based on optical infrared light. This allows for removing the glass overlay that is fragile and easily breaks, from capacitive solutions thus making way for lower production costs among other things (Neonode, 2014). Furthermore, Neonode has also developed technology that allows the user to control a head up interface from the steering wheel. The wheel is touch sensitive and also proximity sensor which makes the steering wheel able to determine where the user has his hand at any given moment. The information is then displayed right in front of the user, allowing for both information decoding while still having both eyes on the road.

**Eye tracking**

Humans are visual beings and both driving a vehicle and operating a GUI are tasks that are heavily vision based. Toying with the idea to further develop eye tracking as a potential way of navigating either the GUI or operating the vehicle are interesting ideas worth entertaining. Perhaps a screen could alert the user of when too long glance time occurs or give enough cues to make sure too many/long glances will not occur in the first place.

**Curved screens**

Many screen manufacturers, such as LG, Sony and Samsung have recently started manufacturing and showcasing curved screens. Without going into too much technical aspects of the viewing angle and pros/cons of a curved screen, a benefit curved screens have are that they reflect less ambient light, thus giving the user a better viewing experience in light environments. Curved screens could also improve color accuracy and contrast (Tarantola, 2014). Samsung has released a smartphone with a slightly curved screen, when testing was done it was concluded that this device had reflectance of around 5 %, some of the lowest numbers measured (Soneira, 2013).

## 4.3 System research

After gathering the results from both the market research and the benchmarking, it was time to instigate a thorough investigation of Volvo's solutions and current layout. In addition, HTA analyses will show how many steps it take to carry out different functions in the current UI of the SID. After that, results of the Heuristic Evaluation will be presented alongside with results from the Enhanced Cognitive Walkthroughs and PUEAs, to give a structured and scientific overview of the problems a user may experience.

### 4.3.1 Investigation of current layout

The current layout of the buttons in the FH-model can be seen in Fig.20 below. As part of the result was identifying all the components of the system layout and what the functions did. However, it was concluded that most of these had very little to do with the SID and was outside the scope of this project. Therefore the section of the system layout that was focused on is seen in Fig. 21 below. The SID as it is today is in a bad position for touch input, especially from an ergonomic point of view since the SID is located in a small "pit", which is difficult to access from the driver position.

Moreover, this section was chosen as appropriate because the functions in this section are functions that could be controlled via a touch UI. Most of the buttons in this section, such as the alphanumeric buttons, the volume rotary dialer and another rotary dialer, are in fact used to control the current SID. Additionally, the buttons and functions located right below, such as climate control, were suggested by users to add to the SID. This is further presented in *"4.4. User studies"*. These are also functions that could be controlled via a touch interface since they are non-vital for driving and often the user does not change them so much during driving. They are also not cluttered with information and should only require quick glances in order to successfully maneuver.

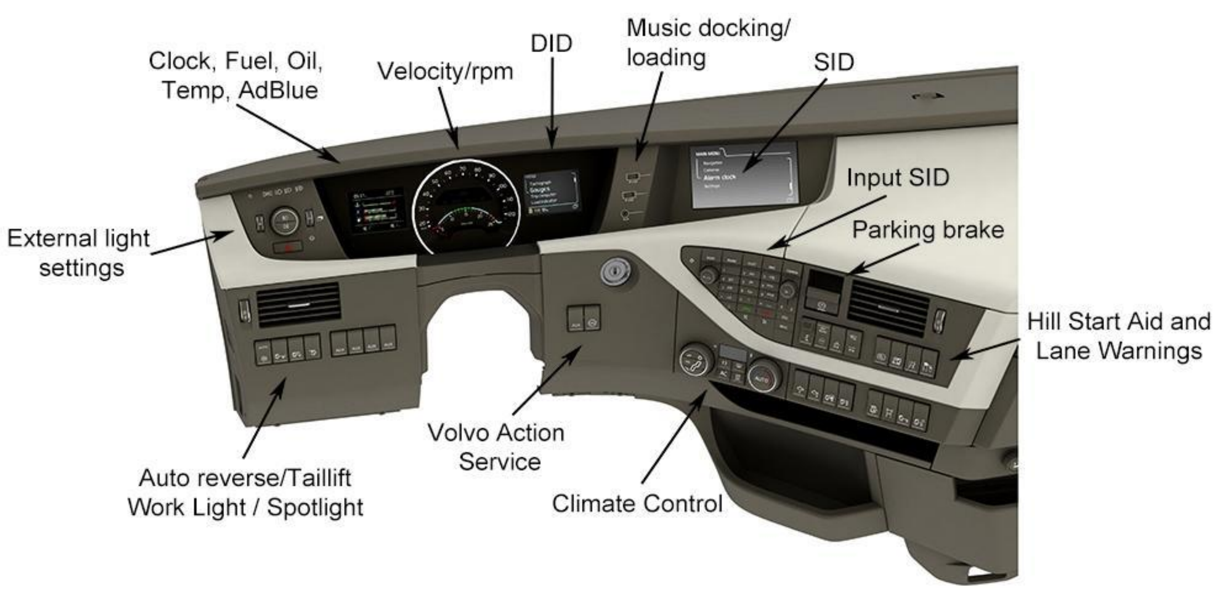


Figure 20: The layout of the FH-model

Figure 21: Suggested area of touch implementation

### 4.3.2 Current user interface in Volvo FH-series

This chapter will cover a thorough review of the current SID interface.

The user is upon startup meet with a main menu screen containing lines of text which leads to all the different functions of the UI. The UI features (if all functions are available) Phone, Audio, Dynafleet, Alarm, Navigation, Camera and Settings. As seen in the picture (Fig. 22), the current UI is very spartan, featuring only text and a few lines indicating pointers and scrolling-functionality. The main part of the screen is empty and although the text could be displayed at a larger size, it is not and no options for this are given to the user.


Figure 22: The main menu of the SID

The phone menu consists basically of a long list, where the user can search for contacts via the "SWJ". In the phone menu it is also possible to make phone calls through manually dialing a number with the use of alphanumeric buttons. Below the contacts list a dotted line, acting as a divider for the call history (the last made and received calls), is seen. The call history section was not marked in anyway, however, there were some icons indicating whether the user had made or reviewed a call.

The above menu was only displayed if the user had a supported smartphone paired via Bluetooth. If the user tried to access the phone-menu without having a smartphone paired, the user was simply met with a prompt stating that the user had to connect a Bluetooth device to enable the desired function, and the user was then returned to the main menu, without instructions on how to pair a Bluetooth device.

The audio menu lets the user access the radio, cd-player, aux control and iPod/USB. Worth mentioning about these menus was that the radio function had several hidden menu structures, that were not displayed directly or given any clues on how to enter. To enter the hidden structure the user had to press the "OK"-button inside the radio menu (which can be seen in Fig. 23 below). This action brought up the hidden menu, seen in Fig. 24 below, where the user was presented with several new menu items, such as radio settings and an intro scan. Moreover, when entering the radio settings, several settings were presented, such as deciding whether to play news and traffic announcements.

Figure 23: Radio menu 1 in the SID

Figure 24: Radio menu 2 in the SID

This hidden menu structure was not very intuitive, thus the user had to perform many operations (i.e. click and scroll many times) to go to the radio settings menu. This issue is further addressed in *"4.3.3 Hierarchy Task Analysis*". Worth mentioning was that once the radio was started, there was no way of turning of the radio. The user could mute the volume or decrease it, but simply not turn it off. Additionally, no music streaming via Bluetooth was possible.

When investigating the iPod/USB functionality, this featured stood out in particular, because it functioned well and provided the user with the same functionality as when navigating in an iPod, but instead presented in a layout more appropriate to the SID. It seemed however unnecessary to limit this functionality to only work with Apple products, since Android device were discovered to not support the USB functionality.

The Dynafleet and navigation functions were not investigated. However, in many of the interviewed users stated that the navigation function was insufficient and for example showed roads that were not optimal for trucks.

### 4.3.3 Hierarchical Task Analysis, HTA

In the following paragraph the different HTA-analyses will be presented (as figures) and briefly explained in text. Full size figures of the analyses can also be found in the appendix (A9)

**Bluetooth pairing of Android and the truck**

The first subtask, when pairing an Android smartphone with the truck is the "*Initial search*" (1.0 in Fig. 25 below). In this search the user performs operations in order to proceed to the main menu of the UI. Generally, the main menu is not displayed directly on startup, wherefore this initial search is required. After having succeeded with this first subtask, there is a risk that the user might turn the "SWJ" to search for the telephone menu, and entering it by pressing "OK". This unnecessary sequence provides the user with a prompt displaying the text: "Connect a Bluetooth device to enable this function", and leaves the user no clues how to perform such a connection.

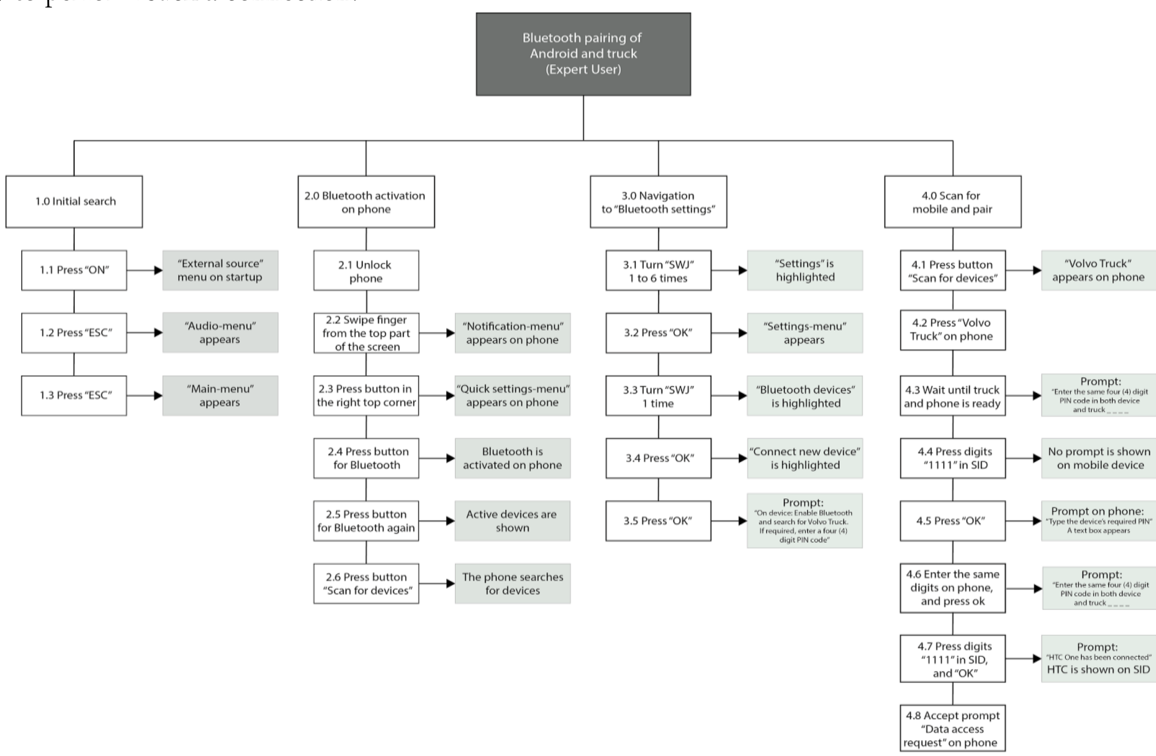


Figure 25: HTA - Bluetooth pairing of Android and truck

The second functional level is the "*Bluetooth activation on phone*" (2.0 in the Fig. 25 above), which operations' depends on the Android phone model. Step 2.0 in the figure is therefore only an example of the required operations, which are not considered necessary to further explain, for this purpose. However, when the user has finished the step 2.6 in above figure, the same misstep, as described in the last paragraph, can occur. That is, the user might try to enter the phone menu again, in hope for it to work after having enabled Bluetooth on the device.

In the third function of the above HTA, “*Navigation to Bluetooth Settings”* (3.0 in the Fig. 25 above), the user is first intended to find the “Bluetooth Settings”-menu by scrolling the SWJ until “Settings” is highlighted. Once inside the “Settings”-menu the user can easily find and enter the menu item “Bluetooth devices”, and after that press “OK” on the menu item “Connect new device”. The result of this third function is a prompt informing the user of the final steps to succeed with the pairing.

The fourth and last function of the HTA is the subtask “*Scan for mobile and pair”* (4.0 in Fig. 25 above), where the user scans for the truck with the device, enters a random code both in the SID and on the phone in order to finish the task. However, if not entering the code in the correct order, the user will have to enter the code thrice, one time on the device and twice in the SID.

The drawn conclusion from the above result was that the task required a numerous amount of operations, some of which were regarded as unnecessary. However, the task is not performed very frequently, but the result still indicates that it requires many operations in order to navigate in the menu structure of the existing SID.

**Call a contact in the SID with an iPhone (while another cell phone is connected)**
A second HTA was made on the attempt to *call a contact in the SID with an iPhone (while another cell phone is connected)*. This HTA was made in tabular format and can be found in the appendix (A10). It was discovered, after having struggled with pairing two phones, that this was not yet an implemented function. Furthermore, this function was regarded as desirable, since drivers commonly use both a private- and a work phone.

**Make a phone call with Android smartphone**
Initially when making a phone call with an Android smartphone, the user performs the subtask “*Navigate to Phone”* (1.0 in Fig. 26 below). The first operations in this subtask are performed analogously to the operations in subtask *1.0 Initial task* in the main task “Bluetooth pairing of Android and phone” (see above). After the last operations in the task “*Navigate to Phone”*, the user also enters the phone menu via turning the “SWJ” and pressing “OK”, which presents only a dialer option (due to compatibility issues between the truck and some Android smartphones).

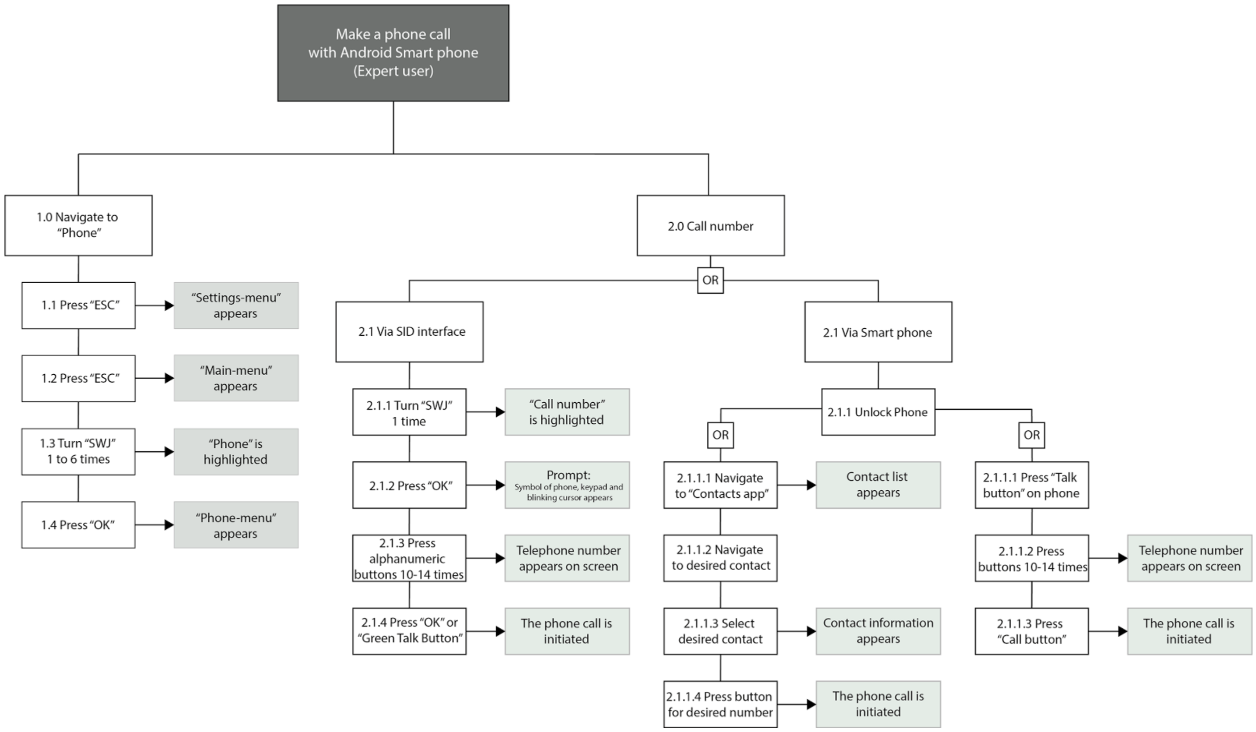


Figure 26: HTA - Make a phone call with Android smart phone

The user can thereafter perform the second subtask "*Call number*" (2.0 in the figure above) either via the SID interface (manually entering the desired telephone number), or through operating the UI of the smartphone (which again depends on the specific smartphone model).

**Make a phone call with iPhone already paired**

To further evaluate differences in functionality when using different smartphones, a HTA was also performed on the main task "*Make a phone call with iPhone already paired*". It was discovered that there were no compatibility issues when using an iPhone instead of an Android phone. After having paired the phone with the system, as was described earlier in this chapter, the user can proceed with the subtask "*Navigation to contacts*" (1.0 in Fig. 27 below). In order to find contacts in the SID, the user has to enter the phone menu by turning the "SWJ" and pressing "OK" as shown in the figure below. Thereafter, there are two alternative ways of proceeding with the phone call, either by searching with the alphanumeric buttons in the SID (see [1.4.1] - [1.4.4] to the right in Fig. 27 below), by scrolling to the desired contact with the "SWJ" (see [1.4.1] - [1.4.2] to the left in Fig. 27 below) or through a combination of the said alternatives (presented by the dotted arrow in the Fig. 27 below).

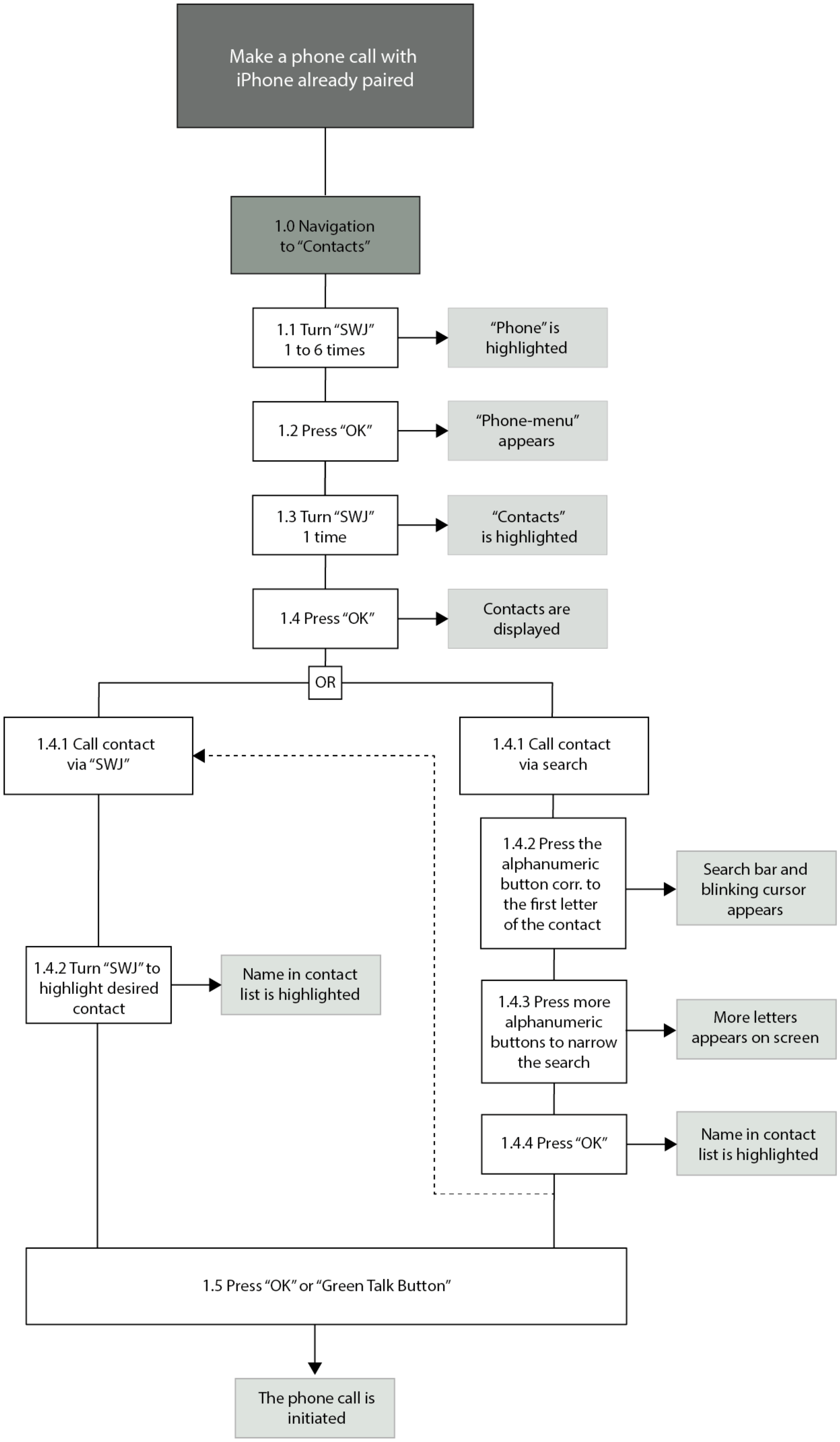


Figure 27: HTA - Make a phone call with iPhone already paired

**Tune radio and add favorite**

A final HTA was made for the main task *"Tune radio and add favorite"*. The first subtask of this task is "*Navigate to Radio-menu"* (1.0 in Fig. 28 below). In order to complete this subtask, the user needs to either press the "AUDIO"-button 1 to 5 times, or navigate to the Radio menu by turning the "SWJ" and pressing "OK" (in accordance with steps [1.1] - [1.4] in the figure below). When the user finishes the first subtask, the radio tuner appears, and the last played radio station is heard.

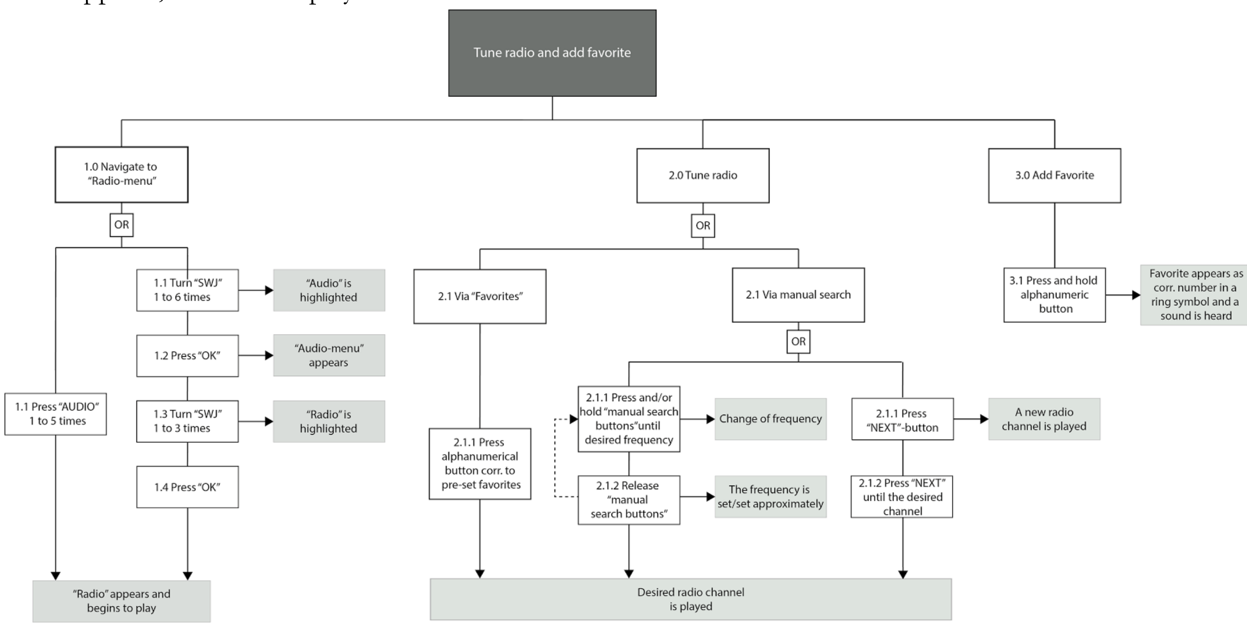


Figure 28: HTA - Tune radio and add favorite

The second subtask in this analysis is *Tune radio* (2.0 in Fig. 28 above), in which the user can choose a radio channel via favorites (2.1 to the left in Fig. 28 above) or via manual search (2.1 to the right in Fig. 28 above). Choosing a radio channel via favorites is performed by pressing a alphanumerical button that corresponds to a pre-set favorite, while manual search instead requires the user to manually press "NEXT"/"PREVIOUS" or the tune buttons to select the desired channel.

The last subtask of this HTA is the task "*Add favorite",* in which the user simply presses and holds an alphanumeric button to add a favorite on that specific number. If the chosen number is later pressed in the Radio menu (or when not being inside the Phone menu) the radio changes accordingly. Also, worth mentioning, is that it was not possible to turn off, or pause, the radio without entering another audio source or pressing the mute button.

When analyzing the above result it is possible to conclude that navigation to different menus or navigating through lists were time demanding tasks, which in all cases contained unnecessary operations.

### 4.3.4 Heuristic Evaluation

After having concluded the Heuristic Evaluation, several areas of improvement for the current SID were discovered. A summarized description of those areas follows below.

**Design patterns and colors**
The interface contained few complementary icons, to assist the user in the perception of a specific task. For example the main menu could be clarified by adding complementary icons to the menu items. However, icons were used in the media player, albeit some were a bit unintelligible. Furthermore, color choices for menus were somewhat insignificant, although consequent. Color could be added to the main menu to further assist the choices. When having entered the main menu all menu items could not be seen at the same time, although there are only a few number of menu items in total.

**Overall functionality**
The system did not provide a fast access to the radio, although it is a common function. Instead it was necessary either to press the "AUDIO"-access button several times or enter the radio through the main menu. Moreover, it was discovered that the two only ways of disabling the sound from the radio was either to enter another audio source or to press the "mute"-button. When having entered the radio menu, there were inadequate cues on how to enter the "radio settings"- menu, where functions such as "intro scanning" or enabling/disabling traffic announcements could be accessed. This specific menu was therefore seen as a hidden menu. Furthermore, no pop-up or other feedback was provided when having changed the radio station in a menu separate from the radio menu.

For some functions in the SID it was required to wait for a long time, without being informed of the progress, while the system was loading. This was particularly prominent when configuring Bluetooth.

When alerts or prompts were presented, the system provided relevant information but did not describe the required procedure for the desired functionality. An example of a relevant but insufficient prompt was a prompt that was shown when having entered the "Phone Menu" without having paired a phone with the truck via Bluetooth first. In this prompt the text "connect a device to enable this function" was shown by the system, without further informing on how to connect a device.

**Button structure and functionality**
It was not possible to press the "OK"-button to close a prompt or alert. Instead it was required to press the "ESC"-button. Furthermore, undo-actions were not always logical. The "ESC"-button was used both to go back and sometimes to cancel.

Among the buttons, there were blank buttons with no functionality. In addition to this, the grouping of the buttons and button structure could be improved, and a home button could be added.

### 4.3.5 Enhanced Cognitive Walkthrough, ECW

As shown in the table below, the most common problem type was that functions or the required course of actions for specific tasks were *hidden* from the user or was due to the earlier knowledge and experience of the *user*. Examples of this were that it was unclear how to succeed with either pairing a phone with the truck via Bluetooth or adding and modifying radio favorites. It was also observed that some functions were *missing*, such as getting access to the call history or contacts on all Android phones, when intending to make a call through the SID. This lack of functionality was not expected, and appropriate *feedback* in form of information regarding this compatibility issue was not provided.

Furthermore it was discovered that the “Radio-menu” interface did not follow the same interaction logic or hierarchy as the rest of the system, that the phone interface was not activated when pressing the green call button on the steering wheel and that pairing of multiple phones was not possible. Pairing of multiple phones could be beneficial, since many drivers carry two phones, one for work related calls and one for private calls. Lastly, it was found that the “Call history” was not presented in an optimal way. Instead of presenting a contact followed by the number of calls in total, every in- or out-coming call was stacked in a long list, thus not taking advantage of the available screen area and increasing the amount of turns on the SWJ required to highlight the desired contact.

Table 4: Matrix showing result of the ECW

| Problem Type\Problem seriousness | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| (U) User | 2 | 1 | 2 | 0 |
| (H) Hidden | 1 | 4 | 2 | 0 |
| (T) Text and icon | 0 | 2 | 2 | 1 |
| (S) Sequence | 0 | 0 | 1 | 0 |
| (F) Feedback | 1 | 3 | 1 | 0 |
| (M) Missing function | 3 | 0 | 0 | 0 |

The usability problems found in the ECW should be regarded as areas of improvement when updating UIs or creating new UIs in trucks. The ECW in its whole can be found in the appendix (A4).

### 4.3.6 Predictive Use Error Analysis, PUEA

The text below summarizes the result from the two PUEAs.

**PUEA for task 1: Pair an Android phone with the truck**

The first PUEA predicted 40 possible user errors. User errors found through analyzing this task were for example:

- The user does not expect having to scan for devices - the user does not press the correct button on the phone. Instead he/she searches in the Truck UI
- The user tries to pair the phone with the truck solely by using the phone
- The user expects that Bluetooth pairing is possible via the "Phone Menu"
- The "Settings Menu" is not directly visible - the user thinks that something is wrong
- The user scans for devices on phone before pressing "OK" in the SID interface
- The user does not understand that he/she should enter the PIN code in the SID, due to in lack of cues

The figure below (Fig. 29) shows the most common error causes and types discovered in the first PUEA. The most frequent error type was that the *information was not obtained* by the user, meaning for example that menus or functions were hidden or no information was provided on how to perform a specific task. Another common error type was that the performed *action was incomplete*, meaning for example that the users interrupted the task before completion, or that the users did not get an indication whether the task was accomplished or not. The far most common error causes were *slips*.

The most common Error Causes

(S) (17/40): Slip. "Good plan, bad execution"
(K) (8/40): Knowledge-based mistake

The most common Error Types

P2 (4/40): Incorrect plan executed
A7: (5/40): Wrong action on the right object
A9: (7/40): Action incomplete
A10: (4/40) Wrong action on the wrong object
R1: (9/40) Information not obtained

Figure 29: Error causes and types of the first PUEA

When further having analyzed the primary consequences and the error recovery of every specific error type and cause, possible error preventions to each error were investigated. The most prominent error prevention was to *Simplify directions for Bluetooth pairing*. It was found that this error prevention was adequate for 47, 5 % of all discovered user errors of this specific task. Furthermore it was suggested that a *more logical and more available button design and structure*, together with *informing the user* and *making code input interface easier to interpret* could prevent more user errors.

Examples of user errors together with the summary regarding the task *"Pair an Android phone with the truck"*, can be found in the appendix (A11).

**PUEA for task 2: Tune radio and add favorite**
By analyzing the second task, 49 possible user errors could be predicted. Examples of user errors are presented below.

- The user activates another function instead (the eyes are focused on the road)
- The user searches for the "NEXT"-button below the SID
- The user uses one of the "manual search"-buttons instead of the "NEXT"-button
- The user hold the button for too long, thus missing the desired radio station
- The user holds the alphanumerical button for an insufficient period of time
- The user presses and holds an undesired alphanumerical button, thus placing the favorite radio channel in a spot unknown to the user

The following figure (Fig. 30) shows the most common user causes and types discovered by the second PUEA. The most recurring error types were that the users often performed the *right actions on the wrong objects, misaligned the actions, performed the wrong action on the right object* or *performed a too long/short action*. The most common error causes were *slips*, accounting for approximately 71 % of the found user errors in the second analysis.

**(S) (35/49): Slip. "Good plan, bad execution"**
(L) (10/49): Lapse. "Forget plan or execution"

The most common Error Types

A1 (8/49): Action too long/short
A5: (9/49): Misalign
A6: (10/49): Right action on wrong object
A7: (8/49) Wrong action on the right object

**Figure 30: Error causes and types of the second PUEA**

When further having analyzed the primary consequences and the error recovery of every specific error type and cause in the second PUEA, possible error preventions to each error were investigated. The most prominent error prevention was to *Make the button structure and design more logical and available*. It was found that this error prevention was adequate for 41 % of all discovered user errors of this specific task. Furthermore it was suggested that a *simplified sequence or directions for radio tuning*, together with *making all the objects in the main menu directly visible (meaning there is no need to scroll),* could prevent even more user errors.

Examples of user errors together with the summary regarding the task *"Tune radio and add favorite"*, can be found in the appendix (A12). Furthermore, a table explaining different error types and causes, according to Bligård (2012), can also be found in the appendix (A13), to further support the comprehension of above results.

## 4.4 User studies

After having concluded the factual studies it was time to move over to the user studies. The user studies started off with interviews with experienced drivers at a Volvo testing facility. These were drivers that were used to speaking to engineers and thus versed in technical formulations and evaluated different truck models on a daily basis. Besides the interviews observations were also done, interesting observations were noted and when appropriate asked about. To get more user data working drivers were also interviewed during ride-alongs. To get the full trucking experience, different trucks were also driven on a test track. Finally the results from the interviews where summarized in an affinity diagram.

### 4.4.1 Interviews

During this phase, four in-depth interviews were carried out. Additionally the result of eight more interviews were taken part of via an internal investigation by a Volvo employee, touching upon some of the same questions and general objective as this study, which made the notes from these interviews applicable for this study. Note that the result from the interview will be further described in *"4.4.5, Affinity Diagram"*, where conclusions were drawn based on the answers of the interview.

The result from two of these interviews will be handled in *"4.4.3 Ride-alongs"* since they took place with drivers on ride-alongs. However the other two interviews were with professional drivers, who were experts on trucks and also on formulating themselves in more technological terms and better expressing needs and desires.

The interviews were heavily oriented towards the usage of smartphones and their implementation in the truck. Users expressed a desire of being able to connect two smartphones (pair) with the truck at the same time, and also communicated frustration about the Bluetooth pairing routine, since it was unnecessary cumbersome. The inconsistency between different smartphones and Bluetooth pairing was also ventilated. *"On iPhone it [The truck] seems to be able to import contacts, with my android or windows phone it does not seem to do this and sometimes the pairing does not work at all."* was a statement made by one of the drivers. The drivers also said that drivers often carry two phones while on the job - one for work and one personal use. The current SID only allows one phone to be paired. It was suggested by the drivers that being able to pair several phones at the same time was desirable. Moreover, somewhere to place or dock the phone would also be appreciated by drivers.

In addition, one interviewee disclosed that drivers often want to start driving as soon as they get into the trucks. Customizing and changing settings will therefore be done on the road and not in the safety of the parking lot or docking bay before the shift starts. Navigation was described as an important feature, however, Volvo's built in navigation was stated as severely lacking by both interviewees. Mainly that the Navigation did not take the fact that the user was driving a truck in consideration, results like the navigation suggesting a route under a too low bridge or on roads where it was impossible to turn around were described by the drivers. For this reason, the drivers stated that they rather used their own GPS-device or smartphone for navigation purposes, as it was more reliant.

Both drivers stated that the radio was an important function and well-used, both of the interviewed drivers also expressed a desire for the ability to stream music via Bluetooth. This should also be an easy function to set up and should not require so many steps as the present system takes.

As stated by one of the drivers *"It should work instantly, no messing around in a lot of menus just to get my music on"*. Bluetooth was also favored over Aux since it was cordless.

The drivers did not find it hard to see the display in the dark, nor did they find it too bright. On the other hand they expressed that the buttons sometimes were hard to see in the dark and they would appreciate either tactile feedback from the buttons or as one driver said *"Braille on the buttons"* to help distinguish them in the dark.

Alarm were also a discussed feature, one of the drivers said that he would like to be able to name different alarms and have a visual indication on the SID for when an alarm was set and at which time it would ring.

The interviewees were both positive towards touch, given the factor that it was implemented in a functional way and with traffic safety in mind. To achieve this, large icons with clear symbols representing the functions was suggested, as well as making things easy and simplified. It was communicated by the drivers that the current SID required a lot of navigating menus in order to get to the desired function. Inconsistency in the UI was also expressed and that the different functions do not seem to respond in the same way. One user stated *"It is like different departments have been developing the different functions and then they have just pasted it together"*.

Overall the drivers stated that the best thing about the UI in the SID was that it mostly worked and did not have too much delayed response time.

### 4.4.2 Observations

Interesting observations made were to a large part regarding the handling and use of smartphones, along with the frequency of button presses alongside of which functions that the driver used.

It was noted that the drivers generally did not interact too much with the SID while driving. Just the occasional glance and changing of the radio station, the changing of station however was mostly done via the SWS. When a driver got an incoming call he glanced at the SID and then answered via the answer button on the SWS. Going into menus and changing things did not happen once (except when asked about the settings).

What was observed however, were that there was an empty button space on the SWS which maybe could be used for interaction with the SID in a new interface if so is required. The drivers mostly used preset favorites as a mean of interacting with the radio, meaning they pressed the alphanumeric keypad when wanting to change station, or simply pressed the next button on the SWS.

Some interesting observations regarding the use of smartphones were however made. The drivers had a number of different ways of placing their various phones. Some placed it on the dashboard tray, others in the cabinet space above the driver's seat. One driver had a very rectangular shaped phone and had figured out that he could press it down between the panels to the left of the SID, thus suspending it there and having it available for easy access. In addition, when one driver got a call on his work phone while he had his private phone paired, he had to struggle to get it out of his pocket and glance at it to see who was calling. The drivers also checked their phone during driving, responding to text messages or simply checking if they had any new notifications.

Other observations were that while the system was muted, the volume up or volume down button did not cancel mute. The user had to press the mute button again in order to be able to hear sound.

The red call button on the SWS when pressed and not in the menu did not bring the user to the phone menu, but pressing the green button or pressing the red/green phone icon on the alphanumeric keypad opened up the phone menu.

### 4.4.3 Ride-alongs

The ride-alongs were conducted alongside the interviews and observations.

One ride-along was with a 63 year old man who had over 35 years of truck driving experience. He currently worked for Schenker delivering goods all over the west coast of Sweden. The day of the ride-along was a particularly lucky day since the route was very diverse and trailing all the way up to Dalsland and not too far from the Norwegian border (the route can be seen in Fig. 31 below). This was lucky since the driver himself had no input or even prior knowledge of where his route would take him before being handed the work orders on the morning.

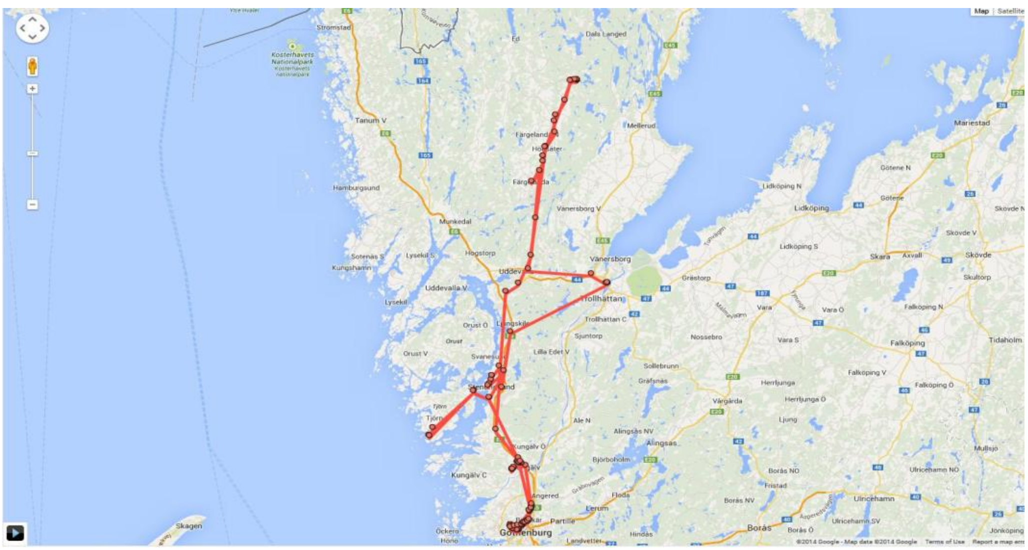


Figure 31: The first ride-along

During the ride-along several loading and unloading sequences took place along with situations like showing up to a payload, ready to unload the goods only to find out no one is there. Other valuable results from this ride-along were first-hand experiences with what a day-to-day job for many truck drivers. This made room for interview questions, observations as well as regular conversation. If a question arose it was brought up and discussed and if it proved potentially useful the question along with the answer was written down.

The driver expressed opinions about mostly using the radio and that he did not listen to music or streamed music very often, however, if it was an available function he stated that he might use it and that he knew that others would appreciate it. Furthermore the driver stated that “it should be an included function”. He further went on about the phone and said that he found it easier to navigate the phone’s UI than the SID’s. The driver also stated that when making a phone call he almost always used the phone directly instead of doing it via the SID UI. The driver also stated that being able to pair two phones was desired, since he himself had two, one for work-related calls and one personal calls. The driver was also positive to touch and said that most phones today are touch based, so people are already used to it. He also suggested that functions such as temperature, telephone, radio, volume, changing songs/radio stations could be controlled via a touch interface. This driver also agreed with previous interviewees that the interface should be simple, intuitive and easy to understand.

The second ride-along took place on Tjörn, in a quarry. The driver was in his 50's and had driven a truck since he was 18 years old. This ride-along was quite different from the first. Were the first ride-along was very diverse and had much time elapse between stops this drivers path was incredibly mundane and monotone. The route was simply going down to the dig site where an excavator operator dug out gravel, filled the truck up, the driver drove up from the dig site, dumped his load along a marked path and then drove down to the dig site again. When asked how many instances a day this could occur the driver answered that he worked 10 hours a day and drove up and down maybe 70-80 times a day. During this ride-along however many different circumstances were present that did not happen during the first ride-along, underpinning the fact that trucks are built for many different scenarios.

Firstly, the roads that this truck driver operated under were what would be classified as extreme conditions, steep roads, bumpy and questionable road condition. During the loading the entire truck vibrated and bumped each time the excavator operator unloaded a scoop of gravel into the payload area. The entire trucked moved each time this occurred. The driver said that when fully loaded he carried around 14-18 tons of gravel. Furthermore, when unloading his payload the driver was entirely dependent on the camera. Since the driver was backing up to a ditch when unloading, backing too far would mean potentially getting stuck in the ditch or in a worst case scenario falling into the ditch.

The driver was also positive towards touch. The driver stated that it was important that the system made it clear if a function was off or on and where in the UI the user was. Furthermore it was said that the UI should be simple and intuitive, not a lot of unnecessary information that might "steal glances". The UI should also be responsive and do not feel "sluggish". Regarding screen size and symbols, the driver said: "the symbols should be clear and simple; the screen size would also have to be larger than the existing SID and in another location, maybe a 10" screen?"

In conclusion the ride-alongs provided with insightful information about the ordinary day for a truck driver and how much they can differ, the relaxed manner in which the observations and interviews/conversations took place also helped extract more information.

### 4.4.4 Test drive

Not very much scientific data derived from the test drive; however, it was a well appreciated drive which yielded understanding that could not be obtained from any other source than direct experience. Sitting in the passenger seat, interviewing and observing is one thing, but to drive is an entirely different experience. During the test drives the difference of driving a Volvo FH fully loaded with two trailers too the smaller model FMX (and also for purely investigating purposes also the FM and FL models) really shone through. Furthermore some basic tasks like trying to operate the SID while driving and changing the radio settings etc. were tested briefly, to get hands on experience on glance time and how much of a distraction from the road these tasks became. In conclusion, the test drive was a great hands-on experience but so brief that it could not count towards any scientific conclusions or result.

### 4.4.5 Affinity diagram (KJ method)

The result of the affinity diagram was that a lot of categories formed and consisted mostly of quotes from the interviews, regarding useful inputs and user desires.

The categories that were formed were the following: *Music, GPS & Navigation, SID-screen, Functionality, Bluetooth, Important functions, During driving, Buttons and controls, Design of interface, Problems, Haptic and Other.*

The music was regarding things working mostly as wished for, however some desires and input were expressed, such as *"I cannot get the music started, it is unclear how to play a song"* and *"I want to connect music via Bluetooth - no cables!"*. Regarding the GPS & Navigation category users express much frustration, such as *"Navigation never works well without touch"* and *"The GPS [Navigation] is the worst! It is not made for trucks and is very unresponsive"*.

Users had more to say regarding the SID-screen, and offering a variety of suggestions regarding it such as: *"[Make the SID] removable - that way both the passenger and the driver can access it, the SID should be placed at the [alphanumeric] buttons."*. Many users also expressed opinions about that the neither the SID screen size nor placement was optimal for touch input today. Regarding the Bluetooth users expressed opinions about that it was either difficult today to pair it properly or that there should be a possibility to pair several phones at once. One user put it elegantly: *"Bluetooth leaves much to be desired and it is not excessively difficult to do this well"*, which summed up most of the opinions regarding Bluetooth.

The most important functions according to the users were the camera and the radio. Users agreed that if functions like YouTube were implemented in the SID they should be locked during driving, but accessibility to the music, radio etc. should remain unhindered. Users also said that they liked the SWS and used it often. Some users thought that buttons were hard to see in the dark however. One user said *"I want to use a combination of touch and SWS while I drive"*.

When considering the design of interface, users stated that they wanted a simple, uncluttered and intuitive interface. There should be clear icons and a responsive UI. One user stated that a touch interface probably would work in a truck environment but it would have to be "*like an iPad for the visually impaired"*.

To view the affinity diagram in full, please see appendix (A14)

# 5. DESIGN GUIDELINES FOR TOUCH SCREENS IN TRUCKS

Following the theoretical background and results, several general design guidelines were formulated. These design guidelines heavily influenced the concept development in chapter 6 as well as evaluation and selection process in chapter 7.

**1. Menu structure, tasks and navigation**

- *Focus on simplicity and make operations intuitive for the user*

It is important that the user understands the interface completely, in order to avoid affecting attention. Therefore the use of *metaphors* can be valuable. Utilize the fact that users are accustomed to smartphones and be inspired by other well-functioning touch-based interfaces. Note however that not all touch applications from other systems can be directly translated for use in trucks. Furthermore, provide users with the opportunities to learn the system, for example via training or a manual of some sort.

- *Provide the user with clues*

It should be possible to easily find every sub menu of an interface, without much effort, and without having to find hidden menus. Furthermore, the interface must provide the user with clues on how to perform every desired task, always provide the status of the system and give sufficient feedback after a performed action or operation. Avoid letting the user memorize required sequences or other information. Moreover, redundancy (for example by complementing objects with text) should be used if it is considered as helpful for the user.

- *Minimize static and dynamic information*

The UI should not contain any unnecessary, or, for the user, irrelevant information and animations should be minimized. Furthermore, unnecessary scrolling in menus or lists should be avoided.

- *Make the interaction consistent*

The interface should look the same in all menus, and work in the same manner regardless of the performed task or operation. Furthermore, users should be enabled to cancel and undo actions, and it should be made easy to return to the previous view or a home screen.

- *Minimize glance time and task completion time*

When designing touch interfaces, it is especially important to validate the interfaces in accordance with NHTSA guidelines, to ensure safety.

**2. Objects and Graphical elements**

- *Clarify and show functions of objects*

Objects, such as icons, should be made clear, and be adequately sized. Design objects with regard to real-world conventions

- *Create logical groupings of objects*

Facilitate necessary searches by grouping objects in a logical manner. Objects and functions that are the most commonly used should be positioned close to the user, and preferably close to the wind screen.

**3. Typography, colors and language**

- *Speak the language of the user*

Avoid the use of abbreviations or "programming language", and use a language that is easy to understand and at the same time informative

- *Make use of Volvos Group's Corporate Identity Manual*

To enable recognition and to build Volvo as a brand, colors and typefaces should be used in accordance to the Volvo Corporate Identity Manual. Furthermore, colors should be used mainly as redundant information.

- *Use the James Bond-rule*

When deciding on typeface sizes for good readability, the James Bond-rule can be useful:

$$\frac{Height\ of\ text}{Distance\ from\ screen} \geq 0{,}007$$

**4. Physical requirements**

- *Enable configurations*

Physical factors, such as brightness, contrast, viewing angle and the position of the touch screen should be made adjustable.

- *Complement interface with physical controls*

Physical controls can be added as redundant controls. For example, buttons for controlling the volume and a home button could be applied to the steering wheel.

In addition to the above requirements, it can be beneficial to use several sensory modalities (for example by adding sound as feedback) when providing the user with clues or information. Furthermore, to reduce possible user errors and unnecessary operations, it is recommended to evaluate future concepts with several methods such as ECW, PUEA and HTA, and to further focusing on improving usability and the user value.

# 6. CONCEPT DEVELOPMENT

After gathering and analyzing all the results and data from previous chapters the concept development phase was initiated. The development started off with the formulation of a vision that was used as an aim and springboard to achieve satisfactory end results. After this a function analysis was created to investigate in more technical terms which tasks a user desired and wished for. As a starting point for ideation a KJ-method was used alongside with an Ishikawa diagram. Finally, the concepts were visualized in the form of wireframes, containing little color and sometimes unfinished icons. The wireframes focused primarily on the layout and functionality of different UIs.

## 6.1 Vision

In order to set the path for the desired outcome, a vision for the final concept result was formulated. The vision was meant to be used as a framework and kept in mind while developing the different concepts to ensure that a satisfactory result was met. The vision was created in accordance with the conclusions drawn from the results and in order to stay on the desired direction.

The formulated vision is presented below.

*"With a simple interface design that focuses on usability and usefulness, our vision is to assist the driver in the interaction with the user interface, while striving towards reducing distractions and mental workload."*

## 6.2 Function analysis

The function analysis provided a variety of desired functions and needs. These needs and desires built upon user needs and previously gathered research. The needs and desires were categories in different sections, namely *Visual information and General information for touch in trucks*. The function analysis can be viewed in its whole in the appendix (A15).

Many of the expressed needs have already been stated in previous chapters; however, the following information supplements those needs.

Information that is used often should be easy to find and grouped in a logical manner. This will make it easy for the user to navigate the system hierarchy as well as matching existing mental models. The user should expect to find the information where it is found, for example, settings for audio should be easily accessible while in the radio or music menu. In addition, the UI should communicate to the user in an understandable and helpful way. If the telephone menu requires a smartphone to be paired to work properly it should be communicated how the user can connect a smartphone to enable this functionality.

Functions and settings should always be accessible to the user and clues should be provided on how to perform different tasks. If additional settings or functions exist, these should be made clear to the user. Moreover, it is important that if the user obtains sufficient feedback when performing a task or an operation. If the user performs the wrong action, it should be possible for the user to correct this or easily return to the start.

## 6.3 KJ method for ideation

The KJ method for ideation resulted in seven different categories to consider when creating a touch GUI for a truck. These categories are first of all presented in the figure below (Fig. 32) and thereafter summarized in text.

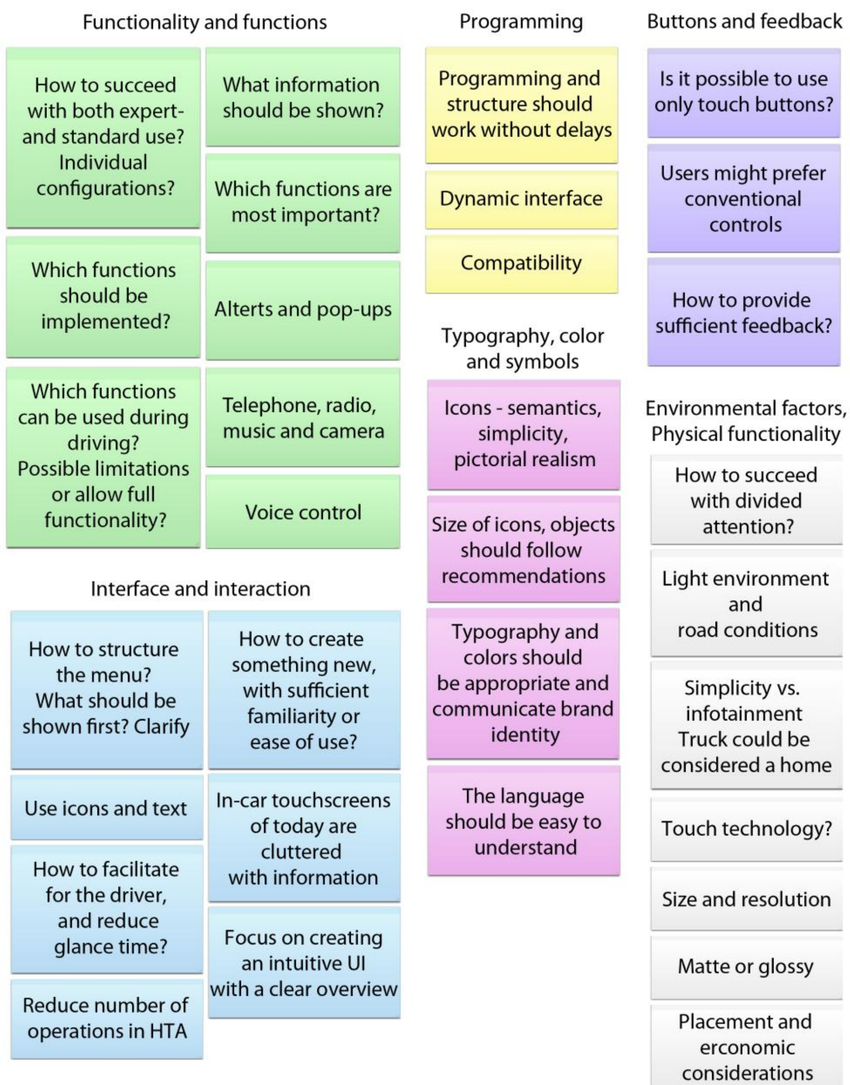


Figure 32: KJ method for ideation

**Functionality and functions**

An issue that arose was how to succeed with creating a good system, both for expert- and standard users, and it was concluded that it could be beneficial with individual configurations, if it was implemented correctly. Furthermore, what functions that the UI would consist of and what functions that were to be allowed during driving were discussed. Regardless of possible limitations to functionality during driving, an important consideration is to examine what information that should be shown and which functions that are the most important.

Based on previous studies it could be concluded that the telephone-, radio-, music- and camera functions were main functions of the SID. Moreover, implementation of voice control was discussed as a possible function to implement. Provided good functionality, voice control would be favorable in a truck UI, to better conform to NHTSAs (2012) guidelines regarding glance time.

**Programming**

It is of great importance that the programming and the structure is well thought out and functional, and that dynamic aspects (such as animations or transitions) or functions of the UI are not delayed. When possible, reduced dynamic aspects should be pursued. Furthermore, compatibility issues regarding different smart phone manufacturers should be eliminated so that all customers are provided with full functionality of the system.

**Buttons and feedback**

It was discussed which buttons that could be replaced by touch buttons, and that some users may prefer analog buttons instead of touch. Furthermore, a problem regarding touch screen technology could be that the feedback when pushing a button is insufficient. The implementation of sound or vibrations, or new touch technology, to better support feedback was therefore discussed.

**Interface and interaction**

The amount of operations, discovered in the Action/Prompt based HTAs (see 4.3.3), needed to be reduced. It was concluded that this could be achieved by implementing an adequately efficient way of structuring the menu in the UI. Furthermore, another discussed subject was the question: "*How is it possible to create something new, at the same time as providing an already familiar or easy-to-learn environment for a UI in a truck?"*. It was concluded that the later developed interface were to focus on simplicity as earlier stated in the vision, but also on being as intuitive as possible.

**Typography, color and symbols**

It was decided that icons and other objects in the UI had to be simple in the design, although in a way that preserved the semantics of the object. Furthermore, to communicate the brand in an appropriate manner, it was decided that the choice of color and typefaces were to be chosen in accordance with Volvo AB's corporate identity guide (Volvo Group, 2011).

**Environmental factors**

One of the most important question that arose during the later KJ-analysis was the question: "*How is it possible to succeed with divided attention?"*, which was further examined by a Ishikawa fish bone (see 5.4 below). Furthermore, it was discovered that both the light- and road environment affects the ability to interact with the UI. Therefore, allowing customization of contrast, brightness, and the physical position of the touch screen could be beneficial. An important question is how to succeed with creating an interface that provides a simple and uncluttered interface, and at the same time be able to provide sufficient and adequate functionality (especially when considering the truck as a home).

**Physical functionality**

Considerations regarding the physical functionality of the touch screen are for example *choice of touch technology* (e.g. capacitive vs. resistive), possible ways of providing sufficient *feedback* (see also chapter [4.2.4]-[4.2.5), *size*, *resolution*, *placement, ergonomics*, or whether the screen should be *matte* or *glossy*. These considerations were deemed outside the framework of the project. However, these areas are necessary to further investigate.

## 6.4 Ishikawa diagram

The figure below (Fig. 33) shows the result of the Ishikawa method, based on the problem *"It is difficult to succeed with divided attention"*.

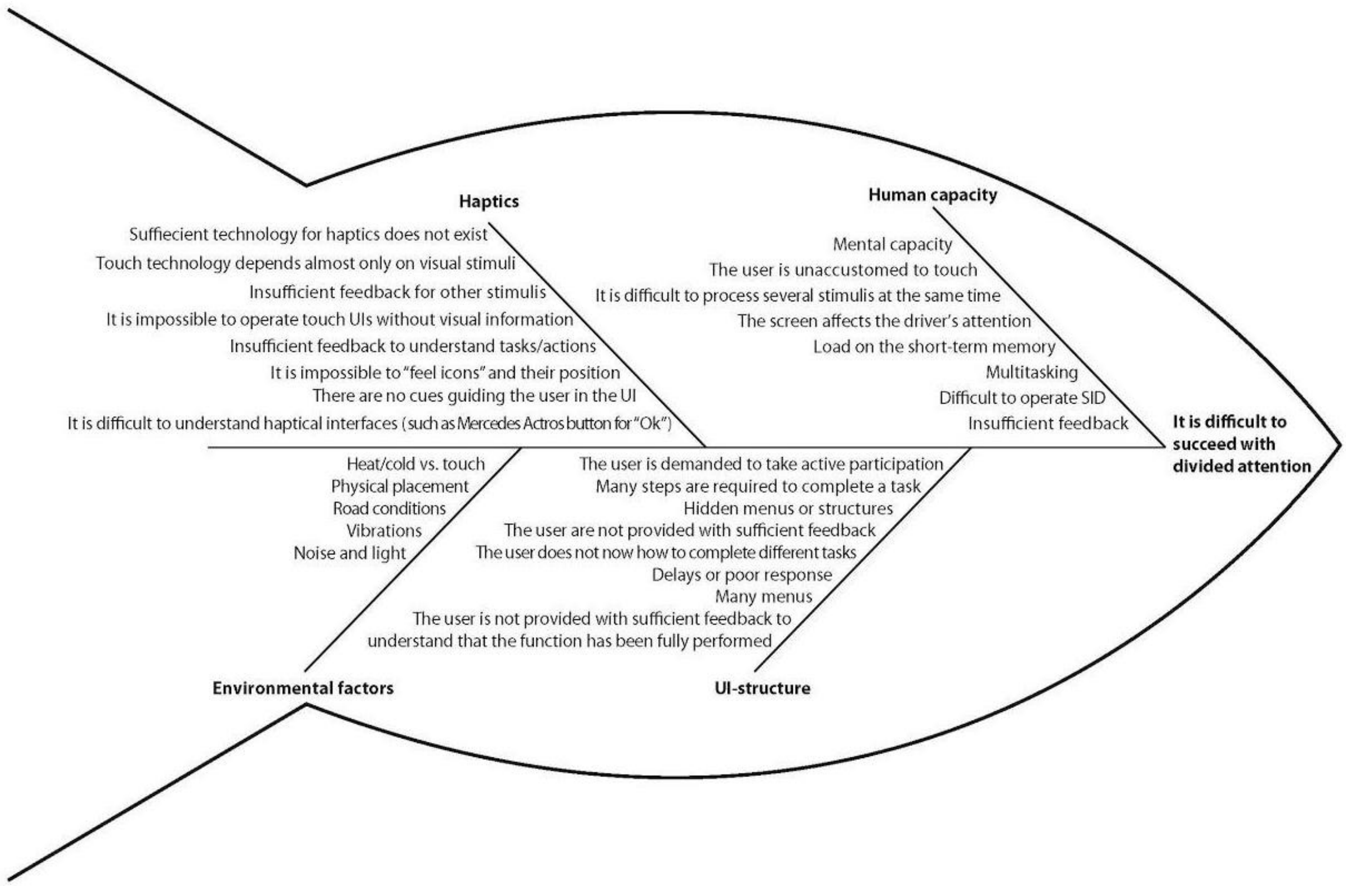


Figure 33: Ishikawa diagram

The first branch in the diagram (from the right) which was considered a causal category was *Human capacity*. In this category several causes were derived. Examples of these are mental capacity, the users' unfamiliarity regarding touch, simultaneously processing of several stimulus, insufficient feedback or that it is difficult to operate the SID. It was therefore regarded as important to further focus on simplicity and to reduce the amount of information that were to be shown on the screen, in so far as it was possible.

The second branch addressed the *UI-structure*. In this branch, possible causes were for example that it is today required of the user to perform many operations in order to complete a task, that the SID contained hidden structures, many menus, and few shortcuts, that feedback was not provided and that the system sometimes had poor response. It was therefore of importance to cut the amount of operations regarded to perform the desired task, and to utilize the potential of touch when it comes to menu structure.

The third casual category examined difficulties regarding touch technology, namely *Haptics*. A problem with touch is that it relies mainly on visual stimulus, and that insufficient feedback is provided for other stimulus, to better assist the human processing. An interesting aspect of this category was the potential of haptic integration in cars. If it was possible for users to feel or know the position of objects on the screen, or even better if the system were to understand the users' intentions, in some (safe) way, without looking at the screen or relying on visual information, it would be beneficial to use in an in-vehicle infotainment system. However, this investigation was regarded as outside the limitations of the project, but it was yet seen as a suitable question to further research.

The fourth, and last, branch of the Ishikawa method was *Environmental factors*. The importance of establishing a well thought out environment for a touch screen was considered, and therefore, making sure that the screen withstands road conditions, vibrations, noise and light was seen as essential. Furthermore, it is important to investigate how to interact with a touch UI during winter, when users potentially wear gloves.

## 6.5 Concept Generation - Ideation and wire framing

### 6.5.1 Classic

The classic concept (as can be seen in Fig. 34 below) had its roots in the existing menu structure and the UI that Volvo uses in the current SID. By simply making the UI touch compatible at the same time as preserving elements from the current UI, the transition for users would go very smoothly since the menu structure would remain the same. The user would experience instant familiarity and all the functions would remain in the same order.

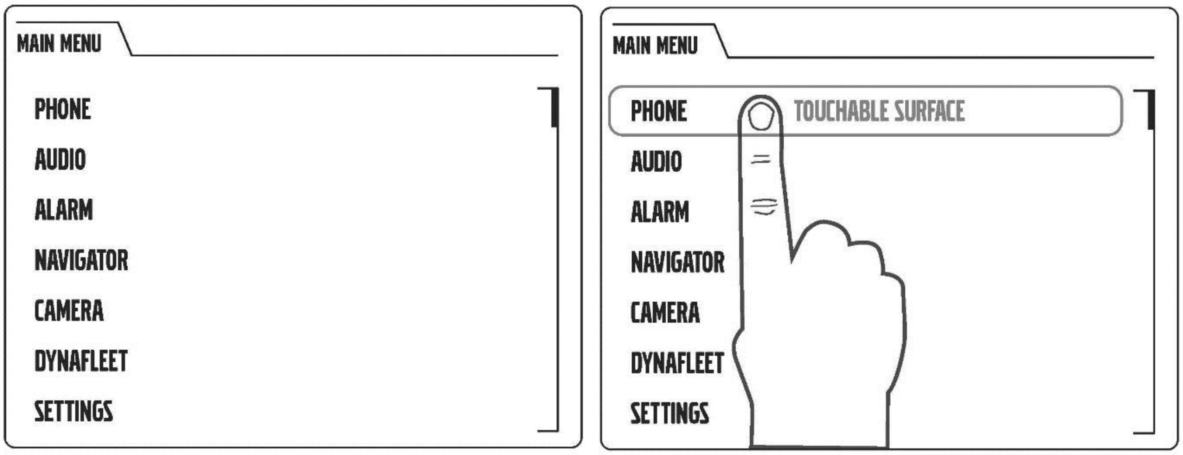


Figure 34: Concept - Classic

### 6.5.2 Carousel

Using the "Classic"-concept as a springboard for branching out and thinking of more effective ways of utilizing the touch technology, and breaking out of the box, resulted in the Carousel Concept (as is shown in Fig. 35 below).

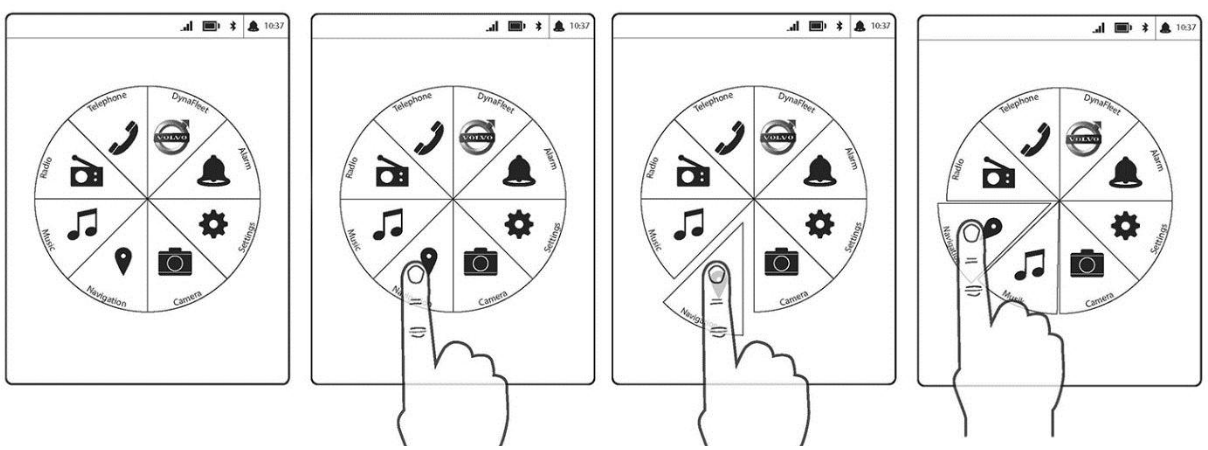

Figure 35: Concept - Carousel

With a large round shape containing the UI's functions in the middle of the screen, the concept was meant to encourage the user to press the large pie shaped buttons. The concept had the ability to also customize the "Carousel" in whichever desired way, since the pieces was meant to be movable and placeable. This would enable individual setups for the users. Furthermore, the users would also be able to swipe the pieces outward or press the pieces, which would result in that activation of that specific function.

### 6.5.3 Swype

Swiping on a touchscreen is a crucial feature. Both in Android and iOS swiping is used in a variety of applications, as well as in the main UI. Swiping is therefore a gesture users are familiar with and know how to use. The Carousel concept had opened up to some swiping capabilities, such as swiping over a function to open it or moving around a function by swiping it over the screen. To further develop the swiping concept, the concept "Swype" (shown in Fig. 36 below) was developed.

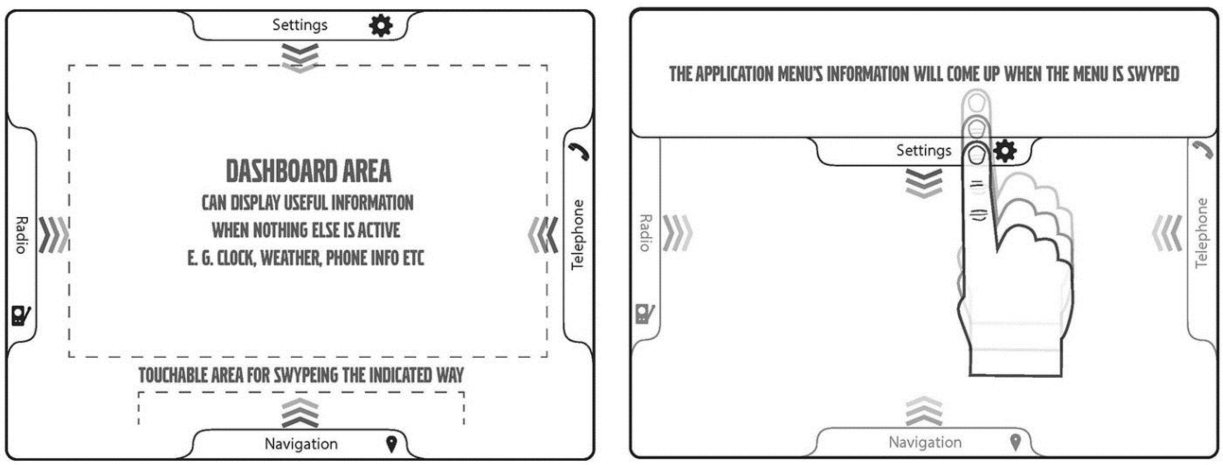


Figure 36: Concept - Swype

The Swype concept would make full use of the functionality users would be expected to already use and know by heart since their familiarity with smartphones and tablets and the functionality to swipe would not be foreign to the user. By having the information "just a swipe away" it would also grant the user easy access to core functions of the UI while at the same time being able to display other information, such as messages or time/weather when no function was currently active.

### 6.5.4 Icon Grid

A more app-based smartphone-like GUI was conceptualized (the home screen of this concept is shown in Fig. 37 below). This interface would have a home screen, familiar with those found on both Android and iOS, from which the user could start new functions that would be represented by large icons presented in a grid, hence the name "Icon Grid".

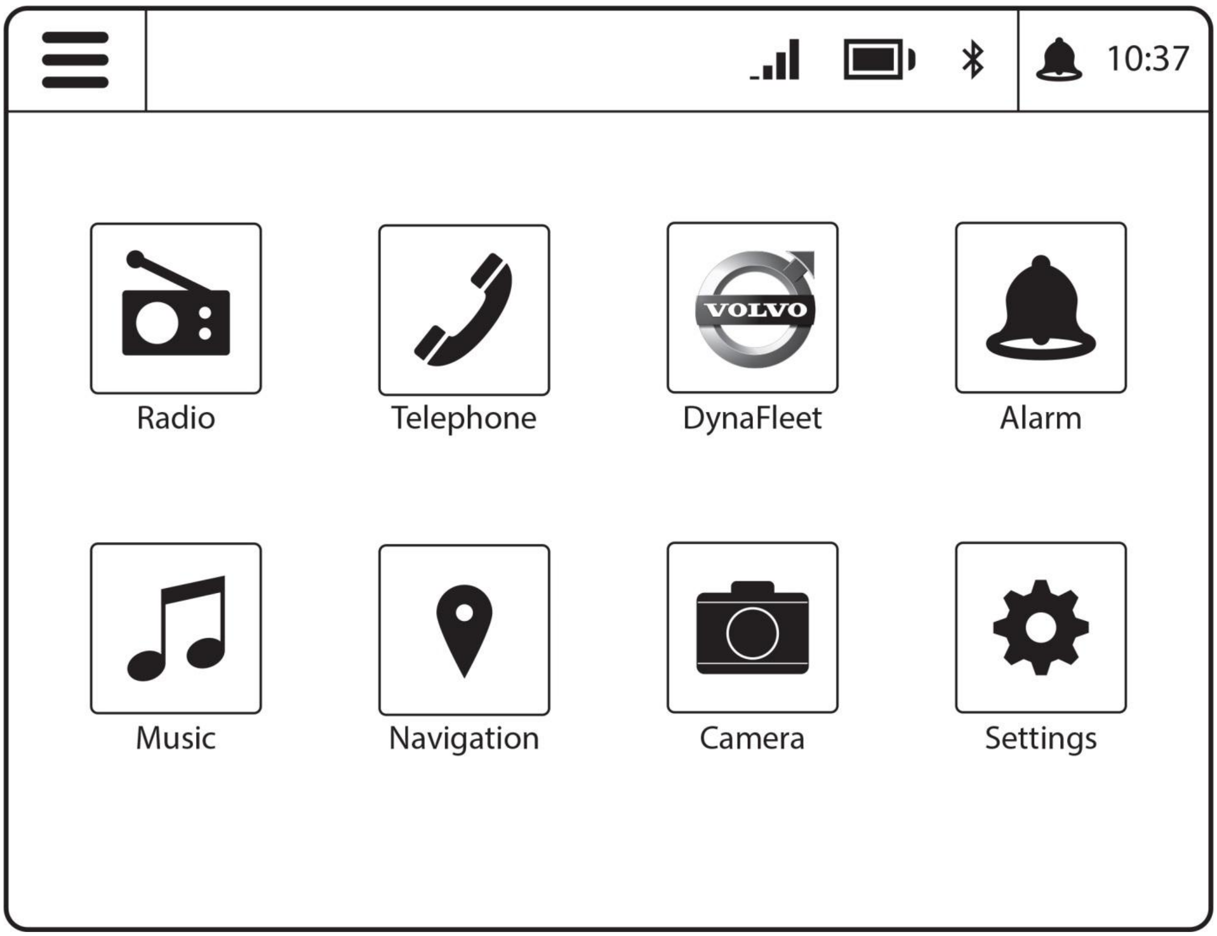


Figure 37: Concept - Icon Grid

The functions would be launched much like a user would start an app on their smartphone or tablet, thus emulating a sense of familiarity and ease of use. Furthermore, a taskbar at the top would be present, where a clock, Bluetooth icons as well as cellphone indications such as reception and battery level would be presented. In this taskbar there would also be room for a "settings button", a "back button" and a "home button".

The "home button" would take the user back to the home screen when the user was inside a function, such as the radio or telephone. This would also be similar to the home button found in smartphone operating systems. The home button would be visible in the same position in all functions except the home screen.

The "back button" would take the user back one step, by pressing the back button multiple times the user would eventually end up back at the home screen, but in basic use it would take the user back to the previous screen they were in. This button would, just like the home button, be visible and in the same position on in all functions except the home screen.

The settings button would open up an "overlay menu" in which the user would find settings relevant to the function/application the user is currently in. I.e. pressing the settings button in the music player would bring up audio and music settings such as equalizer or audio balance/fader.

### 6.5.5 Constant Menu

"Constant Menu" (as shown in Fig. 38 below) was the last concept to come from the ideation/concept generation phase. In this concept a menu would be present at all time at the bottom of the screen. The functions that would be present in this menu would be, from left-to-right, Media, Telephone, Navigation, Dynafleet, Camera and Settings.

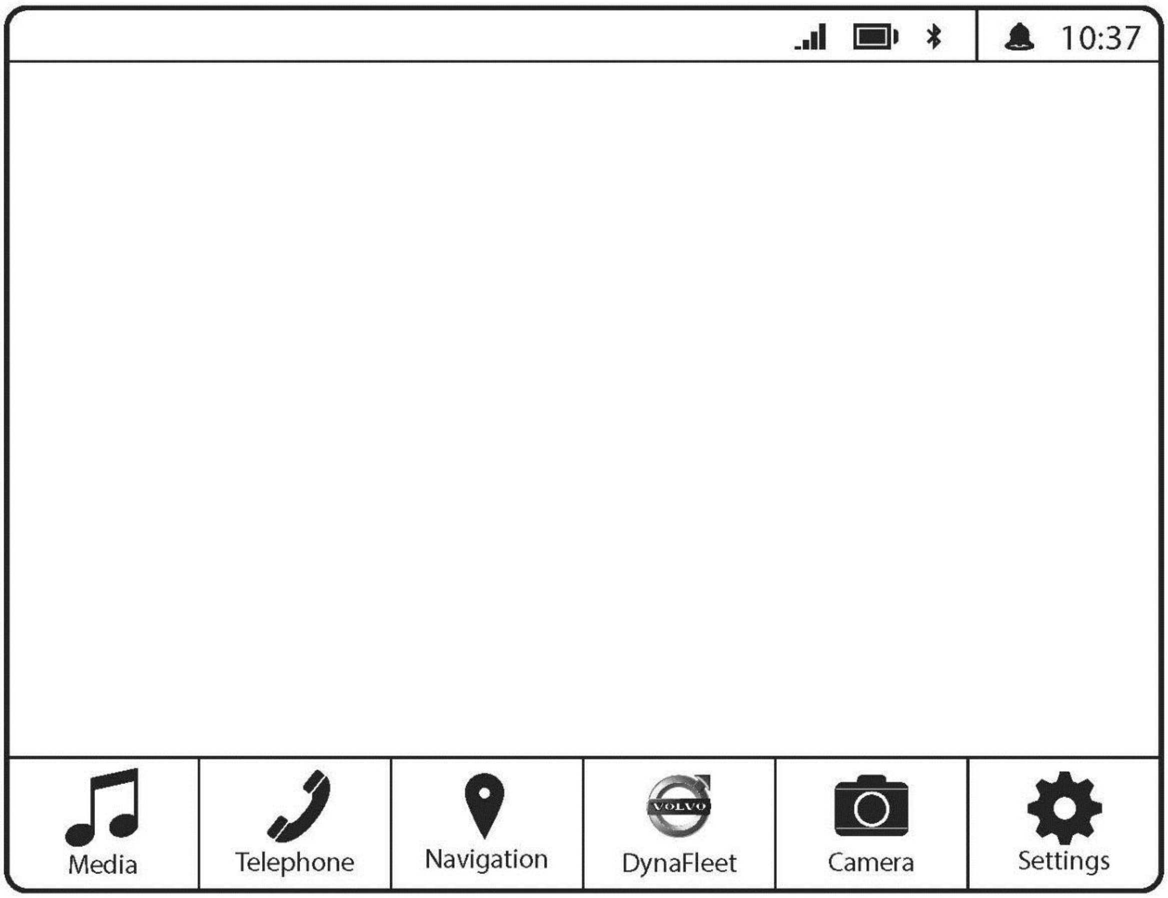


Figure 38: Concept - Constant Menu

The idea was that the user would be able to quickly switch between functions wherever the user was located, thus making the on-screen menu almost like hardware buttons. This would also contribute to sort of a "muscular-memory" since the bottom menu buttons always would be in the same place, making the user able to switch seamlessly between functions even without looking after some practice and use (thus reducing glance time and making the user focus on the primary task, i.e. driving the vehicle).

Furthermore, an indication on which function that is activated would also be present, to help the user navigate the interface even more efficiently. Since the room at the bottom was limited, trying to have as few functions as possible in the constant menu was necessary to enable adequate button sizes. Therefore a grouping of the functions" radio" and "music player" was made, through the "Media"- button. When the user pressed this button a choice was consequently displayed to the user in terms of a radio and a music icon, together with a descriptive text (see Fig. 39 below)

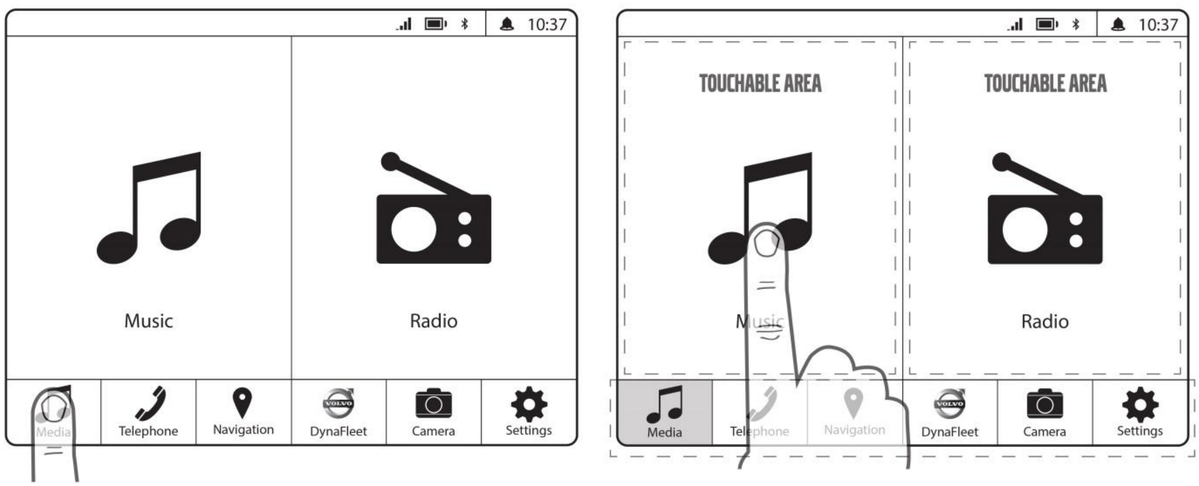


Figure 39: Concept - Constant Menu - Media

# 7. CONCEPT EVALUATION

The developed concepts from the previous chapter were in need of evaluation in order to see which concept that should be further developed. The concepts were evaluated by a pros/cons method and by finding natural flaws with the concepts (and discussing whether these were flaws that could be fixed with further development or if it simply was more efficient to abandon the concept and move on to a more viable solution). The different concepts were also showcased for reference groups and input on the concepts was obtained. Two concepts from the original five made it to further evaluation in the form of a test drive with seven different test drivers. The drivers were instructed to carry out different tasks in the two conceptual UIs while driving; afterwards an interview was conducted alongside with the “100-crowns-method”. An HTA evaluation with the same tasks that were performed on the current SID UI was also conducted in order to compare the efficiency of the new UI and the current SID UI. Finally a concept choice was made based on the result and decisions made in the previous steps.

## 7.1 Pros/Cons

### 7.1.1 Classic

By choosing this approach a golden opportunity to make a more touch friendly UI would be scrapped, the UI would also not use the touch technology to its full potential. How functions like the radio and music player would work were also questions in need of an answer. Ultimately the concept was not chosen because the bad utilization of the touch technology paired with the fact that all the flaws in the existing UI would also be carried over to this UI.

### 7.1.2 Carousel

Even though the Carousel concept made better use of touch technology than the “Classic” concept it still had some major problems, mainly that the screen would still be of a rectangular shape and the Carousel was a circle, resulting in lots of dead space on the screen. Questions such as how the functions would look and if the circle shape was still meant to be a framework for all functions remained, e.g. how would the Navigator fit inside a circle? Another very important factor was that the interface would be very unfamiliar to the user, thus requiring more mental workload and potentially more glances and increased glance time. Furthermore, if a circular shape would not be used in the functions, why even have a circular shape as a home screen, besides the customize argument, there really was not much of a reason to keep the circular home screen, and thus “Carousel” was not chosen for further development.

### 7.1.3 Swype

A main problem with the Swype concept was how it would be able to display more than four functions, since a rectangle only has four sides. If the user were intended to access additional functions by swiping with two fingers there was a risk of confusing the user, thus making the user rely too much on visual feedback to navigate the UI and thus increasing glance time, which was undesirable. The way the text and icons was displayed on the side was also a major problem since the text and icons was tilted 90 degrees and thus making them harder to read. How to work around this display problem and still keep the UI coherent and visually appealing was a problem not yet resolved. The ability to swipe and the reasoning behind swiping was still however deemed valid, but building an entire UI around the mechanic was not worth developing further.

### 7.1.4 Icon Grid

The icon grid featured a home screen with app-like shortcuts to different functions within the UI. The way this was accomplished made the user feel familiar because the structure much resembled those of smartphone UIs, which is something most people use on a daily basis. The home screen and home button also offered a sense of "security" since the top buttons always remained in the same place and if the user felt lost or wanted to get away from the current view they could simply press the back button or the home button to return to the home screen. When comparing to the Constant Menu concept (see also 6.1.5 below) this concept instead involved having to press a home button before being able to enter a new function.

### 7.1.5 Constant Menu

The constant menu's strength laid in the direct accessibility of all applications at direct glance and the instant switching between menus/functions. However this featured sacrificed screen space for the ability of, for instance, switching between functions. If more functions were to appear in the UI the constant menu would meet the risk of having to fit too many icons into the constant menu, thus making the touchable space too small. This could be avoided by adding another menu after pressing "media" for example, letting the user choose between, for example, Spotify, Music, and Radio. However this would add more button presses and take away some of the appeal of "instant" function switching in constant menu.

Both Icon grid and Constant menu had their respective strengths and weaknesses when assessing them in basic pros/cons. It was therefore concluded that further testing and development was needed before making a choice.

## 7.2 Feedback from reference group

The received feedback was to a major part in line with the earlier established pro/con features and the reference group agreed that Classic was a concept that utilized the touch screen capabilities poorly. Swype was seen as an interesting concept but that it might take too much attention and thus exceed NHTSA's (2012) guidelines about glance time and that the overview was possibly lacking. One input on Swype was however that the screen could be split so swiping at the top on the right would bring up another function than swiping at the top on the left, this was a function also seen in the Lenovo Yoga Tablet (see 4.2.2 for more information). Moreover, Carousel received harsh critique and was not seen as much of an improvement, which also was expected feedback.

The two concepts that received the best feedback was constant menu and icon grid. The reference group agreed with the dilemma about instant accessibility at the loss of screen space and encouraged further testing and development of both constant menu and icon grid.

Other input from the reference group regarded shortcuts and gestured based interactions with the touch interface, for example, being able to instantly open the phone menu by swiping over the screen in a specific pattern. An HTA analysis between the current SID UI and our new concepts was also encouraged, which can be found in 6.4 *HTA evaluation.*

## 7.3 Usability test

The main reason for conducting a usability test, was to examine whether the developed concepts were easy to understand and intuitive. It could be concluded that none of the test drivers had difficulties with performing the given tasks, on any of the concepts. However some areas of improvement and comments regarding the two evaluated concepts were extracted.

Most of the test drivers were partial towards the Icon Grid concept, except for a few who preferred the Constant Menu concept. Incentives for the Icon Grid concept were for example that it felt simpler and more intuitive (several test drivers stated that the functions in the Icon Grid concept were intuitive due to the "app"-feeling of it), that it had adequately sized buttons, and most important that it had a home screen (and a home button). A test driver expressed this by saying: "It is good to have a start screen and to always be able to start from the beginning. The home screen and home button make me feel secure". Another driver explained that the app structure is preferable because of the global advantages of it, and further stated that an app structure would work independently of cultural aspects and language. Moreover, some drivers also noted that the screen area was bigger in the Icon Grid concept.

Furthermore, several users considered the "settings menu" (where settings can be made for the active function) as a good feature. However, the original placement of the home button (as can be seen in 5.5.4) was not optimal according to some of the test drivers. Instead it was suggested to move the button to the top left corner of the screen. In addition, some drivers stated that a home button on the steering wheel could be beneficial.

In constant menu concept it was observed that the test drivers sometimes pressed the "Settings menu" in the constant menu instead of the configure menu while navigating in the Radio. As for the constant menu concept in general, the drivers expressed different opinions. On one hand, the recognition factor from the earlier UI (the constant menu buttons represents the direct buttons under today's SID) was appreciated. On the other hand, for some of the test drivers it was confusing to see two menus at the same time. Furthermore, a test driver pointed out that the "Constant menu was too far away from the windscreen, thus generating a longer glance time". Moreover a driver expressed that the Constant menu concept would benefit from a home screen of any sort.

Furthermore it was stated that adequate sound could provide sufficient feedback when pressing buttons on the touch screen, but it was seen as important that such a sound could be disabled.
The result of the statistical evaluation (as described in methods: [3.6.3]) showed that the probability that the concept Icon Grid would get more than 5 tens in a normally distributed population was approximately 56 %. The same probability for Constant menu was approximately 44 %. This indicated Icon Grid as the preferred UI among the test drivers in the usability test.

## 7.4 HTA evaluation

The HTA below (Fig. 40) shows the required operations for the main task "Make a phone call with iPhone already paired" in the concept "Icon Grid". The initial subtask *"Navigation to Contacts"* has been reduced into fewer operations, when comparing with the original HTA analysis (see chapter 4.3.3). This reduction is particularly substantial when considering that "SWJ" turns has been eliminated.

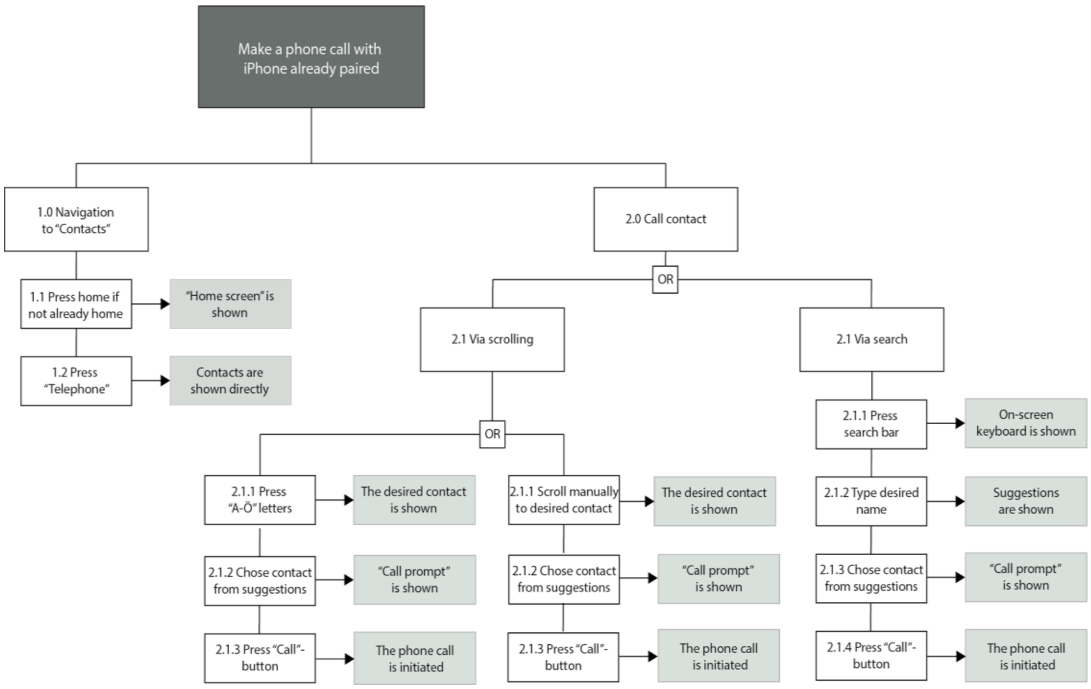


Figure 40: HTA evaluation

Furthermore, scrolling through contacts has been made easier and faster. Searching through contacts in a list can be done by pressing the letter corresponding to the first letter of the desired contact. When pressing the letters redundant information is also shown, such as enlargements of the actual letter. If more precision is required, "manual touch scrolling" (meaning performing a swiping motion up and down with one finger) is possible. However, a thorough investigation regarding effects on attention and glance time, when performing manual touch scrolling during driving, is needed to ensure safety.

When instead calling a contact "*Via search*" (2.1 to the right in the figure below) the user is provided with an on-screen keyboard that eliminates letters according to possible entries. This enables a more efficient search for a specific contact, and consequently reduces task completion time.

A separate HTA was not made for the concept "Constant Menu", since the only differences between the two concepts can be found in the first subtask "*Navigation to Contacts*". The concept "Constant Menu" instead provides direct access to the Phone menu (without having to enter the Main menu first).

Moreover, a comparison between the icon grid-concept and the current input system can be viewed in table 5. Since the current SID only allows the user to move one step at a time within the UI, a new touch system such as the icon grid cuts down the amount of operation/clicks substantially. This is because a touch UI allows the user to make his or hers selection by touching the desired function directly, while in the current system the user has to navigate through several list-views one step at a time, thus raising the amount of clicks/operations since each "scroll" with the SWJ was counted as an operation.

The comparison between the different input methods assumes that the user starts in a previous menu/function and has to navigate back to the home screen/main menu and carry out the described task. The only time the current system resulted in fewer operations than the new concept was via the direct access buttons, since these buttons instantly navigated the user to the desired function. However, this was only always true for the telephone direct access button. The direct audio button for example, brought up a variety of choices which could result in as many as five clicks for the user to enter the desired function.

The Bluetooth pairing resulted in the largest amount of reduced operations, this comparison excluded the operations required on the phone since many phones handle this differently and it was deemed unnecessary to investigate the Bluetooth pairing from the phone-side further.

Another task that would result in significantly less operations, if done via a touch UI, would be the search function in the telephone/music functions. In the current UI searching is done via an alphanumeric keypad, thus if the user wants to write the letter "c", the user must press a button three times. With an on-screen touch keyboard, the user is provided with a direct access to each letter.

Table 5: Tabular HTA comparison

| Task | Number of clicks/operations | | |
|---|---|---|---|
| | **Icon grid** | **SID (SWJ)** | **Direct access buttons** |
| **Open telephone menu** | 2 | 7-12 | 1 |
| **Navigate to radio** | 2 | 7-15 | 1-5 |
| **Navigate to radio settings** | 3 | 10-18 | 4-8 |
| **Bluetooth paring (Phone activation excluded)** | 7 | 17-22 | N/A |

## 7.5 Concept choice

The concept Icon Grid was chosen for final development, for several reasons.

The first and maybe the most vital reason was the obvious familiarity from the use of smartphones and tablets in general. Even sophisticated smartphone operating system such as iOS and Android (see Fig. 41) is basically just a hidden grid in where the different icons and/or widgets are placed. By drawing a similarity to these operating systems and both simplifying it further as well as making the icons larger (see Fig. 42) the user should be able to experience the "familiarity effect" while also having a UI more adapted for in-vehicle use than a smartphone UI. This familiarity and simplification was also in accordance to previously formulated design guidelines in chapter 5 as well as results from the user studies in chapter 4.

Furthermore a home screen was regarded as preferable and safe among several of the test drivers in the usability study above. Moreover, the Icon Grid concept provided a significantly larger screen area than the concept "Constant Menu", which made the UI of "Icon Grid" less cluttered and more easily perceived. The "Icon Grid" enabled the ability to add new functions more easily than "Constant Menu" concept. This was because the limitations in screen size of the "Constant Menu" concept. If, for example, wanting to add more media functions, such as Spotify, the "Icon Grid" was seen as a more natural platform for this purpose. When adding the fact that the concept "Icon Grid" was statistically evaluated to be the preferred interface, the concept choice was even more underpinned.

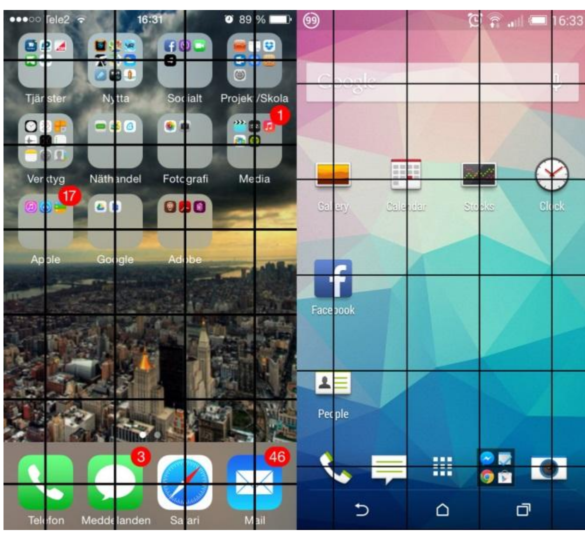

Figure 41: Grid familiarity 1

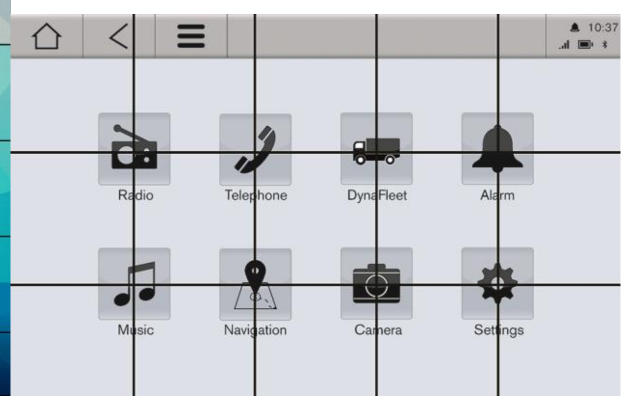


Figure 42: Grid familiarity 2

# 8. FINAL CONCEPT DEVELOPMENT

Once a final concept choice was made it was time to develop this concept to its full potential. Color, typeface and final layout, in accordance to received feedback and earlier research, were all pressing matters to develop. The result of this phase is shown below, were the concept "Icon Grid" will be presented in different views, with some complementary comments.

The first presented view, in figure 43 below, shows the main menu of the final "Icon Grid" concept. In this revised version of the concept, colors and typefaces, in accordance with Volvo Corporate Identity Manual, were added as redundant information. The icons were also further updated, and the "home"-button, together with the "back"- and the "settings"-button were repositioned in accordance with the result of the usability study. When rendered on a 10,1" display with the resolution of 1280 x 800 pixels the buttons are approximately 30 mm in both length and width. Additionally, the buttons on the taskbar that the user can interact with, such as the "Home"-button or "Back"-button, are approximately 15 mm long and 20 mm wide.

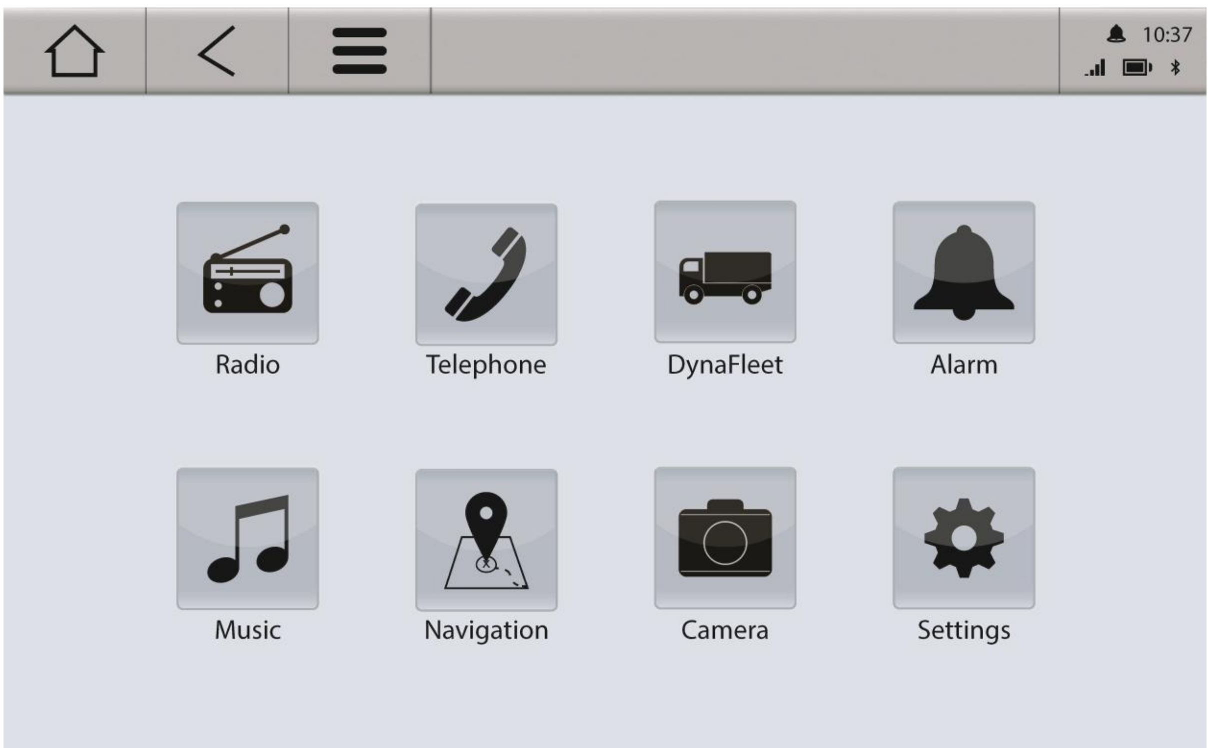


Figure 43: Final concept - Main menu

When entering the music menu, through pressing the "Music" icon in the above figure, the first presented view is "Now playing" (see Fig. 44 below). The "Now playing" view featured large buttons actions such as changing songs or playing/pausing the music. This updated version of the concept took advantage of the positive aspects from the "Constant menu" concept, and therefore featured a menu (which can be seen to the left in Fig. 44 below) with providing the user with the ability to instantly change between the different views in the music player. Furthermore, the buttons were positioned to the far left, to ensure easy access for the driver. The updated colors, as previously mentioned, enabled an easy distinction between the different "levels" of the concept. The taskbar in the upmost position of the screen is always displayed to the user and the position of the buttons on the taskbar remains constant over time.

Figure 44: Final Concept - Music - Now playing

The below showed version of album view in the final concept (see Fig. 45) enabled two rows of "album art" in display at the same time. In the earlier described "Constant Menu" concept, only 1,5 rows could be shown at the same time. Furthermore the active menu is highlighted in the menu to the left)

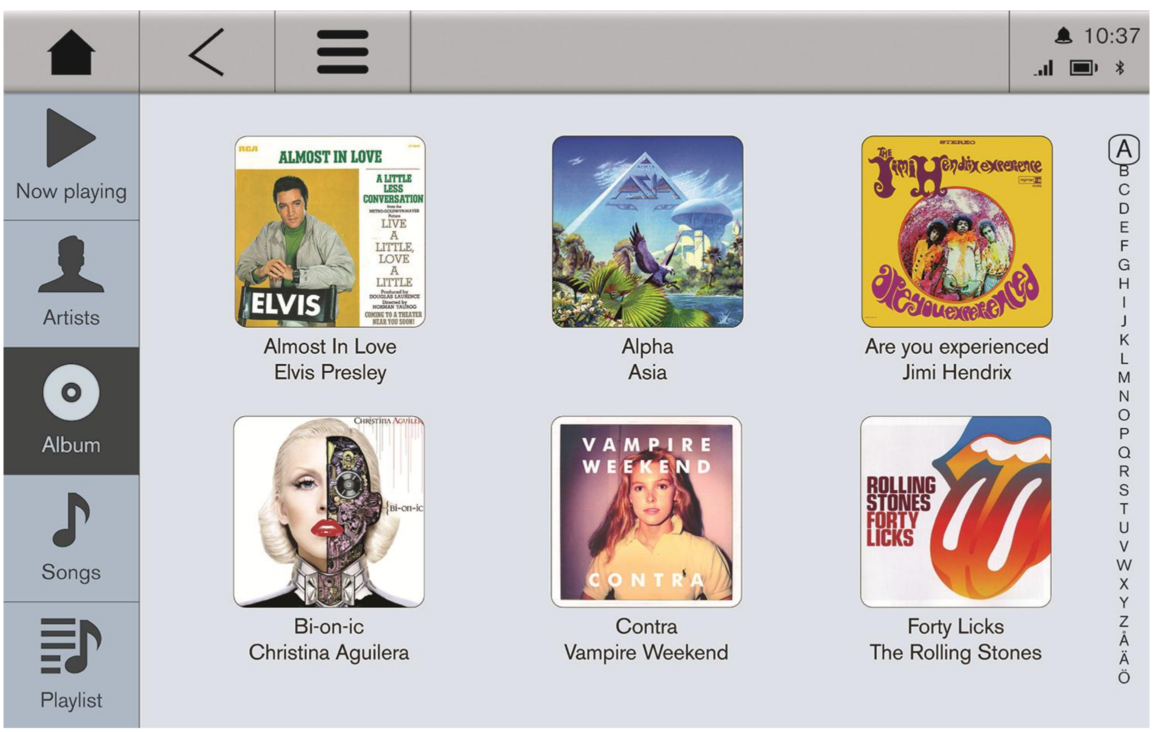

Figure 45: Final Concept - Music – Album

The figure below (Fig. 46) shows an example of the layout for the "slide-out" settings menu in the music player (which can be accessed by pressing the "settings"-button, the third button in the taskbar from the left). Moreover the "settings"-button becomes inverted when pressing it. It is possible to exit the settings menu in several ways; users can press the settings button again, swipe from the right to the left on the menu or press the faded area of the screen (to the far right). Naturally the user always returns to the home screen when pressing the "home"-button.

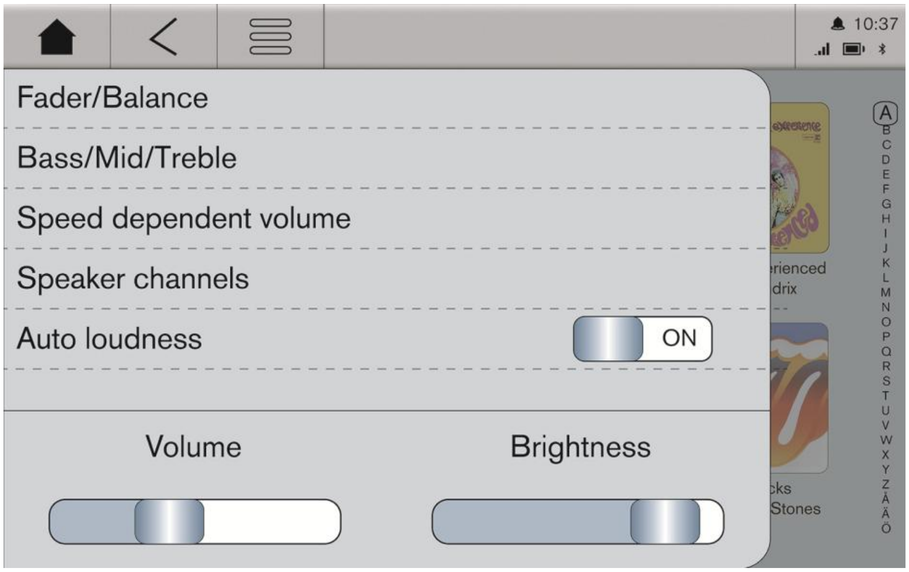


Figure 46: Final Concept - Music - Example of settings

To help the user in the search in list views (such as searching through songs, artist, or contacts) design cues were provided by showing the present letter on the screen, while scrolling (this can be seen in Fig. 47 below). Furthermore, an "alphabetic scroll" was also implemented in the final concept, to the far right of the screen. This allows the user to quickly jump to a specific letter, or at least in the near proximity of it, thus intending to simplify the search.


Figure 47: Final Concept - Music - Songs


Figure 48: Final Concept - Radio menu

The figure above (Fig. 48) shows the radio function of the final interface, and the figure below (Fig. 49) shows the telephone interface of it. When pressing the search bar in the “Contacts” view, an on-screen keyboard appears. When typing letters on this keyboard, the keyboard eliminates letters that leads to no matching contacts (much like one of the GPS-devices in the earlier Benchmarking chapter). When entering the “Phone application” (before having paired a smart phone with the truck via Bluetooth, and while not driving) Bluetooth paring can be made in accordance to Fig. 50 below. This new Bluetooth pairing will reduce the number of operations required to succeed with the pairing of a phone and a truck (all required operations are presented directly and simplified).

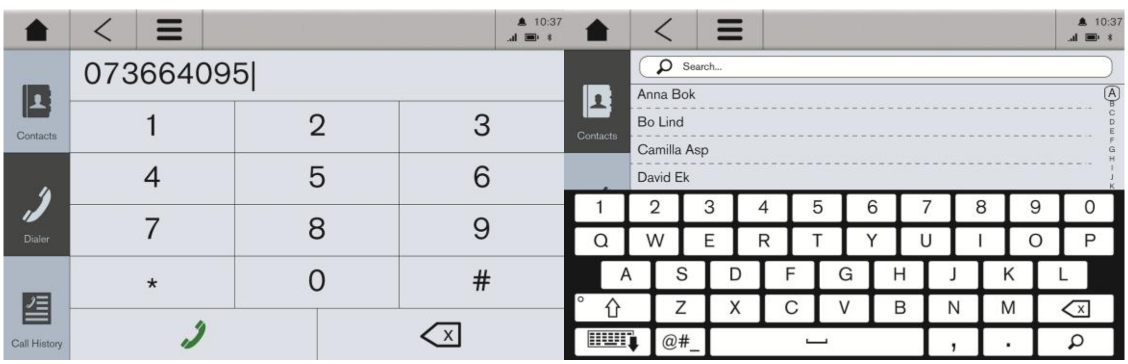


Figure 49: Final Concept - Telephone menu

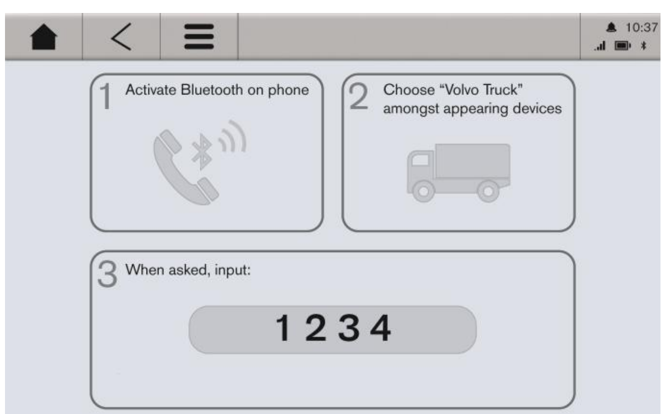


Figure 50: Bluetooth Story

# 9. DISCUSSION

When considering the question whether or not to introduce touch interfaces in vehicles, one is presented with a rather difficult dilemma. The primary task when operation a vehicle is, and will always be to drive the vehicle in a safe manner (mainly focusing on the PVAL). Infotainment tasks are, as previously stated, to be regarded as tertiary tasks. However, it would be beneficial to at least consider the possibility of introducing touch interfaces in vehicles, if these interfaces can be made as easy and as safe as possible (with regards to NTHSAs guidelines etc.).

If not implementing touch technology in vehicles, there is a possibility that drivers will be using their smartphones instead, and thus posing a much bigger threat to road safety, since these smartphones are not intended mainly to be used during driving. Furthermore, people are becoming increasingly experienced with the use of smartphones and touch technology in general. Therefore, implementing such technologies in a driving environment, could, if done correctly, provide the user with good user value and usability. What can be seen as a disadvantage of touch technology in trucks is that many trucks operate under road conditions that are not suited for the interaction with touch screens. In addition some touch technologies cannot be used with gloves as an example.

When addressing the possibility of touch integration in the Volvo FH, it is important to consider the pure ergonomic and design aspects of such integration. The current interior environment of the Volvo FH is not optimized for a touch screen, and will therefore have to be redesigned. This could prove to be a great opportunity to add other functionalities (or more user friendly old ones) at the same time, thus rendering the cab of the Volvo FH even better than before. Furthermore, by changing the UI of the SID to a touch based UI, it is possible to thoroughly investigate and improve the current UI, based on factors derived from methods such as HTAs, ECWs and PUEAs. Moreover the dynamic abilities (meaning for example updateability) of a touch based UI, cannot be disregarded, when comparing with conventional systems.

Initially it was stated that this project was intended to investigate "far and wide rather than in-depth", which proved to be an accurate statement. It is however necessary to consider if the results would be different if the amount of methods instead was reduced. If instead focusing more on testing and evaluating concepts, more specific design guidelines could possibly be concluded (for example button sizes or screen size) together with more developed concepts. However, the final concept was based on the theoretical background and the results in the project. By reducing the amount of methods and instead focusing more on concept evaluation, there is a risk of not underpinning the final choices sufficiently. However, the conducted usability test was not performed in the desired way, due to lack of time. The result of the test would have benefited by some kind of subjective rating scale, where the test drivers could express their opinions more scientifically and measurably. On the other hand, the main purpose of the test was to see the concepts in use, and to assist the design selection process. Given more time, Eye-tracking studies would be preferable to better assure safety and compliance with NHTSA's guidelines.

When analyzing the complete project and the quality of the results, there is little doubt that the results and concepts cannot be of, at least some, use. However, as stated previously, further investigation is required to verify the accuracy of the results, as well as more in-depth research, regarding for instance other touch technologies or alternative ways of interaction. If the same project was to be repeated, the project could benefit from a shift in focus towards more testing and less Benchmarking/Market Research.

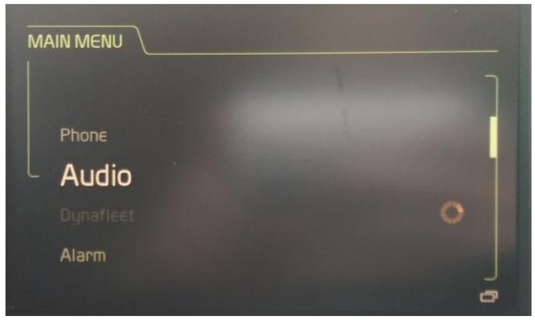


Figure 51: SID before

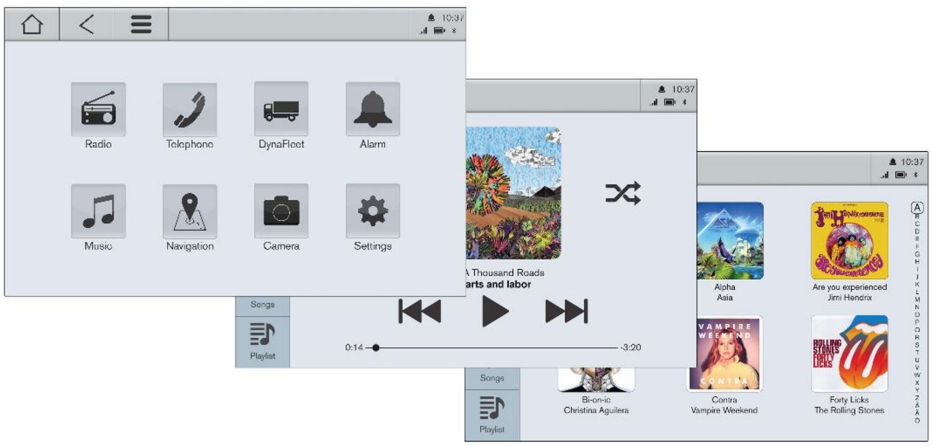


Figure 52: SID after

Fig. 51 above shows the current SID interface and Fig. 52 shows the final concept. To better conform to the design guidelines presented in chapter 5, and to create a UI that is intended to be used during driving, several considerations and design choices were made. First of all, in accordance with results from both the system analysis and user studies, the menu objects were made visible directly in the final concept, to enable an easier overview. If comparing this with the original SID UI, where not all menu objects are presented on the home screen (in Fig. 51 above it is only possible to see "Phone", "Audio", "Dynafleet" and "Alarm" without having to scroll), it is possible to notice that functions are more easily accessed in the final concept.

This easier overview was also complemented with different color levels. First of all the taskbar was intended to be separated from the other available functions, and to always be constant at the top of the screen. Furthermore, the home button allows the users to access the home screen directly, without having to press "ESC" several times to return to the main menu screen (as is required in the current SID UI). The home button, together with the back button, further enables the user to cancel and undo undesirable actions more easily than in the current SID UI.

Colors were further used as redundant information. The taskbar was made in the darkest gradient of the applied color, while the sub menus (for example the "application icons" and the sub menus in the music player, which are shown in Fig. 52 above) were made in a lighter gradient of the same color. The lightest gradient corresponded to the activity area, where the content of the specific sub menu was displayed. This was made to further assist the users in the search for the desired function.

The final concept was consistently designed and provided the users with clues (in accordance to the design guidelines). This was for example done by eliminating hidden menus (such as in the radio menu of the current SID), complementing text with icons (In Fig. 51 above there are no icons that guides the users in the correct direction) and by creating a consistent UI, where the required information is more easily accessed.

Furthermore sub menus (such as buttons for "Playlists" or "Songs" in Fig. 52 above) were placed close to the driver, to reduce the required time to access the functions and to better conform to conventions (such as the reading direction in Europe). Moreover, the most common functions were positioned close to the driver, such as the radio and telephone function in Fig. 52 above. However, it is important that the placement of the *physical* touch screen will be convenient, and not for example be obscured by the steering wheel or become inaccessible by other means. Therefore it is recommended that such ergonomic aspects are further investigated.

As described earlier, the final concept made use of metaphors (in this case the grid familiarity of iOS and Android), and the buttons were adequately sized, mainly to enable faster overview. This size requirement was expressed explicitly by the drivers from the user studies, and also concluded in the benchmarking (where Apple for example only had enlarged the iPhone UI when designing the iPad, thus making readability and maneuverability hard). Furthermore the James Bond-rule was used when choosing the typeface sizes and Volvo Group's Corporate Identity Manual was used for colors.

The final concept was also made simple, with the intention of making the screen less "cluttered" with information at the same time as maintaining user value. However it is important to notice that further research is required on how the final concept will perform in terms of glance times and task completion times. This will have to be evaluated in form of Eye-tracking studies, in accordance to NHTSA's directives.

To conclude this chapter, the "Constant menu" concept can be preferable (if no more functionality is added) because of the instant familiarity received from the simulated "direct access buttons". Furthermore, the final concept does not utilize to the extent that it could possible do. Gestures are almost not used at all, neither is multi-touch. If such gestures are implemented, the interaction in the final UI could possibly be further improved. However, further investigation and development is recommended, in order to conclude if gestures are intuitive and safe enough to be used in driving environments.

# 10. CONCLUSION

The aim of this project was to investigate whether it was possible to implement touch displays in the Volvo FH series, and to further develop a suitable touch screen UI for the same truck model. A selection of applicable theories was first presented in the theoretical background, in order to investigate important aspects when designing touch interfaces. These were used later to underpin later design choices and decisions.

The initial phase of the actual project consisted of a thorough market investigation, together with benchmarking on a variety of relevant products and new technologies. These above described findings are recommended for further investigation.

The current UI was later examined in a structured manner, with methods such as HTA, ECW and PUEA, to discover existing problems (in the current UI of the SID), or areas of improvement. To complement the market research, user studies were carried out, both with ordinary truck drivers and professional test drivers; the findings were presented in an affinity diagram.

When having performed the above steps, it was possible to initiate the concept development phase, in which a touch screen UI suitable for the Volvo FH series, was developed and evaluated by various methods.

The presented design guidelines acted as a way to conclude the complete project, and were recommended to be used when further developing touch interfaces for truck applications.
Finally a discussion regarding advantages and disadvantages of touch screens in trucks was conducted. The result of this discussion was the recommendation that it was possible to implement touch displays in the Volvo FH series; if thoroughly considering safety aspects as well as offering both user value and usability to the drivers.

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# Appendix

# Table of contents

# A1 - Gantt chart

| Tasks | Start | End | Duration (weeks) |
|---|---|---|---|
| **Introduction** | **5 Feb** | **2 Mar** | **4 weeks** |
| Introduction to Volvo GTT | 5 Feb | 16 Feb | 2 wks |
| Litterature studies | 5 Feb | 2 Mar | 4 wks |
| **Benchmarking** | **17 Feb** | **2 Mar** | **3 weeks** |
| Market investigation | 10 Feb | 23 Feb | 2 wks |
| Macro-environmental scanning | 10 Feb | 2 Mar | 3 wks |
| Micro-environmental scanning | 17 Feb | 2 Mar | 2 wks |
| Market segmentation and positioning strategy | 24 Feb | 2 Mar | 1 wk |
| **Research Phase** | **24 Feb** | **16 Mar** | **3 weeks** |
| System analysis | 24 Feb | 2 Mar | 1 wk |
| Observations | 3 Mar | 16 Mar | 2 wks |
| Interviews and surveys | 3 Mar | 16 Mar | 2 wks |
| Focus group | 12 Mar | 14 Mar | 2 days |
| **Analysis of Research Data** | **24 Feb** | **26 Mar** | **4,5 weeks** |
| Summary and analysis of collected data | 24 Feb | 23 Mar | 4 wks |
| Requirements specification | 10 Mar | 23 Mar | 2 wks |
| Problem specification | 21 Mar | 24 Mar | 4 days |
| Feedback | 25 Mar | 26 Mar | 1 day |
| **Concept Generation Phase** | **26 Mar** | **27 Apr** | **4,5 weeks** |
| Initial concept development | 26 Mar | 6 Apr | 1,5 wks |
| Feedback and revision of requirements | 2 Apr | 9 Apr | 1 wk |
| Final concept development | 7 Apr | 27 Apr | 3 wks |
| **Concept Evaluation Phase** | **21 Apr** | **29 Apr** | **1,5 weeks** |
| Evaluation and selection of concept | 21 Apr | 29 Apr | 1,5 wks |
| **Prototype Generation and Evaluation** | **29 Apr** | **1 Jun** | **4,5 weeks** |
| Visualization | 29 Apr | 18 May | 1,5 wks |
| Concept evaluation and improvement | 12 May | 28 May | 1,5 wks |
| Final usability test and reflection | 26 May | 1 Jun | 1 wk |
| Final revision of requirements specification | 29 Apr | 1 Jun | 4,5 wks |
| **Documentation and Presentation** | **5 Feb** | **6 Jun** | **18 wks** |
| Report and documentation | 5 Feb | 6 Jun | 18 wks |
| Presentation | 12 May | 6 Jun | 4 wks |

# A2 - Gantt chart description

| Tasks | Description |
|---|---|
| **Introduction** | **Planning, literature, tests** |
| Introduction to Volvo GTT | Planning, visit factory, tests, appointments, definition of goals, purpose and limitations |
| Litterature studies | Previous thesis work, articles, literature provided by examinator/tutor at Chalmers etc. |
| **Benchmarking** | **Usability tests, market analysis** |
| Market investigation | Benchmarking, usability test of existing and current products within different industry segments (such as  cars, trucks, air planes and consumer products) |
| Macro-environmental scanning | PESTLE, stakeholder analysis (e.g. Stakeholder mapping or Triple Task, TT), trend analysis, competitor analysis |
| Micro-environmental scanning | Market analysis, Five Forces, SWOT |
| Market segmentation and positioning strategy | Segmentation strategy, positioning matrix |
| **Research Phase** | **System analysis, interviews and observations** |
| System analysis | Analysis of complete interface system (method: System analysis), HTA, CW |
| Observations | ”Ride along”, tests, heat mapping/link analysis |
| Interviews and surveys | Current situation, implementation of touch screens, user behavior |
| Focus group | Touch screen |
| **Analysis of Research Data** | **Summary, specification and feedback** |
| Summary and analysis of collected data | Selection of methods, documentation, analysis and visualization of data, personas, S-LCA |
| Requirements specification | Initial requirements specification, QFD, 7QC/QM, KJ, HTA, Customer journey mapping, PHEA, etc. |
| Problem specification | ”Den utökade frågemetoden”, 5 whys etc. |
| Feedback | Tutor at Volvo/Chalmers |
| **Concept Generation Phase** | **Sketching, workshops, feedback and visualization** |
| Initial concept development | Ideation, sketches, prototypes, tests/workshops: placement and design of touch screens in trucks, attention etc. |
| Feedback and revision of requirements | Analysis of requirements - tutor at Chalmers/Volvo, revision of requirements |
| Final concept development | Visualization (for example: creative suite, keynote/ppt) |
| **Concept Evaluation Phase** | **Evaluation and selection of final concept** |
| Evaluation and selection of concept | Various selection matrices |
| **Prototype Generation and Evaluation** | **Visualization, prototyping, usability tests and improvements** |
| Visualization | Illustrator, (programming), building touch screen prototype |
| Concept evaluation and improvement | Usability tests, further concept improvements |
| Final usability test and reflection | Test in both lab- and natural environment with users and tutors |
| Final revision of requirements specification | Review and final evaluation of existing requirements |
| **Documentation and Presentation** | **Writing, preparation of presentation material** |
| Report and documentation | Continuous documentation of work |
| Presentation | Preparation of final presentation |

# A3 - Heuristic Evaluation - Summary and example

**Viktiga noteringar:**

- **Hur stänger man av radion? Mute eller att gå till en inte tillgänglig audio source?**
- **Vid av- påstängning så är det inkonsekvent startskärm**
- **Ingen direkt radioknapp**
- **Byte av radiostation syns inte när man inte är i radion. Finjusteringsknapparna [< och >] fungerar inte utanför radion.**
- **Går inte att trycka "OK" för att stänga pop-up/felmeddelande, man måste trycka på Esc.**
- **Färgvalen har ingen betydelse. Dynafleet = Orange. Camera = Lila, Audio = Grön, Settings och Alarm = Gulgrön. Varför?**
- **Dold meny i radion som är väldigt otydlig till både hur man kommer in och vad man skall använda den till.**
- **ESC är ibland tillbaka och ibland avbryt. Varför heter den "ESC"?**
- **Finns behov utav hemskärm/hemknapp?**
- **Tomma knappar i layouten. Varför existerar de?**
- **Grupperingen utav knapparna hade kunnat göras bättre.**
- **Systemet säger relevant information till fel men ger inga lösningsförslag.**

## Heuristic Evalualtion - A System Checklist

### 1. Visibility of System Status

**The system should always keep user informed about what is going on, through appropriate feedback within reasonable time.**

Page 1 © Usability Analysis & Design, Xerox Corporation, 1995

| # | Review Checklist | Yes | No | N/A | Comments |
|---|---|---|---|---|---|
| 1.1 | Does every display begin with a title or header that describes screen contents? | ✓ | O | O | Man får ingen total info om olika steg |
| 1.2 | Is there a consistent icon design scheme and stylistic treatment across the system? | O | ✓ | O | Samma färger I visa menyer/Struktur. Bra med symboler I SID/DID |
| 1.3 | Is a single, selected icon clearly visible when surrounded by unselected icons? | ✓ | O | O | Två-fyra storlekar store, högre opacitet |
| 1.4 | Do menu instructions, prompts, and error messages appear in the same place(s) on each menu? | ✓ | O | O | Tydligt olika typer av meddelanden |
| 1.5 | In multipage data entry screens, is each page labeled to show its relation to others? | O | O | ✓ | |
| 1.6 | If overtype and insert mode are both available, is there a visible indication of which one the user is in? | O | O | ✓ | |
| 1.7 | If pop-up windows are used to display error messages, do they allow the user to see the field in error? | O | ✓ | O | Hur gör man nu då? Efter meddelandet |
| 1.8 | Is there some form of system feedback for every operator action? | O | ✓ | O | T.ex. klicka röd lur/grön. Röd lur vid kontakter |
| 1.9 | After the user completes an action (or group of actions), does the feedback indicate that the next group of actions can be started? | ✓ | O | O | |
| 1.10 | Is there visual feedback in menus or dialog boxes about which choices are selectable? | O | ✓ | O | Symboler finns ej manga av |
| 1.11 | Is there visual feedback in menus or dialog boxes about which choice the cursor is on now? | ✓ | O | O | Högre opacitet osv. Se 1.4 |
| 1.12 | If multiple options can be selected in a menu or dialog box, is there visual feedback about which options are already selected? | O | O | ✓ | |
| 1.13 | Is there visual feedback when objects are selected or moved? | O | ✓ | O | Ingen animation |
| 1.14 | Is the current status of an icon clearly indicated? | O | O | ✓ | |

## A4 - Enhanced Cognitive Walkthrough

| 0.0 | **Bluetooth pairing of android and truck**<br>Failure/sucess story | Usability problem | PS | PT |
|---|---|---|---|---|
| (1) | It depends on the situation. If expert user 0.0 will not be difficult to succeed with. If not expert user the Bluetooth settings are hidden from the main menu. | The “Phone-menu” might be interpreted as the correct course of action. | 3 | U/H |
| (2) | Yes/No. If “Phone-menu” is selected the user sees the following prompt: “Connect a Bluetooth device to enable this function”, leaving the user with no instructions on how to carry out the task. | Instructions are unclear. | 3 | S |
| (3) | No. The user is left with inadequate instructions (see question 2). | Instructions are unclear. | 2 | F |
| (4) | Yes. When the pairing is completed, a prompt: “HTC One has been connected” is displayed. In the Bluetooth settings the paired device is shown in a list and in all other menus a symbol for signal strength and battery of the device is shown. These symbols could have a more logical connection to the action (e.g. a small phone icon.). | No (large) usability problem | 4 | T |
| (5) | Yes (see question 4)/No. The user is not given information about compatibility issues. Only iOS users experience full compatibility. | Not all cell phones are fully compatible with the system and no information related to this is given. | 2 | F |
| ($E^2$) | Lack of redundant information/choices. Long sequences to perform relatively easy tasks. Pairing of multiple phones is not possible. | - | - | - |

| 0.1 | **Make a phone call with Android Smart phone**<br>Failure/sucess story | Usability problem | PS | PT |
|---|---|---|---|---|
| (1) | Yes. “Phone-menu” is at the top of the “Main menu” and dedicated buttons for phone actions are located on the steering wheel and beneath the SID. | No usability problem. | 5 | - |
| (2) | Yes (see question 1). | No usability problem. | 5 | - |
| (3) | Yes (see question 1). | No usability problem. | 5 | - |
| (4) | Yes. Haptic feedback with physical buttons, the output on the SID matches the corresponding input from the buttons. | No usability problem. | 5 | - |
| (5) | Yes. A dial tone is heard through the truck’s speaker system. | No usability problem. | 5 | - |
| ($E^2$) | When inputting number in dialer, the phone call cannot be dismissed by using the “hang-up button”. | | | |

| 2.0 | **Call number (call a contact or use call history via SID interface, when the system is paired with Android Smart phone)**<br>Failure/sucess story | Usability problem | PS | PT |
|---|---|---|---|---|
| (1) | Yes, but the requested function (Call contact/call history) is not available. | Function is unavailable. | 1 | M |
| (2) | Yes. But the functions are unavailable. To be able to carry out the task, the user must resort to the phone interface instead. However, no cues are given. | The user does not know that the phone is incompatible. | 1 | U |
| (3) | No (see question 2). | The user does not know that the phone is incompatible. | 1 | U |
| (4) | No (see question 1). | Function is unavailable. | 1 | M |
| (5) | No (see question 1). | Function is unavailable. | 1 | M |
| ($E^2$) | Dangerous to use a phone interface instead of the SID interface, while driving. Input through the alphanumeric buttons does not open the "call number" dialog automatically. | | | |

| | **Make a phone call with iPhone already paired (via contacts and call history)**<br>Failure/sucess story | Usability problem | PS | PT |
|---|---|---|---|---|
| (1) | Yes. "Phone-menu" is at the top of the "Main menu" and dedicated buttons for phone actions are located on the steering wheel and beneath the SID. | No usability problem. | 5 | - |
| (2) | Yes/No. "Contacts-menu" is visible and accessible through "Phone-menu". "Call history" is displayed directly in the "Phone-menu" without a clear separation from the other options. | When comparing to the rest of the system, it is inconsequent to display "call history" directly. Different options are not separated. | 3 | T |
| (3) | Do not know. It depends on whether the user is familiar with the icons. The symbols for incoming and outgoing calls can be misinterpreted, because of sizing and ambiguity. According to the principals of pictorial realism (Roscoe, 1968). | Easy to misinterpret the information and options. | 3 | T |
| (4) | Yes. Both sound and visual feedback. | No usability problem. | 5 | - |
| (5) | Yes (see question 4). | No usability problem. | 5 | - |
| ($E^2$) | "Call history" is not presented in an optimal way.<br>Would "favorite contacts" be a useful feature to implement? | | | |

| | **Tune radio**<br>Failure/sucess story | Usability problem | PS | PT |
|---|---|---|---|---|
| (1) | Yes. It is a basic function in a radio. | No usability problem. | 5 | - |
| (2) | Yes. The "Radio-menu" interface suggests that the user is able to tune the radio. | No usability problem. | 5 | - |
| (3) | It depends. There is no actual information on how the tuning works if the user has not pushed any buttons. Trial and error is allowed. | The user may be unfamiliar with the interface and buttons. | 3 | U/H |
| (4) | No. When radio channels have already been predefined the user can easily chose between channels (alphanumeric buttons or "NEXT"-button). When using the manual search button it is rather unclear how to tune in a channel. | Unclear way of doing a manual search. | 3 | F |
| (5) | Yes. Sound is heard through the truck's speaker system. | No usability problem. | 5 | - |
| ($E^2$) | The "Radio-menu" interface does not follow the same interaction logic as the rest of the system. Setting up favorite channels or entering radio settings are hidden functions. | | | |

| | **Set up a favorite radio channel**<br>Failure/sucess story | Usability problem | PS | PT |
|---|---|---|---|---|
| (1) | It depends on the user's experience with the system. | Without sufficient knowledge the usability suffers | 2 | U/H |
| (2) | No/Yes. In the "Radio-menu" there is information on how to enter the "station list". However, no information on how to set up a favorite channel is provided to the user. The symbol corresponding to "Favorite number" is lacking pictorial realism. | Given the cues, the user does not understand how to set up a favorite radio channel. | 2 | H/T |
| (3) | No. "Press Ok for station list", as displayed in the "Radio-menu" is not sufficient information. | Given the cues, the user does not understand how to set up a favorite radio channel. | 2 | H/T |
| (4) | No. The only given feedback is a sound signal and a small visual indicator (the "Favorite number" Is lacking pictorial realism). | The user does is not provided with sufficient feedback. | 2 | H/F |
| (5) | No (see question 4). Also, when having succeeded with the setup of a favorite, there is no way of deterring whether it worked or not. | The user is not provided with an understandable overview of the favorites. | 1 | H/F |
| ($E^2$) | Det går inte att göra det man vill. Tabort kanaler från favoriter, hur vet man att man ska hålla inne knappen?, sökfunktionerna är väldigt diffusa. FM1-FM2-FM3-AM1? osv. I vissa fall gick det inte att stå vid en radiostation i listan och välja den som favorit – då blev det slumpmässigt en annan kanal | | | |

| Problem Type\Problem seriousness | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| (U) User | 2 | 1 | 2 | 0 |
| (H) Hidden | 1 | 4 | 2 | 0 |
| (T) Text and icon | 0 | 2 | 2 | 1 |
| (S) Sequence | 0 | 0 | 1 | 0 |
| (F) Feedback | 1 | 3 | 1 | 0 |
| (M) Missing function | 3 | 0 | 0 | 0 |

| Problem seriousness \ Task importance | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| (U) User | | | | |
| (H) Hidden | | | | |
| (T) Text and icon | | | | |
| (S) Sequence | | | | |
| (F) Feedback | | | | |
| (M) Missing function | | | | |

Task importance: 1 is highest importance – 5 is no importance

1: Tune radio, Bluetooth pairing of Android/iPhone and truck, Call number via android or Iphone

2:

3: Set up a favorite radio channel

4:

## Questions:

Level 1: Analysis of functions

(1) Will the user know that the evaluated function is available?
*Does the user expect, on the basis of previously given indications that the function exists in the machine?*
(2) Will the user be able to notice that the function is available?
*Does the machine give clues that show that the function exists?*
(3) Will the user associate the clues with the function?
*Can the user's expectations and the machine's indications coincide?*
(4) Will the user get sufficient feedback when using the function?
*Does the machine give information that the function has been chosen and to what position the user is in the interaction?*
(5) Will the user get sufficient feedback to understand that the function has been fully performed?
*Does the user understand, after the performed sequence of actions, that the right function has been performed?*

Level 2: Analysis of operations

(1) Will the user try to achieve the right goals of the operation?
*Does the user expect, on the basis of previously given indications, what is to be performed?*
(2) Will the user be able to notice that the action of the operation is available?
*Does the machine give clues that show that the action is available and how to perform it?*
(3) Will the user associate the action of the operation with the right goal of the operation?
*Can the user's assumed operation and the machine's indications coincide?*
(4) Will the user be able to perform the correct action?
*Do the abilities of the user match the demands by the machine?*
(5) Will the user get sufficient feedback to understand that the action is performed and the goal is achieved?
*Does the user understand, after the performed operation, that he/she has done right?*

# A5 - Interview guide

## Intervjuguide

**1. Övergripande frågor och funktionalitet**

1.1 Vem? Ålder? Kön? Hur brukar dina körmiljöer vara?
1.2 Olika vägförhållanden – svårigheter?
1.3 Vilka funktioner använder du oftast?
1.4 Önskvärda funktioner?
1.5 Vilka funktioner/knappar får man inte rubba på? (utseendemässigt osv)

**2. Placering och ergonomi**

2.1 Placering av skärmar? Hur påverkas uppmärksamheten när man använder SIDen? Skyms sikten t.ex. av ratten?
2.2 Är det lätt att förstå befintliga reglage? Vilka knappar används oftast för att styra SIDen? Hur fungerar byte mellan SIDen och DIDen?
2.3 Navigering i gränssnittet? Hemknapp? Tillbaka? Ångra? Vad händer om man gör fel?
2.4 Olika reglage – återkoppling, utformning, osv.
2.5 Läsbarhet och kontrast? Mörkerinställningar?

**3. Tillvägagångssätt för uppgifter**

3.1 Hur fungerar det aktuella upplägget i SIDen? Vad är bra? Vad är dåligt?
3.2 Hur gör du för att...
  3.2.1 Byta ljudkälla, ändra radiostation och ställa in favoriter?
  3.2.2 Koppla in mobil för användning av telefon? Användning av telefon? Spela upp musik från mobiltelefon eller cd-spelare? Hur vill du kunna koppla in din telefon? Din musik? Använder man sig av ljudinställningar? Vilka inställningar? Vet man vad alla inställningar är? (Fader/Balance, Speed dependent volume, background sound etc)
  3.2.3 Ställa in alarm?
  3.2.4 Använda kamera?
  3.2.5 Använda DynaFleet?
  3.2.6 Navigation?

**4. Implementering av touch**

4.1 Använder du smartphone idag? Vilka applikationer? Använder du smartphone under tiden som du kör? Vad använder du i sådana fall?
4.2 Vad tror du om idén att implementera en touchdisplay somSID-system i FH-serien?
4.3 Vad är viktigt att tänka på? Hur ska knapparna och gränssnittet se ut? Hur ska det inte se ut? Feedback?
4.4 Hur ska man göra för att minimera distraktionen från vägen om man skulle använda en touch display? Vad finns det för befintliga problem kring interaktionen, som får en att kolla bort från vägen för mycket?
4.5 Vilka funktioner skulle du vilja ha på en touchdisplay? Vilka skulle passa/inte passa? Varför?

**5. Övriga frågor**

5.1 Sover du i bilen? Använder du keyfob för att låsa och därmed också larma lastbilen när du tillbringar natten i hytten eller använder du bara låsknapp i dörr etc?
5.2 Hur är det med informationsflödet i SIDen? Är du nöjd med hur informationen tillhandahålls? Varför/varför inte? Märker du av information i form av t.ex pop-ups? Vad tycker du omdessa pop-

ups? Vad tycker du om denna information? Hade det kunnat genomföras på något sätt som hade varit bättre för dig?

5.3 DID, Är den ändrad från standardinställningar? Hur ser den ut? Varför har föraren ändrat det på detta viset? [Ta kort]

# A6 - Usability Evaluation

1. Användaren ska hitta till olika funktioner i gränssnittet, utan instruktioner
a) Hitta Radio/Tuner och radioinställningen AF-mode
b) Hitta till kontakter och samtalshistorik
c) Hitta till musikspelare och album
d) Scrolla bland album

Kommentarer

| Icon Grid | Constant Menu |
| --- | --- |
| | |

Hundralapps-metoden

X ☐

X ☐

2. Användaren ska hitta till telefongränssnittet, scrolla ner i samtalslistan för att hitta kontakten "Lisa Poppel". Därefter ska användaren klicka på denna kontakt för att ringa.

Kommentarer

| Icon Grid | Constant Menu |
| --- | --- |
| | |

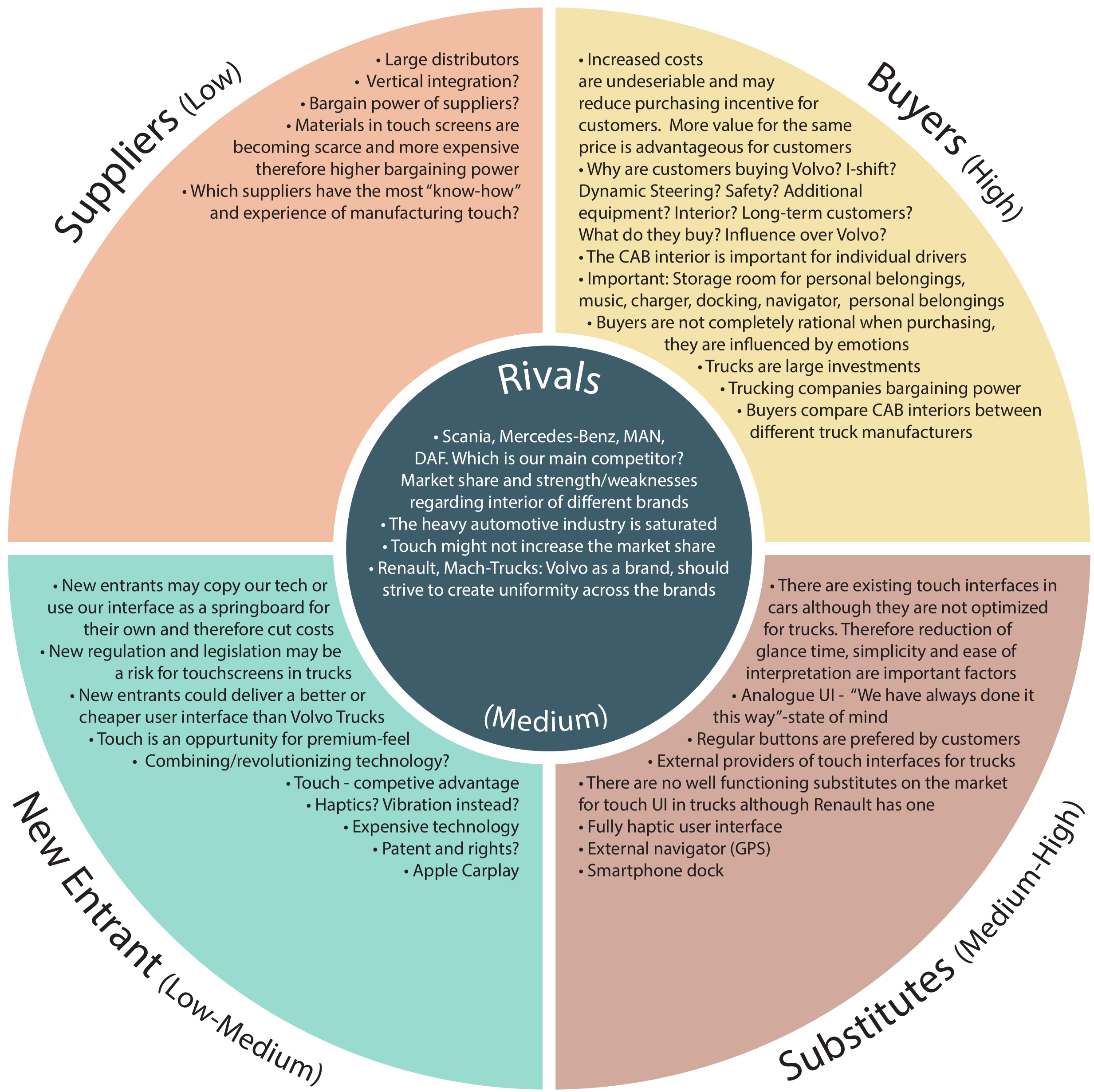
# A7 - PESTLE

| P | E | S | T | L | E |
|---|---|---|---|---|---|
| • Indium is not exported<br>• Risk of conflicts between countries<br>• Railroad infrastructure is prioritized instead of trucks<br>• Radical legislation change regarding fossile fuels | • Cheaper than conventional buttons<br>• Increasing demand for smartphones<br>• Increased costs because of the development of a good interface<br>• R&D budget is cut<br>• Touchscreens are mainly produced in China<br>• Reduced supply of materials - increasing costs<br>• Material taxes<br>• World production of Indium:<br>1. China<br>2.Canada/South Korea/Japan<br>• Trucking companies tightens budget - less premium interiors and additional equipment<br>• Salary of truckers? | • Elderly people and touch technology<br>• Entertainment - living accomodation for some drivers<br>• Understanding of smartphones<br>• Perception of symbols and language<br>• International context?<br>• Culture?<br>• Color blindness<br>• Premium-feel<br>• Third party resellers<br>• Touch technology is popular<br>• Volvo Trucks - Highest score in overall cab evaluation results<br>• Integration between smartphones and the truck<br>• Existing functions in Volvo trucks - "it has always been this way-mentality"<br>• Multimodal approach | • Integration of haptics in touchscreens - minimized mental workload<br>∘ Tactus technology (morphing buttons)<br>∘ Texturized touchscreens<br>∘ Vibration<br>• Curved screens<br>• Gyro/accelerometer<br>• Growing icons when approaching the screen<br>• Eye tracking - Samsung<br>• Capactive/resistive screen?<br>• Car play Volvo<br>• Progressive market - innovation<br>• Touchscreen instead of physical buttons? Is touch technology always the best choice?<br>• Existing in-car touch interfaces are cluttered with information<br>• Updatable software with touch displays | • Regulations regarding the usage of smartphones in cars. How is this affecting the implementation of touch interfaces?<br>• NHTSA's guidelines - for example 2 seconds glance time and 12 seconds task completion time<br>• ISO-standards<br>• Fossil fuels and carbon dixoide taxes<br>• Environmental taxes<br>∘ Euro 6 | • Deplation of Indium and other materials<br>• How to succeed with dived attention?<br>• Volvo positioning strategy - safety - touch?<br>• Diverse road conditions - affecting touch input?<br>• Different countries<br>• Light and heat conditions<br>• The primary task is driving<br>• How to fit touch into the interior? Match existing interfaces<br>• Restricted possibilites for the passenger - entertainment, navigation and SID input<br>• Touchscreen for other applications in the truck, for example it could be mobile and dockable |

# A8 - Five Forces

## Entry barriers

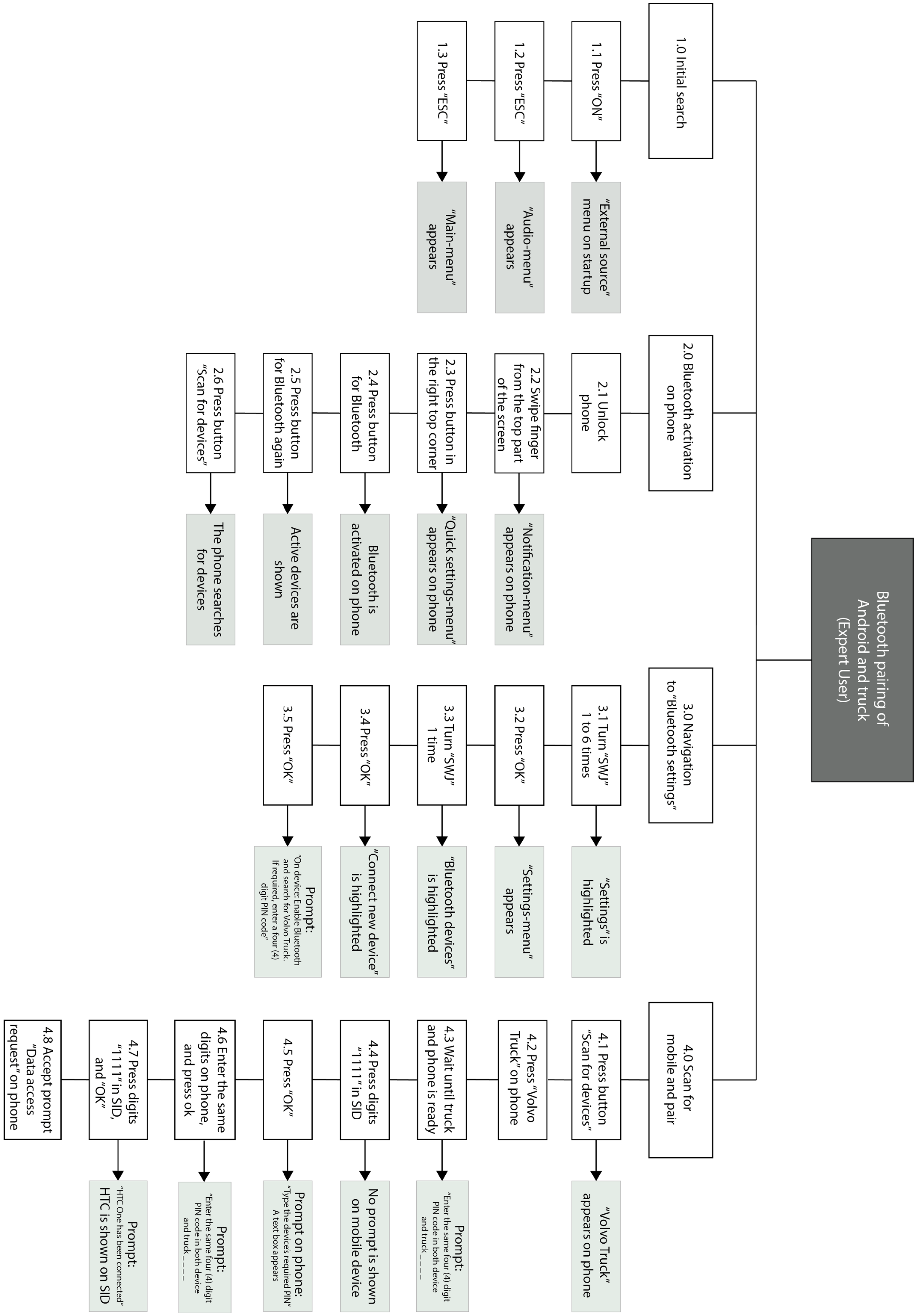
- Patent necessary for new touch User Interface - We are breaking new ground
- Competitors will follow
- Technology procurement
- Conflicts with existing patents
- Finding a trustworthy and reliable manufacturer
- Good know-how and development of an user friendly UI is expensive
- Touch in corealtion with Volvos safety image

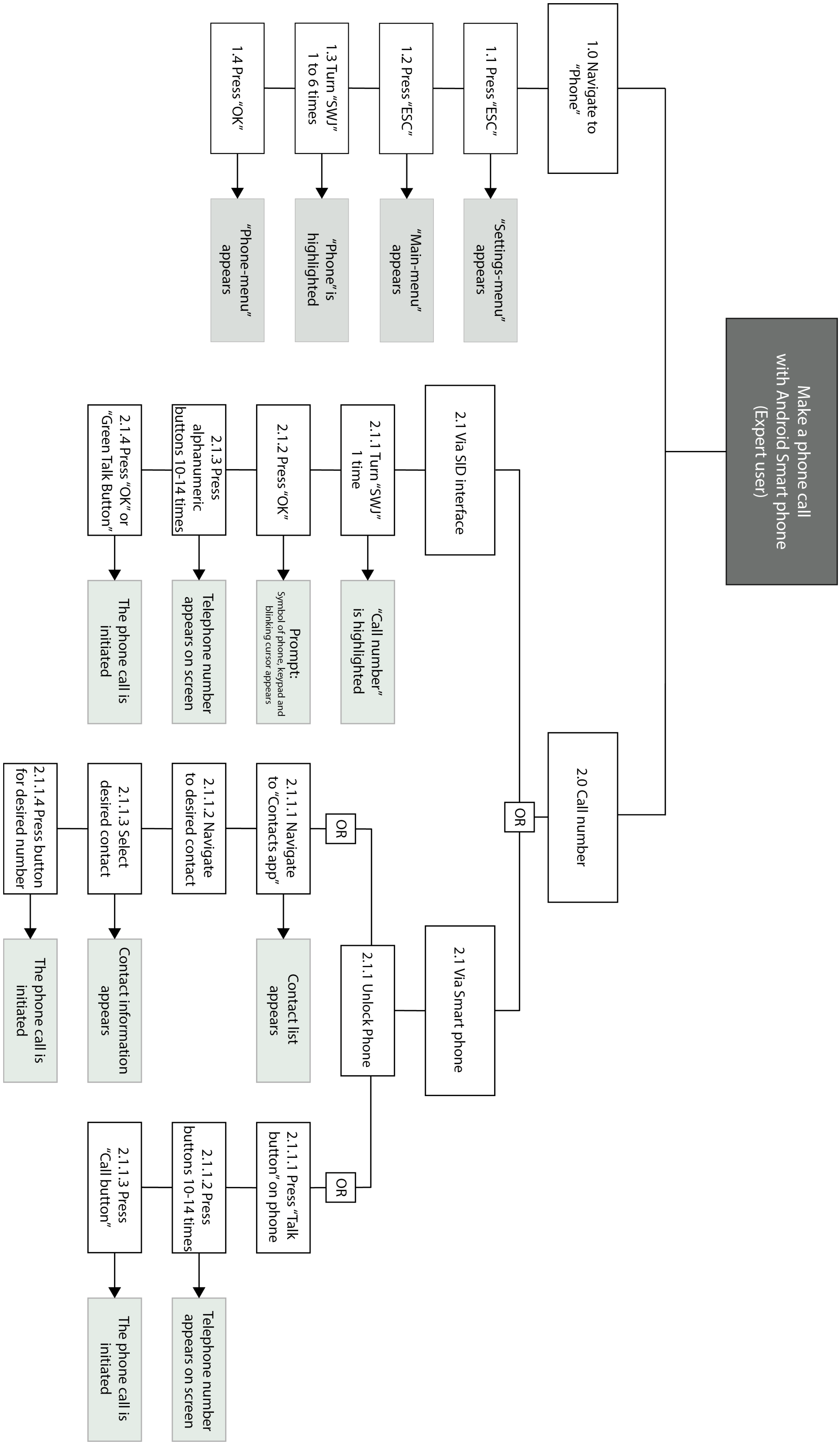


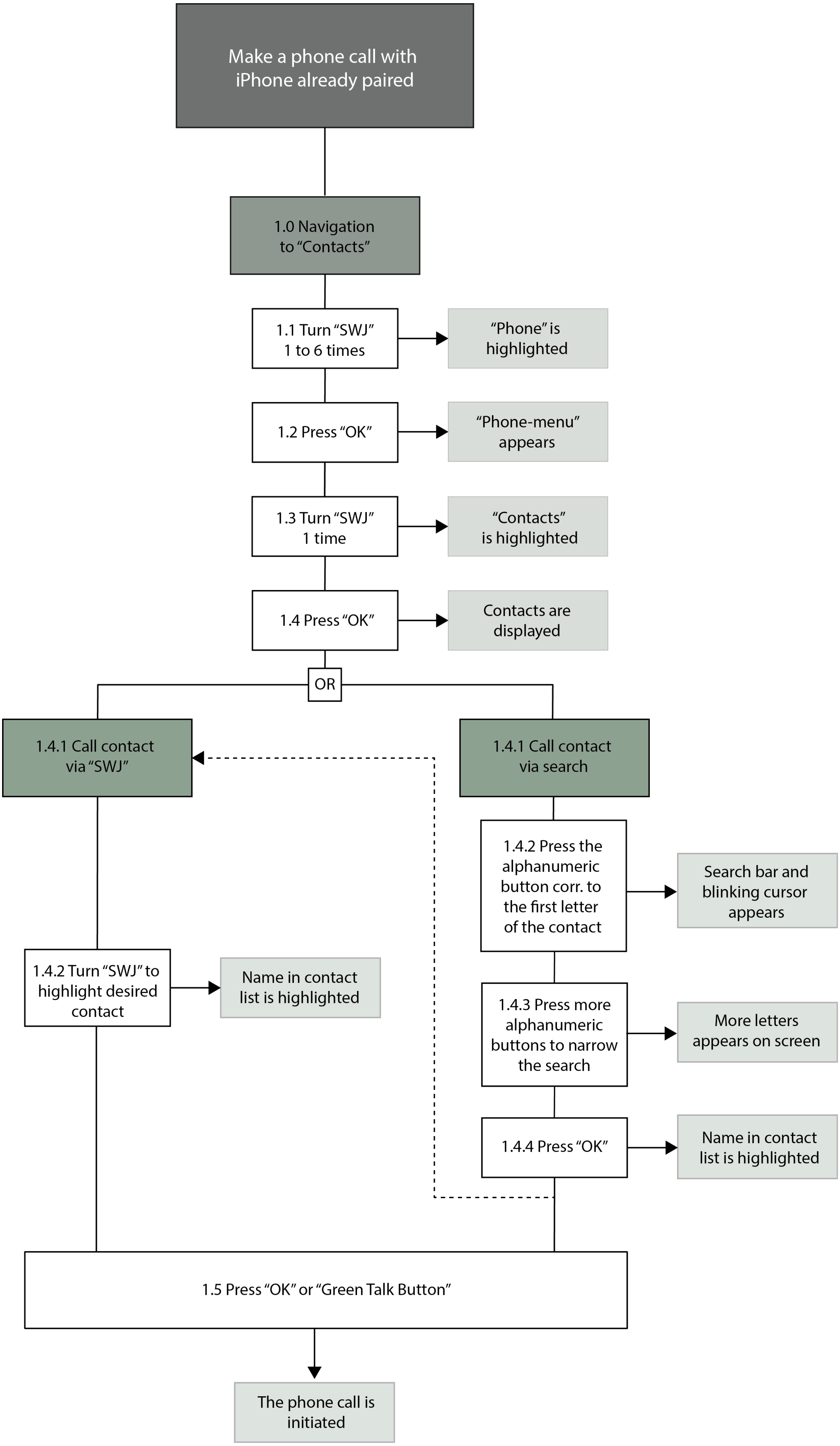

## Exit barriers

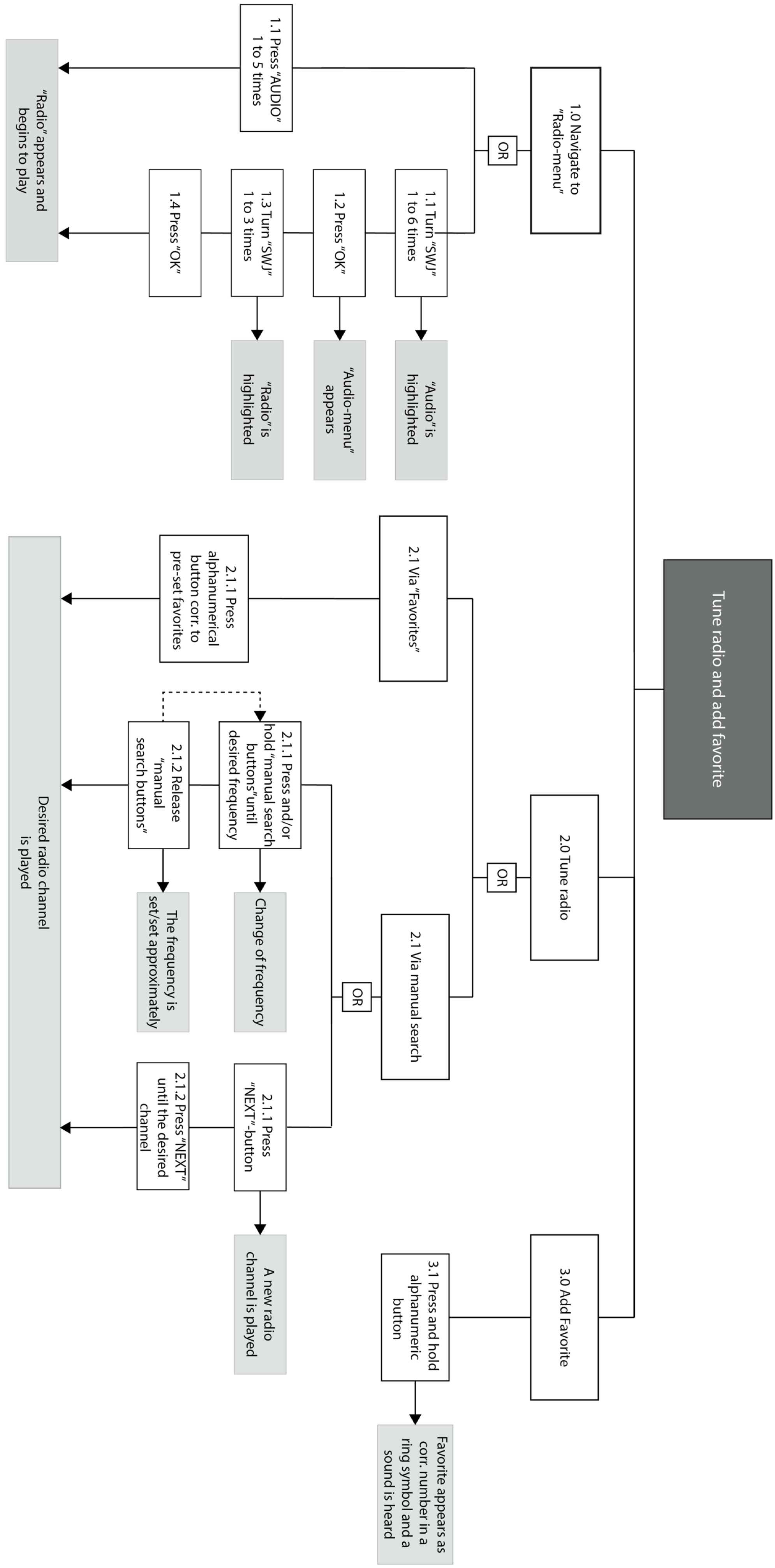
- What to do with developed technologies and research?
- Support and service for trucks sold with the touch UI
- Can be exluded from trucks relatively easy
- What kind of UI should be used instead?

# A9 - HTA


Bluetooth pairing of Android and truck (Expert User)
1.0 Initial search
1.1 Press "ON"
"External source" menu on startup
1.2 Press "ESC"
"Audio-menu" appears
1.3 Press "ESC"
"Main-menu" appears
2.0 Bluetooth activation on phone
2.1 Unlock phone
2.2 Swipe finger from the top part of the screen
"Notification-menu" appears on phone
2.3 Press button in the right top corner
"Quick settings-menu" appears on phone
2.4 Press button for Bluetooth
Bluetooth is activated on phone
2.5 Press button for Bluetooth again
Active devices are shown
2.6 Press button "Scan for devices"
The phone searches for devices
3.0 Navigation to "Bluetooth settings"
3.1 Turn "SWJ" 1 to 6 times
"Settings" is highlighted
3.2 Press "OK"
"Settings-menu" appears
3.3 Turn "SWJ" 1 time
"Bluetooth devices" is highlighted
3.4 Press "OK"
"Connect new device" is highlighted
3.5 Press "OK"
Prompt: "On device: Enable Bluetooth and search for Volvo Truck. If required, enter a four (4) digit PIN code"
4.0 Scan for mobile and pair
4.1 Press button "Scan for devices"
"Volvo Truck" appears on phone
4.2 Press "Volvo Truck" on phone
4.3 Wait until truck and phone is ready
Prompt: "Enter the same four (4) digit PIN code in both device and truck _ _ _ _
4.4 Press digits "1111" in SID
No prompt is shown on mobile device
4.5 Press "OK"
Prompt on phone: "Type the devices required PIN" A text box appears
4.6 Enter the same digits on phone, and press ok
Prompt: "Enter the same four (4) digit PIN code in both device and truck _ _ _ _
4.7 Press digits "1111" in SID, and "OK"
Prompt: "HTC One has been connected" HTC is shown on SID
4.8 Accept prompt "Data access request" on phone


Make a phone call with Android Smart phone (Expert user)
1.0 Navigate to "Phone"
1.1 Press "ESC"
"Settings-menu" appears
1.2 Press "ESC"
"Main-menu" appears
1.3 Turn "SWJ" 1 to 6 times
"Phone" is highlighted
1.4 Press "OK"
"Phone-menu" appears
2.0 Call number
OR
2.1 Via SID interface
2.1.1 Turn "SWJ" 1 time
"Call number" is highlighted
2.1.2 Press "OK"
Prompt:
Symbol of phone, keypad and blinking cursor appears
2.1.3 Press alphanumeric buttons 10-14 times
Telephone number appears on screen
2.1.4 Press "OK" or "Green Talk Button"
The phone call is initiated
2.1 Via Smart phone
2.1.1 Unlock Phone
OR
2.1.1.1 Navigate to "Contacts app"
Contact list appears
2.1.1.2 Navigate to desired contact
2.1.1.3 Select desired contact
Contact information appears
2.1.1.4 Press button for desired number
The phone call is initiated
OR
2.1.1.1 Press "Talk button" on phone
2.1.1.2 Press buttons 10-14 times
Telephone number appears on screen
2.1.1.3 Press "Call button"
The phone call is initiated


Make a phone call with iPhone already paired
1.0 Navigation to "Contacts"
1.1 Turn "SWJ" 1 to 6 times
"Phone" is highlighted
1.2 Press "OK"
"Phone-menu" appears
1.3 Turn "SWJ" 1 time
"Contacts" is highlighted
1.4 Press "OK"
Contacts are displayed
OR
1.4.1 Call contact via "SWJ"
1.4.1 Call contact via search
1.4.2 Press the alphanumeric button corr. to the first letter of the contact
Search bar and blinking cursor appears
1.4.2 Turn "SWJ" to highlight desired contact
Name in contact list is highlighted
1.4.3 Press more alphanumeric buttons to narrow the search
More letters appears on screen
1.4.4 Press "OK"
Name in contact list is highlighted
1.5 Press "OK" or "Green Talk Button"
The phone call is initiated



Tune radio and add favorite
1.0 Navigate to "Radio-menu"
OR
1.1 Press "AUDIO" 1 to 5 times
"Radio" appears and begins to play
1.1 Turn "SWJ" 1 to 6 times
"Audio" is highlighted
1.2 Press "OK"
"Audio-menu" appears
1.3 Turn "SWJ" 1 to 3 times
"Radio" is highlighted
1.4 Press "OK"
2.0 Tune radio
OR
2.1 Via "Favorites"
2.1.1 Press alphanumerical button corr. to pre-set favorites
2.1 Via manual search
OR
2.1.1 Press and/or hold "manual search buttons" until desired frequency
Change of frequency
2.1.2 Release "manual search buttons"
The frequency is set/set approximately
2.1.1 Press "NEXT"-button
A new radio channel is played
2.1.2 Press "NEXT" until the desired channel
Desired radio channel is played
3.0 Add Favorite
3.1 Press and hold alphanumeric button
Favorite appears as corr. number in a ring symbol and a sound is heard

# A10 - HTA tabular

## Hierarchical task analysis

**0. Call contact with an iPhone (while another cell phone is connected)**

1. Navigate the system
1.1 ”Settings” -> Press OK
1.2 Bluetooth devices -> Press OK

1.2.1 Connect new Device -> Press OK
1.2.2 Disconnect HTC One -> Select Yes -> Press OK
1.2.3 Prompt: “On device: Enable Bluetooth and search for Volvo Truck. If required, enter four (4) digit PIN code.”
1.2.4 On iPhone: Navigate to Settings -> Touch
1.2.5 Bluetooth -> Touch
1.2.6 Turn on Bluetooth -> Touch
1.2.7 Search for “Volvo Truck”

1.2.7.1 Not found
1.2.7.2 Turn off Bluetooth -> Touch
1.2.7.3 Turn on Bluetooth -> Touch
1.2.7.4 Search
1.2.7.5 Select “Volvo Truck” -> Touch
1.2.7.6 Failure to connect -> Touch OK
1.2.7.7 Turn off Bluetooth -> Touch
1.2.7.8 Turn on Bluetooth -> Touch

1.2.8 Select “Volvo Truck” -> Touch
1.2.9 Insert Pin on iPhone -> Touch [e.g. 1111]
1.2.10 Insert pin on Volvo Truck ->Press [1111] on alphanumeric buttons
1.2.11 Connected
1.2.12 On iPhone: Choose what should be synced (Synchronize contacts, Phone favorites, Latest calls, All contacts) -> Touch
1.3 Esc -> Esc -> “Home Screen”

2. Navigate to “Phone” -> Press OK
2.1 Navigate to “Contacts” -> Press OK
2.1.1 Search by pressing alphanumeric buttons -> Press buttons
2.1.2 Select desired contact
2.1.3 Call contact -> Press OK

Notes:

- Inte möjligt att ha två mobiler connected via bluetooth samtidigt. Man får information om att den första mobilen kommer bli disconnected när man försöker connecta en ny.
- Röd knapp fungerar inte för att ta sig ur sökfältet när man söker efter kontakter på mobilen.
- Grön knapp gör att man hoppar ur sökningen när man skriver ett namn och tillbaka till ”phone” grundskärm.

# A11 - Predictive Human Error Analysis

**Bluetooth Paring of Android and Truck**

| User error | Error type | Error cause | Primary consequence of the error (3) | Error recovery (6) | Prevention of error (8) |
|---|---|---|---|---|---|
| **1.0 Initial Search** | | | | | |
| The user is not aware where in the interface the pairing is possible | R1 | K | The user can not complete the task | The user has to read the manual | (1) Clarify what sequence is required for the desired task |
| The user does not find the main menu if omitting one operation in 1.0 | A9 | K | The user can not complete the task | The user has to press "ESC" or "ON" | (2) Make the menu structure logical |
| The user tries to pair the phone with the Truck solely by using the phone | A10 | K | It take more time to complete the task | The user has to read the manual or try the pairing task in a different way | (3) Simplify directions for Bluetooth pairing |
| **1.1 Press "ON"** | | | | | |
| The user presses any other button apart from "ON" instead | S2 | S | The SID is not turned on | The user has to press "ON" | (4) Make the button structure logical and more available |
| The user presses another button after having pressed the "ON"-button | A6 | L | The wrong menu is entered | The user has to press "ESC" | (1) Clarify what sequence is required for the desired task |
| **1.2 Press "ESC"** | | | | | |
| The user presses the access key/ button for "Phone" | P2 | K | A prompt is shown: "Connect a Bluetooth device to enable this function", leaving the user unaware of how to finish the action | The user has to read the manual or try the pairing task in a different way | (3) Simplify directions for Bluetooth pairing |

## Summary of Bluetooth pairing

**Possible Error Preventions**
(1) Clarify what sequence is required for the desired task
(2) Make the menu structure logical
(3) Simplify directions/sequence for Bluetooth pairing
(4) Make the button structure logical and more available
(5) Make all objects in the main menu visible directly, meaning there is no need to scroll (since the amount of menu objects is not that substantial)
(6) Differentiate texture/separate buttons more extensively
(7) Individual names for different trucks
(8) Inform the user
(9) Make code input interface easier to interpret

| Prevention type | Number of occurrences | ”Probability” that the prevention type is found amongst the user errors |
|---|---|---|
| (1) Clarify what sequence is required for the desired task | 2 | 0,05 |
| (2) Make the menu structure logical | 2 | 0,05 |
| **(3) Simplify directions for Bluetooth pairing** | **19** | **0,475** |
| **(4) Make the button structure logical and more available** | **5** | **0,125** |
| (5) Make all objects in the main menu visible directly, meaning there is no need to scroll (since the amount of menu objects is not that substantial) | 1 | 0,025 |
| (6) Differentiate texture/separate buttons more extensively | 1 | 0,025 |
| (7) Individual names for different trucks | 1 | 0,025 |
| **(8) Inform the user** | **6** | **0,15** |
| **(9) Make code input interface easier to interpret** | **3** | **0,075** |

| Error Cause / Error Type | (L) Lapse | (S) Slip | (R) Rule-based mistake | (K) Knowledge-based mistake | (V) Violations | Number of occurrences per Error Type |
|---|---|---|---|---|---|---|
| **P2** | 0 | 1 | 2 | 1 | 0 | **4** |
| **A1** | 1 | 0 | 0 | 0 | 1 | 2 |
| **A2** | 0 | 1 | 0 | 0 | 0 | 1 |
| **A3** | 0 | 1 | 0 | 0 | 0 | 1 |
| **A6** | 1 | 1 | 0 | 0 | 0 | 2 |
| **A7** | 0 | 5 | 0 | 0 | 0 | **5** |
| **A8** | 0 | 0 | 2 | 0 | 0 | 2 |
| **A9** | 2 | 3 | 1 | 1 | 0 | **7** |
| **A10** | 0 | 3 | 0 | 1 | 0 | **4** |
| **R1** | 3 | 1 | 1 | 4 | 0 | **9** |
| **R3** | 0 | 0 | 0 | 1 | 0 | 1 |
| **T1** | 0 | 0 | 1 | 0 | 0 | 1 |
| **S2** | 0 | 1 | 0 | 0 | 0 | 1 |
| **Error Cause per category** | 7 | **17** | 7 | 8 | 1 | 40 |

The most common Error Causes

(S) (17/40): Slip. "Good plan, bad execution"
(K) (8/40): Knowledge-based mistake

The most common Error Types

P2 (4/40): Incorrect plan executed
A7: (5/40): Wrong action on the right object
A9: (7/40): Action incomplete
A10: (4/40) Wrong action on the wrong object
R1: (9/40) Information not obtained

# A12 - PUEA 2

| User error | Error type | Error cause | Primary consequence of the error (3) | Error recovery (6) | Prevention of error (8) |
|---|---|---|---|---|---|
| **Tune radio and add favorite** | | | | | |
| | | | | | |
| | | | | | |
| **1.0 Navigate to ”Radio-menu”** | | | | | |
| The user activates another function instead (the eyes are focused on the road) | A6 | S | Another function is activated | The user has to return to the main menu and start from the beginning | (4) Make the button structure logical and more available |
| The user enters another menu instead of the ”Radio-menu” | S2 | S | | The user has to return to the main menu and start from the beginning | (4) Make the button structure logical and more available |
| The user does not find the radio function | A4 | K | The user stops the task | The user has to read the manual or try to find the radio function in a different way | (2) Make the menu structure logical |
| The user miscounts the number of ”SWJ”-turns needed to enter the ”Audio”-menu | A1 | S | The wrong item is highlighted | The user has to scroll once more | (5) Make all objects in the main menu visible directly, meaning there is no need to scroll (since the amount of menu objects is not that substantial) |
| | | | | | |

## Summary of Radio tuning

(1) Clarify what sequence is required for the desired task
(2) Make the menu structure logical
(3) Simplify directions/sequence for Bluetooth pairing/Radio Tuning
(4) Make the button structure logical and more available
(5) Make all objects in the main menu visible directly, meaning there is no need to scroll (since the amount of menu objects is not that substantial)
(6) Differentiate texture/separate buttons more extensively
(7) Individual names for different trucks
(8) Inform the user
(9) Make code input interface easier to interpret
(10) This user error is regarded as an accepted error
(11) Debug the system

| **Prevention type** | **Number of occurrences** | **”Probability” that the prevention type is found amongst the user errors** |
|---|---|---|
| (1) Clarify what sequence is required for the desired task | 3 | 0,06 |
| (2) Make the menu structure logical | 3 | 0,06 |
| **(3) Simplify directions/sequence for Bluetooth pairing/Radio Tuning** | **8** | **0,16** |
| **(4) Make the button structure logical and more available** | **20** | **0,41** |
| **(5) Make all objects in the main menu visible directly, meaning there is no need to scroll (since the amount of menu objects is not that substantial)** | **6** | **0,12** |
| (6) Differentiate texture/separate buttons more extensively | 3 | 0,06 |
| (7) Individual names for different trucks | 0 | 0 |
| (8) Inform the user | 0 | 0 |
| (9) Make code input interface easier to interpret | 0 | 0 |
| (10) This user error is regarded as an accepted error | 5 | 0,10 |
| (11) Debug the system | 1 | 0,02 |

| Error Cause / Error Type | (L) Lapse | (S) Slip | (R) Rule-based mistake | (K) Knowledge-based mistake | (V) Violations | Number of occurrences per Error Type |
|---|---|---|---|---|---|---|
| **P2** | 1 | 0 | 0 | 0 | 0 | 1 |
| **P3** | 1 | 0 | 0 | 0 | 0 | 1 |
| **A1** | 3 | 5 | 0 | 0 | 0 | **8** |
| **A2** | 0 | 4 | 0 | 0 | 0 | 4 |
| **A4** | 0 | 1 | 0 | 1 | 0 | 2 |
| **A5** | 0 | 9 | 0 | 0 | 0 | **9** |
| **A6** | 2 | 6 | 2 | 0 | 0 | **10** |
| **A7** | 3 | 5 | 0 | 0 | 0 | **8** |
| **A9** | 0 | 1 | 0 | 0 | 0 | 1 |
| **A11** | 0 | 1 | 0 | 0 | 0 | 1 |
| **C1** | 0 | 1 | 0 | 0 | 0 | 1 |
| **R1** | 0 | 1 | 0 | 0 | 0 | 1 |
| **T1** | 0 | 0 | 0 | 1 | 0 | 1 |
| **S2** | 0 | 1 | 0 | 0 | 0 | 1 |
| **Error Cause per category** | **10** | **35** | 2 | 2 | 0 | 49 |

(S) (35/49): Slip. "Good plan, bad execution"
(L) (10/49): Lapse. "Forget plan or execution"

The most common Error Types

A1 (8/49): Action too long/short
A5: (9/49): Misalign
**A6: (10/49): Right action on wrong object**
A7: (8/49) Wrong action on the right object

# A13 - PUEA Explanation

**Tabell 5.7 enl Bilgård**

| **Error Type** | | **Explanation** |
|---|---|---|
| **Plan** | P1 | Plan preconditions ignored |
| | P2 | Incorrect plan executed |
| | P3 | Correct but inappropriate plan executed |
| | P4 | Correct plan executed but too soon/too late |
| | P5 | Correct plan executed in wrong order |
| | | |
| **Action** | A1 | Action too long/short |
| | A2 | Action mistimed |
| | A3 | Action in wrong direction |
| | A4 | Action too little/too much |
| | A5 | Righ action on the wrong object |
| | A6 | Wrong action on the right object |
| | A7 | Action omitted |
| | A8 | Action incomplete |
| | A9 | Wrong action on wrong object |
| | A10 | Unnecassary action |

**Tabell 5.8 enl Bilgård**

| **Error Cause** | **Explanation** |
|---|---|
| **(L) Lapse** | A memory lapse, forgetting the intention. Why am I doing this? '*Forget* plan or execution'. |
| **(S) Slip** | Failure of attention during execution. A correctly planned action is not correctly executed. 'Good plan, bad execution'. |
| **(R) Rule-based mistake** | Occurs during problem-solving of familiar situations. Misapplications of good rules, i.e. well-known rules are used incorrectly to make a decision. 'Bad plan, good execution'. |
| **(K) Knowledge- based mistake** | Occurs during full attention to problem-solving activities, or problems never encountered before. Wrong decision based on own conclusions drawn from prior knowledge and known rules. 'Wrong conclusions, correct execution' |
| **(V) Violations** | Intended act or omission of act that violates present regulation and/or instruction, e.g. braking rules. Error action can be cutting corners to save time, omitting safety checks etc. |

## A14 - Affinity Diagram

| Kategori | Objekt |
|---|---|
| **Musik** | |
| | ”Jag använder iPod medan jag kör” |
| | ”CD:n känns överflödig” |
| | ”Använder radion mycket – streamar inte så mycket, men det måste fungera” |
| | ”Får inte igång musiken – oklart hur man spelar upp” |
| | ”Låtnamn i överkant av skärmen” |
| | ”Koppla musik via Bluetooth – inga kablar” |
| | ”Uppspelning skall fungera direkt” |
| | ”USB/AUX är bra” |
| | ”Inställningar som jag gör i radion är att ställa in favoriter, det är ej krångligt idag” |
| **GPS och NAVI** | |
| | ”Navigation är aldrig bra utan touch” |
| | ”GPSen är sämst! Den är ej anpassad för lastbilar, och är seg” |
| | ”Jag använder hellre min egen mobil än GPS i lasbil p.g.a. att det är segt.” |
| | ”GPS Fokus” |
| **SID-skärm** | |
| | ”Löstagbar SID – åtkomlig för passagerare/chaufför – placering vid knapparna” |
| | ”Löstagbar skärm” |
| | ”Dubbla chaufförer – åtkomst för båda” |
| | ”SID-placering långt fram – dåligt nu” |
| | ”Glas-skärm rekommenderas” |
| | ”Svårt att se SID för den är i en grop” |
| | ”Bra med justerbar skärm” |
| | ”Om det är soligt eller mörkt så speglar sig allting i displayen och det kan bli för mörkt” |
| | ”Bra med justerbar skärm” |
| | ”Den borde vara lika stor som en padda” |
| | ”Löstagbar skärm som man kan ha i baksätet/hytten så man t.ex. kan planera sin rutt” |
| | ”Tillräckligt stor display” |
| | ”Bra placering av touch-skärm är viktigt” |
| | ”Hur blir det med handskar?” |
| | ”Mina fingertoppar var inte lämpade för touch idag (kalla och torra), vilket gjorde att jag emellanåt inte kunde få skärmen att reagera. Kanske kan det vara en fördel om skärmen reagerar mer på tryck än på kapacitans” |
| | ”Nattkörning är inget problem (blädning etc.)” |
| | ”Viktigt med rätt position så att man slipper luta sig” |
| **Funktionalitet** | |
| | ”Det finns bara en mute-knapp. Denna måste tryckas på igen för att få ljud. Höja/sänka volymen bryter inte mute” |
| | ”Tune-down funktion i iPod-modulen vid inkommande samtal” |
| | ”Andra funktioner med touch – t.ex. tippning av last” |
| | ”När jag sov/arbetade i lastbilen förr använde jag TV och Playstation” |
| | ”Kan personliga inställningar synkroniseras med TAHCO-kort?” |
| | ”Visa alarmindikator och namnge alarm. Idag visas bara en liten symbol i hörnet” |
| | ”Mer info är välkommet – t.ex. info om last-tyngd” |
| | ”ECO-drive borde börja på topp-poäng och man borde få avdrag istället för så som det är idag” |

| | |
|---|---|
| **Bluetooth** | |
| | ”Många synkroniserar sina mobiler” |
| | ”Bluetooth lämnar mycket att önska men det är inte överdrivet svårt” |
| | ”När man har parkopplat en telefon, och den andra ringer, vad gör man då?” |
| | ”Jag vill kunna spela musik via Bluetooth. Det är mycket möjligt att jag hade lyssnat på mer musik i sådana fall” |
| | ”Att koppla in två mobiler är önskvärt” |
| | ”Bluetooth-sync fungerar inte med LG (Android)” |
| | ”Flera mobiler via Bluetooth” |
| | ”Två mobiler via Bluetooth (privat- och arbetstelefon) |
| **Viktiga funktioner** | |
| | ”Kameran går igång automatiskt när man backar – det är bra!” |
| | ”Kamerafunktionen är mycket viktig” |
| | ”Jag använder mest radion (i SID) och DynaFleet coaching” |
| | ”Navi och DynaFleet används inte så mycket” |
| | ”Jag ringer och smsar med mobilen” |
| | ”Radio och iPod använder jag oftast” |
| | ”Musik och alarm är viktiga funktioner” |
| **Under körning** | |
| | ”Man borde komma åt vissa saker med touch, så som: musik, väder, telefon, Navi, DynaFleet, men låsa funktioner som YouTube etc.” |
| | ”Göra under körning: Temperatur, telefon, radio/musik/byta låt/station, volym, vinterväglag och boggie” |
| | ”Förbjudet med YouTube” |
| | ”Säkerhetsystem fungerar bra” |
| | ”Lättare interaktion som att öka/sänka volym/scrolla i listor går bra vid körning” |
| **Knappar och reglage** | |
| | ”Klumpig joystick. Man får stanna och mata in” |
| | ”Jag vill ha en kombination av touch och rattknappar medan jag kör” |
| | ”Tomma platser på ratten (knappar)” |
| | ”Jag gillar hjulen och knapparna” |
| | ”Joysticken fungerar bra” |
| | ”Smidigt att använda rattknappar. Jag använder de ofta” |
| | ”Man knappar (ändrar) inte så mycket medan man kör, eller tittar på SID:en” |
| | ”Snabbknappar används men rattknappar är mer bekväma” |
| | ”Fysiska knappar är svåra att se i mörker” |
| | ”Det är svårt att knappa medan man kör (i kurvor etc)” |
| **Utformning av gränssnitt** | |
| | Enkelt och tydligt, inte för plottrigt |
| | Lätt och snabbt gränssnitt, inte invecklat |
| | Fungerande touch – mer trafiksäkert. Det är mycket pill med SID:en idag |
| | ”Fungerar men måste nog se ut som en iPad för synskadade” |
| | Tydliga symboler (grundtecken) |
| | Inkonsekvent gränssnitt idag |
| | Oftast lättast att ringa med mobilen om man jämför med SID:en |
| | Större ikoner är bättre och lättare |
| | Större ikoner gör det lättare |
| | Vid touch: konsekvent respons: liten swipe = liten förflyttning etc. |
| | Smartphone (windows) är enkelt att mata in på. SID är svårare och krångligare |

| | |
|---|---|
| | Information och inställningar |
| | Touch tillåtet för funktioner som kräver mindre ansträngning; t.ex. volymjustering, bläddra i listor, dock inte för nuvarande textinmatningsfunktion (skriva bokstäver med fingret). Ett digitalt tangentbord i displayen är ett bättre alternativ |
| | Information och meddelanden: DynaFleet och ECO drive är ibland störande |
| | Information är alltid bra. Infon är oftast klar och tydlig |
| | Det får inte bli för mycket information, en knapp som förklarar informationen hade varit bra |
| | ”Jag ändrar inställningar så fort jag börjar köra” |
| | Man ska se att grejerna är på/av i ett touch UI. Responsivitet är vitalt |
| | ”Att ha allting på ett ställe hade varit kanon” |
| | Hemskärm |
| | Personal settings |
| **Problematik** | |
| | Skärmen som sköter stereon samarbetar inte med DynaFleet (olika modulsystem för funktionen) |
| | ”Vet inte hur jag ändrar språk i SID” |
| | Man kan inte byta radiostation när man är inne i Navi:n (olika modulsystem för funktionerna) |
| | ”Det är ett helvete att koppla upp mobilen” |
| | ”Bluetooth-parkoppling orsakar besvär. Det är krångligt och innebär många steg” |
| **Haptik** | |
| | ”Mer haptisk feedback” |
| | ”Switch mellan SID och DID fungerar bra, men jag vill ha ”blindskrift”” |
| | ”Vibrationer för touchskärm är bra” |
| | ”Återkoppling med parad telefon fungerar bra” |
| **Övrigt** | |
| | Byte mellan SID och DID fungerar bra |
| | ”Jag vill ha en högteknologisk lastvagn” |
| | ”Alltid samma lastbil” |
| | ”Många har en egen bärbar dator” |
| | ”Hållare till mobil är önskvärt” |
| | ”Bra stöd för hand behövs” |
| | ”Vart placeras telefonen? Laddningsuttaget kanske?” |
| | ”Jag är positiv till TOUCH!” |

# A15 - Function analysis

N = Nödvändigt, Ö=Önskvärt,

| Verb | Substantiv | Prioritet | Kommentar |
|---|---|---|---|
| | **Visuell information** | | |
| **Förenkla** | Hantering | N | För aktuell målgrupp (personas/brukarstudier) |
| **Utnyttja** | Redundans | N | |
| **Minimera** | Ansträgning | N | Ex. Hitta 1 av 3, vs 1 av 50 |
| **Minska** | Mental belastning | N | Förenkla mönster, gruppering, tumregelbeslut minska mentalbelastning |
| **Minimera** | Distraktioner | N | Inte titta bort från vägen länge än rekommendation |
| **Involvera** | Sinnen | Ö | Haptisk feedback, ljud, texturerad touchskärm |
| **Begränsa** | Begreppsdriven bearbetning | N | Datadriven, omedveten och automatiserad |
| **Möjliggöra** | Rätt tolkning | N | Tolkning av ofullständig stimuli, ej bilda egna osanna slutsatser |
| **Bejaka** | Visuella intryck | N | Vi är visuella varelser, 80 % av sinnesintrycken via ögonen, man förlitar sig främst på synintryck |
| **Motverka** | Vridning av kropp och huvud | Ö | 170° synfält horisontellt |
| **Optimera** | Kontrast | N | Ljusstyrka, bra belysning för bra färgseende. F.lux, nattkörning, eyestrain. |
| **Bejaka** | Färgblindhet | Ö | 8 % av den manliga befolkningen - rött/grönt-färgblindhet. Små färgskillnader som beslutsmedel är inte bra. |
| **Begränsa** | Animationer | N | Svårare att fokusera, drar onödig uppmärksamhet. |
| **Underlätta** | Sökning/scanning | N | Höger till vänster, uppifrån till ner, iögonfallande objekt, förväntingar, data och begreppsdriven simultant. |
| **Minimera** | Information | Ö | Inte för mycket likadan information, svårt att ta till sig. |
| **Möjliggör** | Feedback | N | Bekräftning utav objekt, veta att man gjort rätt, små konsekvenser för felupptäckt – lägre nivå för att hitta rätt. |
| **Stödja** | Datadriven och begreppsdriven bearbetning | N | Ökade krav vid krävande uppgift, genomtänkt visuell presentationsform med ledtrådar som stödjer de olika bearbetningarna |
| **Bejaka** | Stimuli | N | Styrka hos stimuli? Efter 40-års ålder försämras synsinnet. Ljusförhållande, storlek och varaktighet. |
| **Beakta** | Färgkodning | Ö | Förstahand gråskala, färgkodning med stor |

| | | | |
|---|---|---|---|
| | | | försiktighet, helst med redundans. |
| **Bejaka** | Färglära | N | Vissa färger ej bra ihop. Tänk igenom valen. Färger i förhållande till kontrast? (svart text på vitbakgrund optimalt t.ex) |
| **Tillräcklig** | Skillnad | N | 1/60 av luminans kan upptäckas – beror dock på omständigheterna |
| **Grunda** | Färgval | N | Rött och grönt ej ihop,<br>Röd: stopp, fara, varmt, eld<br>Gul: varning, sakta, testning<br>Grön: ok, kör, fortsätt, på<br>Blå: Kall, vatten, lugnt |
| | **Generellt för touch i lastbilar** | | |
| Öka | Informationsvärde | N | Viktigt, relevant och användbar information för användaren |
| Motsvara | Förväntningar | N | Utifrån tidigare erfarenhet, och var informationen tidigare fanns tillgänglig |
| Förenkla | Växling | N | Mellan aktiviteter – uppmärksamhet på vägen vs. Skärm |
| Minimera | Påfrestan på KTM | N | Korttidsminnet, 30 s : info tillg. vid ingen repetition; see-and-point vs. remember-and-type |
| Minimera | Sammansatta enheter i KTM | N | ~7±2 sammansatta enheter i KTM samtidigt (Miller, 1956) |
| Använd | Vedertagna begrepp | N | Konkreta beskrivningar, vedertagna begrepp och generisk kunskap, verklighetsförankrat, utnyttja att människor har kunskaper om touch-teknik |
| Kategorisera | Objekt | N | Med medvetenhet – t.ex. undvika hopblandning |
| Verklighetsanpassa | Objekt | N | Symboler bör vara tydliga |
| Använd | Text | N | Till symboler och bilder, en form av redundans |
| Vara | Språk/Kulturanpassningsbar | N | Ska gå att ändra språk |
| Uttrycka | Vänlighet | N | Inte skriva felmeddelandet ”ILLEGAL USER ACTION” |
| Möjliggöra | Felsteg | N | Det ska inte leda till irreversibla konsekvenser vid felsteg. Tydliga sätt att ångra, avbryta och godkänna uppgifter |
| Tydliggöra | Uppgift | Ö | Hur ska man göra en uppgift och hur man ska uppnå ett mål? |
| Vara | Konsekvent | N | Samma genom hela gränssnittet, logik, färgkodning, uniformt inmatningssystem |
| Använd | Logisk gruppering | N | Av funktioner och symboler |

| | | | |
|---|---|---|---|
| Vara | Responsiv | Ö | Resistiv vs. kapacitiv t.ex. |
| Visa | Struktur | N | Översikt, och visa var i gränssnittet man befinner sig |
| Möjliggör | Startposition | Ö | Hemskärm (enligt Android/iOS) |
| Undvik | Oönskad gruppering | Ö | T.ex. färger kan leda till gruppering |
| Använd | Konventioner | N | T.ex. riktningar vid ökning eller minskning av värden (↑ vs ↓). Även vridning med/moturs |
| Använd | Symboler | Ö | För de olika funktionerna (inte bara text) |
| Beakta | Teckenstorlek och typsnitt | N | Rekommendationer beroende på avstånd och ljusförhållanden |
| Förmedla | Information | N | Vad händer just nu? |
| Ge | Feedback | N | Visa att inputen har mottagits, och ge feedback (även i rätt tidpunkt) |
| Minimera | Responstid | Ö | Undvik långa laddningar |
| Minimera | Steg | Ö | För uppgiften |
| Tydliggöra | Tillbakagång | Ö | Bakåt/hemknapp |
| Motverka | Felsteg | Ö | Se till att inte bygga in fel – använd PUEA och PHEA |
| Förenkla | Återställning | Ö | Vid feltryck ska det vara enkelt att återställa |
| Tydliggöra | Felmeddelanden | N | |
| Förmedla | Funktion | N | Synliga objekt och val, inte dold design |
| Instruera | Funktionalitet | Ö | Som en instruktionsmanual |
| Erbjuda | Snabbkommandon | N/Ö | Så att det går snabbare mellan olika alternativ, t.ex. hemknappen, telefonlur |
| Uppmuntra | Simplicitet | Ö | Med erforderlig funktionalitet, estetiskt tilltalande |
| Använd | Logik | N | Naturlig och logisk order på objekt |
| Underlätta | Läsbarhet | N | Snabbt läsa av information |
| Möjliggöra | Primäruppgift | N | Minimera brytning av uppmärksamhet – NHTSA 2 s (1,6 s) vända bort, 12 s totala uppgiften |
| Motivera | Språkbruk | Ö | Undvika långa ord, ovanliga uttryck och förkortningar, komplicerade symboler etc. |
| Motivera | Objektplacering | N | Info som används ofta ska vara lätt att hitta. |
| Minimera | Nivåisering | Ö | Svårt att bedöma storlek, tjocklek eller färg på presenterad variabel om antalet möjliga nivåer som variabeln kan anta överstiger 5. 3 rekommenderas. |
| Illustrera | Realism | Ö | T.ex. vid visning av temperatur kan en termometer användas |

| | | | |
|---|---|---|---|
| Anpassa | Efter mentala modeller | N | Överrenstämma med anv. mentala modell över hur det verkliga systemet fungerar. |
| Gruppera/Prioritera | Funktioner | N | Gemensam funktion i grupper |
| Matcha | Andra sinnesintryck | N | T.ex. visuellt och haptisk stimuli måste säga samma sak |