Redesign of an Instrument Panel Cluster
in the electric vehicle Saab Zero Emission

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Abstract
Driving and understanding electric vehicles can be quite different from a traditional vehicle. The expectations from the driver of an electric vehicle needs to be considered when designing the Instrument Panel Cluster interface.

This thesis treats the testing, evaluation and redesign of the instrument panel cluster’s interface in the electric vehicle Saab Zero Emission. The instrument panel cluster is the area in front of the steering wheel which holds the gauges and instruments. The areas other than the Instrument Panel Cluster, such as the center console and infotainment/navigation system were not included in the study.

The Instrument panel was tested and evaluated using an array of different methods including heuristic evaluation, cognitive walkthrough and user testing. The user testing was performed in a driving simulator using the think aloud method, to enable the observer to follow the users cognitive path.

Using the result from the testing and evaluation, new designs for the instrument panel cluster were made. Several overall layouts and individual gauges were developed separately. When the final layout was selected using evaluation matrixes, gauge designs were chosen to form a complete solution.

The result was a cluster which is adapted for an electric vehicle. The speedometer is an analog gauge and the rest of the instruments in the panel are presented on a seven inch color display. To avoid overloading the user with information, the cells which contain the different gauges can be expanded or collapsed. The expanded view reveals more details whilst the collapsed view only shows that gauge’s main information. Only one cell can be expanded at a time, and the user switched between the cells by using buttons on the steering wheel. The interface is adapted for en electric vehicle and intended to be more user friendly and ergonomic in a cognitive sense.

The cluster was implemented in the Saab Driving Simulator for future testing and evaluation. In order to further develop the interface, the improvements should be tested and compared with the test results of the present interface.
Nydesign av huvudinstrument
i elbilen Saab Zero Emission

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Sammanfattning

Att köra en elbil kan skilja sig från ett traditionellt fordon på flera sätt. Förväntningarna från föraren måste tas i beaktning när användargränssnittet i bilens instrumentpanel utformas.

Denna masteruppsats behandlar test, utvärdering och nydesign av Huvudinstrumentet i Saabs elbil Zero Emission. Huvudinstrumentet är den del av instrumentpanelen som sitter framför ratten och innehåller mätartavlor och andra instrument. Andra områden såsom mittkonsolen och musik- och navigatorsystem inkluderas inte i studien.

Huvudinstrumentet testades och utvärderades med metoder, bland andra heuristisk utvärdering, Cognitive walkthrough och användartest. Användartesten utfördes i en körsimulator med hjälp av tänk-högt-metoden för att möjliggöra för observatören att följa med i testpersonens tankebanor.

Med hjälp av resultaten från testutvärderingen skapades en ny design av huvudinstrumentet. Övergripande upplägg och design av individuella delar av klustret utformades parallellt. När ett slutgiltigt upplägg valts, med hjälp av en beslutsmatris, lyftes sedan individuella delar in för att skapa en komplett lösning.

Resultatet blev ett huvudinstrument anpassat för en elbil. Hastighetsmätaren är analog medan resten av instrumentet visas på en sju tum stor färgdisplay. För att undvika kognitiv överbelastning kan cellerna, som innehåller de olika instrumenten, expanderas och förminskas. I sitt expanderade läge visas mycket information medan bara den viktigaste informationen visas i det förminskade läget. Endast en cell i taget kan vara expanderad, och detta styrs med knappar på ratten. Användargränssnittet är avsett att vara mer lättanvänt och kognitivt ergonomiskt.

Instrumentet implementerades i Saab körsimulator för att möjliggöra framtida test och utvärdering. För att ytterligare förbättra och utveckla användargränssnittet bör det testas och resultatet jämföras med resultatet från dagens användargränssnitt.
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<td>Cognitive Walkthrough</td>
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<td>DTE</td>
<td>Distance To Empty</td>
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<td>GPS</td>
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<td>HE</td>
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1. Introduction

Driving and understanding electric vehicles can be quite different from a traditional vehicle. There are challenges associated with designing the Human-Machine Interaction (HMI) matching it to the driver’s needs and expectations of an electric vehicle.

Saab Zero Emission (ZE), publicly known as Saab ePower, is an electric powered concept car based on the existing Saab 9-3. This thesis work consisted of test and evaluation of the HMI of its Instrument Panel Cluster (IPC). Several different tests and evaluations were conducted, including user testing in a driving simulator. The IPC is the area that holds gauges and instruments in front of the steering wheel, see Figure 1.1. Based on the result from the evaluation, a new design was made and implemented in the driving simulator for further testing and evaluation.

![Figure 1.1. The Instrument Panel Cluster of Saab ZE.](image)
2. Problem Definition and Purpose

Since this was the first electric vehicle (EV) from Saab Automobile, the design of its instrumentation was a new area. In late 2010 a prototype series of EVs was in its final stage. The IPC in that series was made with the goal to change as little as possible from the existing fuel version considering the small series. If Saab chooses to proceed with a production version of ZE a more purpose built solution for the IPC is desirable. The aim was to be able to construct an IPC which is more optimized for an electrical vehicle. The interface should be more user friendly and ergonomic in a cognitive sense.

The purpose of the testing in the simulator was to find out what key functions are central for an electrical car. And determine whether the existing interface makes it possible to control these functions and how intuitive the system is for first time users. To define the problem a number of questions were formed:

- Is the setup from fuel-driven cars applicable in an electric vehicle without modification?
- How much heritage from fuel driven cars is needed in an electric vehicle. Is it possible to start over from a usability perspective?
- Are the electric vehicle specific symbols understandable?
- Is information regarding electric propulsion missing?
- Is there any abundant information?
- Are the gauges understandable?

2.1 Demarcation

Since the timespan of a master thesis is 20 weeks, the work was focused on the IPC. All other instruments in the car, such as the center console and infotainment/navigation system were not included in the study. The driving simulation was only used as a tool for testing the IPC and was not as a part of the study itself.
3. Background

A background study was conducted to obtain insight and knowledge about electric vehicles, HMI and methods for testing interfaces. The study included learning about the Saab ZE project, but also electric vehicles in general. In conjunction with the background study a platform and an outline for the course of the thesis was made.

The car industry is facing a new paradigm in propulsion systems. When oil is threatening to run out new energy sources is tried out and old ones are tried again. Electricity is often claimed to be the cleanest one, if produced with proper methods [Electric Car, en.wikipedia.org]

Electric hybrid vehicles such as Toyota Prius has been on the market since the late 1990s. A hybrid vehicle usually consists of a combustion engine and an electric engine that power the vehicle simultaneously. There are also power train configurations where the power from the two motors are shared through a power splitter (planetary gear) which can be variably adjusted. A series hybrid is powered only by an electric motor and a petroleum motor act as a generator, filling up energy to the batteries. A pure electric vehicle or plug in vehicle has no combustion engine at all. It runs solely on the energy stored in its battery pack, which is charged using a power outlet. Many major car manufacturers are in the process of introducing an EV in their product line or as a small scale testing series. [Elbil, www.ne.se]

3.1 IPC History

The instrument panel cluster started out as a piece of wood in front of the driver, which is a heritage from the horse wagon. Car manufacturers started to use this place to put instruments. In the beginning the instruments were usually positioned in the center of the panel, but in most modern car the placement is right above the steering column.

3.2 Instrument Panel Cluster

The IPC in Saab ZE is based on the cluster in the Saab 9-3, Figure 3.1. The ZE version of the IPC shares the overall shape with the combustion engine car and all the gauges and displays are the same. The information they show, however, are not the same.

![Figure 3.1. IPC of a fuel driven Saab 9-3](image-url)
As seen in Figure 3.2 the speedometer is located in the same place. Since the top speed of the electric vehicle is lower, the scale has been reduced from 260 to 160 kilometers per hour. To the left of the speedometer the tachometer is replaced with a Distance To Empty (DTE) gauge. Below the Speedometer a Driver Information Cluster (DIC) is situated. A small cluster of three gauges is placed to the right of the speedometer. From the left going clockwise is the auxiliary load gauge, the driver efficiency gauge (ecometer) and the State Of Charge gauge (SOC).

**Figure 3.2.** The Instrument Panel Cluster in the Saab ZE. From left to right: Distance To empty, speedometer, auxiliary load, ecometer, State of Charge. Below the speedometer the Driver information Cluster is situated.

3.2.1. Distance To Empty Gauge

The DTE gauge, Figure 3.3, shows the vehicle’s current range in kilometers. The scale of the gauge runs up to 200 kilometers, but the range of the car from a full battery is yet to be tested. The range may also vary dynamically depending on how the car has been driven. An aggressive driving style shortens the range.

**Figure 3.3** The Distance To Empty gauge indicates how far the vehicle will reach with the current charge.
3.2.2. Auxiliary Load Gauge

The auxiliary load gauge, Figure 3.4, indicates how much electricity is used by components such as the air conditioning unit, heated seats and defroster which all decrease the driving range if used. The gauge helps the driver to be more aware of the peripheral components in the car and their energy consumption.

![Figure 3.4](image)

*Figure 3.4. The auxiliary load gauge displays the use of peripheral energy consumption*

3.2.3. Ecometer

The ecometer provides instantaneous information regarding how the driving style affects the energy consumption, Figure 3.5. When the driver exhibits good driving the indicator points at the green area.

![Figure 3.5](image)

*Figure 3.5. The ecometer helps the driver to drive more energy efficient.*

If the driver accelerates hard or has a vehicle speed which makes the battery consumption exceed in response to larger amounts of aerodynamic drag, the indicator will point to the orange field on the right. If the negative acceleration by braking is larger than -0.2 g, energy is lost through mechanical braking heat and is not regenerated to the battery. The indicator will then point towards the orange field on the left.
3.2.4. State of Charge Gauge

The state of charge is the amount of energy currently available from the high voltage battery pack. The SOC gauge, Figure 3.6, always shows 100 percent when the car is fully charged.

![Figure 3.6. The state of charge gauge](image)

3.2.5. Driver Information Cluster

The DIC, depicted in Figure 3.7, is located at the bottom of the speedometer. It is a digital display showing the trip computer and menus for car settings such as rain sensor and comfort preheaters. The vehicle has two preheaters, one electrical and one fuel driven. The DIC also show pop up messages containing notifications. The left part of the DIC is an area for displaying symbols.

![Figure 3.7. The Driver Information Cluster](image)

3.2.6. Telltales

Telltale is symbols that pop up on the instrument panel to alert or warn the driver. Some telltales are displayed together with text in the DIC to clarify the information and warnings. All the telltales used in the vehicle are ISO-symbols [International organization for standardization, 2009]. Telltales that are unique for the electric vehicle are:

**Charge**

The amber charge symbol, Figure 3.8, is shown when the charging system needs attention due to malfunction or if the battery level is critically low. The texts that appear with this symbol are one of the following:

- Charging aborted. See owners manual.
- Plug-in attached. Disconnect before start.
- Battery level low. Charge now.
Propulsion System Active
The propulsion system active telltale indicates that the vehicle is ready to drive. The green symbol, Figure 3.9, lights up in the DTE gauge when the key has been cranked and remains lit until the key is turned to the OFF position. The symbol does not have any additional text describing its message since it is displayed in the DTE gauge.

Customer Usable State Of Charge
The customer usable state of charge symbol depicts an amber battery, Figure 3.10. This telltale is lit next to the SOC gauge when the state of charge reaches below 15 percent.

Reduced Power / Limited Performance
When the motor system detects limited propulsion performance the amber symbol “reduced power,” Figure 3.11, is lit together with an audible chime. The limitation is temporary and the driver is not expected to take the car to a mechanic. The DIC displays the text “Limited performance” to alert the driver that full power is not available.
**Exclamation**
The amber exclamation symbol, Figure 3.12, is not exclusive for the electric vehicle in itself, but there are telltale messages that are specific for the electric vehicle that use the exclamation symbol. The telltales that use the exclamation symbol are:

- Heater fuel level low. Refill.
- Electrical system needs servicing.

![Exclamation Symbol](image)

*Figure 3.12. Exclamation symbol used for several telltales.*

**Electrical Motor Needs Servicing**
The symbol in Figure 3.13 is not only used for electrical vehicles, but is here joined with the text “Electrical Motor Needs Servicing” and an audible chime. The indication is shown for electrical motor failure. The failure is not self healing and the customer is expected to take the car to a mechanic.

![Electrical Motor Symbol](image)

*Figure 3.13. The symbol is used to indicate electrical motor failure.*
4. Theory Of HMI and How to Design it for an Electric Vehicle

The human mind receives information from the world through the senses. The perception of the information is very dependent on the context from which the information is extracted. The mind builds a perception based on, and distorted by inner and outer factors. The outer factors are the size of the stimulation, contrast, intensity and frequency. The inner factors are our needs, experiences, feelings and expectations.

4.1 Consequences from electric powering of vehicles

Since there are differences in the information in an electric vehicle, compared to conventional cars, it is important to make sure the driver does not get confused. If a gauge looks similar to something used in a conventional car, but has a completely different meaning, the driver might interpret it wrong as a result of previous knowledge and habit.

The major drawback with an electric vehicle from a fuel driven vehicle is the energy storing capacity. A tank of gasoline, or other hydrocarbons used as a combustible fuel source, embodies more energy per volume than a present available battery. This means that less energy fit in each individual vehicle, and results in a substantially shorter range of the vehicle.

Saab ePower has an estimated range of up to 200 kilometer which is good for an electric vehicle but still considerably less than a vehicle with a combustion engine. Along with the short range of the electric vehicles the charging time of the batteries are several hours while a gasoline tank can be refilled in mere minutes. This gives economic driving behavior a more important role. Not only does it extend the range, but it can save the driver from time consuming charging stops.

The driver of an electric vehicle has to be made aware of how different driving behaviors affect these factors.

4.2 Driving an Electric Vehicle

The basic functions in an electric vehicle does not differ from the ones in a conventional combustion engine driven car. The main aspects of driving are still the same, but there are however some differences.

An electric motor emits considerably less noise that a combustion engine does. In a stationary position it emits no sound at all, and when driving the car the difference in sound level is subtle. This means that an important audible feedback of the vehicles status is decreased, if it is not replaced by another feedback. This replacement feedback, however, should not distract the driver from primary tasks such as steering, accelerating, braking and keeping track of traffic. [Fender, 2011]
4.3 Human–Machine Interaction (HMI)

The Human-Machine Interface is the materialization of the interaction between people and devices or machines. The interaction itself occurs as a user interface, which should be designed to make the technology understandable and easy to use. The HMI usually consists of a visual or audible display and a set of controls. The information from the display is processed by the human and may result in a response to the machine through its various controls. The input from the controls is then processed by the machine, and feedback is given through the display, see Figure 4.1.

![Figure 4.1](image)

*Figure 4.1.* The Human-Machine Interface is the space where interaction between humans and machines occurs.

The controls can be of various kinds, such as: mechanical devices, handwriting and gestures, speech input or eye tracking. The output can handled with the use of methods such as: survey, mechanics, vector devices, raster devices, frame buffers and image stores, canvases, event handling, sound and speech output, 3D displays and motion [Input and Output devices, www.sigchi.org].

There is a difference in interactions with complex systems such as process controlling in a nuclear power plant and consumer products such as stereos, computers and cars. Consumer products should not require any prerequisite knowledge while the operators of a nuclear power plant have rigorous training. Consumer products which cannot rely on specific training prior to usage requires high system acceptability from the users, to be a successful product. [MMI, www.arkiv.certec.lth.se].

The HMI has the potential to add usability to the product if it is designed properly. Nielsen claims that usability consists of *Learnability* (easy to get started with), *Efficiency* (effective when it is mastered), *Memorability* (easy to remember), *Few errors* (the user should make few mistakes), and *Satisfaction* (the user should be satisfied with the product). [Nielsen, 1993]
4.4 Design Principles for User Interfaces
In a HMI with high Usability the cognitive workload on the operator should be low, leaving the focus on the task and not on the interaction with the interface. The cognitive workload is the load on psychological processes involved in the accusation, organization and use of knowledge. [Hollnagel, 2003].

Models of how technology works is built up from past experiences. The clues and the information available should ease the user to build a proper mental model. The human has a good capability to see patterns and regard things that occur more often as more probable. By implementing this in the design of the interface, the usability increases. [Hollnagel, 2003].

Consistency with other displays enhances the user’s possibility to transfer skill from one system to another. Consistency helps the user predict what the system will do in a given situation and to avoid errors. [Nielsen, 1993].

Humans have limited memory capacity. The interface should relieve the user from concentrating on the technology, leaving focus on the task to be performed. This can be done by defining or limiting the alternatives of action.

By making the information needed to perform a task easily accessible, at the moment of the execution, less knowledge is required by the operator. This is known as knowledge in the world versus knowledge in the head. While knowledge in the world helps first time users perform an action, it is slower to access than learned knowledge in the head. [Hollnagel, 2003].

4.5 Thirteen Principles of Display Design
When designing a display or dashboard Wickens 13 principles of human perception and information processing [Wickens, 2004] can be used to create a good display design. A good balance between the different principles results in an effective design. The 13 different principles is divided into four categories depending on their character.

Perceptual principles

1. Make displays legible (or audible). Legible displays are necessary, although not sufficient, for creating usable displays. The same for audible displays. Once displays are legible, additional perceptual principles should be applied.

2. Avoid absolute judgment limits. Do not require the operator to judge the level of a represented variable on the basis of a single sensory variable, like color, size, or loudness, which contains more than five to seven possible levels.

3. Top-down processing. People perceive and interpret signals in accordance with what they expect to perceive on the basis of their past experience.

4. Redundancy gain. When the viewing or listening conditions are degraded, a message is more likely to be interpreted correctly when the same message is expressed more than once. This is particularly true if the same message is presented in an alternative physical form.

5. Discriminability. Similarity causes confusion: Use discriminable elements. Similar appearing signals are likely to be confused either at the time they are perceived or after some delay if the signals must be retained in working memory before action is taken. AJB648 is more similar to AJB658 than is 48 similar to 58, even though in both cases only a single digit differs.
Mental Model Principles

6. **Principle of pictorial realism.** A display should *look* like the variable that it represent. Thus, if we think of temperature as having a high and low value, a thermometer should be oriented vertically. If the display contains multiple elements, this elements can be configured in a manner that looks like it would in the represented environment.

7. **Principle of the moving part.** Moving elements should move in a spatial pattern and direction compatible with the user’s mental model of how it actually moves in the physical system. For example, the moving element on an altimeter should move upward with increasing altitude.

Principles Based on Attention

8. **Minimizing information access cost.** There is typically a cost in time or effort to “move” selective attention from one display location to another to access information. Good designs are those that minimize the net cost by keeping frequently accessed sources in a location in which the cost of traveling between them is small.

9. **Proximity compatibility principle.** Sometimes, two or more sources of information are related to the same task and must be mentally integrated to complete the task. These information sources are thereby defined to have close mental proximity.

10. **Principle of multiple resources.** Processing a lot of information can be facilitated by dividing that information across several different resources.

Memory Principles

11. **Replace memory with visual information: knowledge in the world.** People ought not be required to retain important information solely in working memory or retrieve it from long-term memory. Good design must balance *knowledge in the world* and *knowledge in the head*.

12. **Principle of predictive aiding.** Humans are not very good at predicting the future. When our mental resources are consumed with other tasks, prediction falls apart and we become reactive, responding to what has already happened, rather than proactive. A predictive display removes a resource-demanding cognitive task and replaces it with a simpler perceptual one.

13. **Principle of consistency.** Our long term-memory may trigger actions that are no longer appropriate, and this is a pretty instinctive and automatic human tendency. Because there is no way to avoid this, good design is consistent with other displays that the user may be concurrently or may have perceived in the past.

4.6 Ten Usability Heuristics

Another approach to designing a user interface is to use heuristics. Ten key factors to be implemented in a system is listed in Nielsens usability heuristics [Heuristic list, www.useit.com].

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

**Match between system and the real world.** The system should speak the user’s language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.

**User control and freedom.** Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. The system should support undo and redo.
Consistency and standards. Users should not have to wonder whether different words, situations, or actions mean the same thing. Therefore the system should follow platform conventions.

Error prevention. Even better than good error messages is a careful design which prevents a problem from occurring in the first place. This can be done either by eliminating error-prone conditions or check for them and present users with a confirmation option before they commit to the action.

Recognition rather than recall. Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.

Flexibility and efficiency of use. Accelerators, unseen by the novice user, may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. This allow users to tailor frequent actions.

Aesthetic and minimalist design. Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.

Help users recognize, diagnose, and recover from errors. Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.

Help and documentation. Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large. [Heuristic list, www.useit.com].

4.7 ISO Standard
The international standard for usability is defined in ISO 9241-11 [ISO 9241-11, 1998]. Usability is defined by the standard as:

"Extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use”

It is significant to establish who the user is, in which situation the product is being used, and which goals the product should help the user achieve. This of course in combination with user satisfaction. The core of the definition are the keywords effectiveness, efficiency and satisfaction. These words are described by the ISO 9241-11 as:

Effectiveness - to which extent the goal or task has been attained.

Efficiency - describes which degree of effort is needed to complete the task. The less effort, the better efficiency.

Satisfaction - Relates to the degree of satisfaction and positive impression from using the product.

These keywords are affected by:

The user - Who is using the product? Is it a highly trained professional, or is the user a novice trying the system out for the first time?
Task - There is always one and sometimes multiple tasks needed to reach an objective. The description of the tasks should be related to the objective. The task should not just be a statement of the functions the product offers, but rather a description of the activities and steps needed to reach the objective.

Equipment - A description of the software, hardware and materials needed.

Environment/Situation - A description of the physical and social environment in which the product is meant to be used.

The goals or objectives are supposed to describe the user's purpose for using the product, in other words what the user wants to achieve with the usage. The goals are described based on the user's perspective and should be formulated in such a way that they can be measured. The relationship between objectives and usability requirements is how the objectives can be met with effectiveness, efficiency and satisfaction.

4.8 HMI in Vehicles

The essence of controlling the vehicle is to affect the behavior of the vehicle in the desired way and thereby achieve the desired response. This requires the ability to somehow sense, measure or perceive the response from the system. [Hollnagel, 2005]

Driving a car is an operation in a multitasking operation with the task of controlling the vehicle. It comprise a moment-to-moment control of the vehicle and tactical decisions of how to reach a destination. In addition to handling the vehicle itself, the driver needs to track and monitor the surrounding traffic, control signs and hazards. [Wickens, 2004]

Simultaneously with driving a vehicle, in-cab viewing is required to read gauges, manage navigation systems and audio systems etc. Many intense cognitive activities like these compete with the visual scanning activities for the available cognitive resources. These in-cab viewings can be described in terms of the number and duration of glances. The duration of the glances should be short and the number of glances should be few. Glances shorter than 0.8 seconds with no less than three seconds between them makes the driver feel safe and comfortable. To make this possible a simple, user friendly design of the internal displays and controls is essential. [Wickens, 2004]
4.9 The Interaction Between Driver and Vehicle

A car is designed to move or to serve as a means of transportation, and the driver-car system must therefore be seen within the context of driving. The driver-car system exists within the environmental system which is made up of the streets and roads. This forms a new joint cognitive system, the car-driver-road system, or traffic system (figure 4.3). This system has properties regarding performance and control that are not found in the driver-car system.

![Figure 4.3](image)

Figure 4.3. The different levels of joint cognitive systems concerning driving. [Hollnagel, 2005]

The traffic system as a joint cognitive system is defined within its environment, which in this case is the traffic infrastructure. This includes traffic lights and signs as well as intangible factors such as rules or law of traffic. The infrastructure system is in itself a part of its environment, in this case the topography. [Hollnagel, 2005]
5. Overview of Execution
Following the background study there were two phases of the thesis. Phase I, consisting of stage one through four, was to evaluate the existing ZE instrumentation. Phase II, stage five and six, was to use the collected information from phase one to design a new IPC for future electric vehicles. The new IPC was then prepared for further testing.

5.1 Stages of Phase I

Stage One - Initial Evaluation
Before planning the user testing, methods that do not require any test participant were used to evaluate the system. These were quick and low cost methods suited for detecting flaws in the system early on in the evaluation process and furthermore determine which parts of the interface that are in need of evaluation.

Stage Two - Planning the User Test
The next main event of the thesis was the user testing in the driving simulator at Saab. The simulation was performed to detect strengths and weaknesses of the existing IPC in Saab ZE. Planning the test included deciding how many test participants to use and what tasks they should perform, as well as how the data should be collected. Along with deciding how the test should be performed, documentation was prepared such as: instructions for the participants, interview questions and consent forms.

When the planning of the simulation test was completed, documented and all the necessary preparations had been made, pilot testing took place to make sure the testing procedure worked as planned and stay within the time limits. The pilot tests were performed to make sure the tests were well prepared and the simulation experience would be the same for all the test participants with equivalent conditions.
Stage Three - Conducting Simulation Tests

The simulation took place in the driving simulator facility at Saab in Trollhättan, Sweden, according to the methods and standards set up in the previous stages. The simulator consists of a car and a three by twelve meter screen which arches 220 degrees around the front of the car, Figure 5.1. The image is projected onto the screen with four synchronized projectors. Inside the car, the center console has been replaced with a large touchscreen where any information or image can be displayed. The instrument panel cluster has been removed and replaced with a digital display, on which any instrument cluster can be virtualized.

![Figure 5.1. The simulator layout](image)

Stage Four - Analyzing and Evaluating the Simulation Tests

When the simulation study had been performed the collected data was analyzed and evaluated to determine which parts of the system were good and which areas were in need of improvements. Some of the collected data were objective data, but a large portion of the information was subjective thoughts from the users. The subjective data had to be compared to determine in which areas many users experienced trouble.
5.2 Stages of Phase II

Stage Five - Redesigning the IPC
When the evaluation was complete the results were used to develop a new IPC. The new IPC was not as restricted to the shape of the original Saab 9-3 as the first ZE IPC. This allows for a more purpose built solution with no absolute boundaries.

Stage Six - Programming of the new IPC
When the functionality and the layout of the new IPC was determined the process of programming it to run in a Windows [Microsoft Corporation, Windows] environment began. First the layout and the separate graphical object where created in Photoshop [Adobe Systems Incorporation, Photoshop] and Illustrator [Adobe Systems Incorporation, Illustrator], but as many objects as possible where later created using programing, to be able to modify them dynamically during program runtime. Objects that where changed were primarily bounding boxes and text strings. The methods for communication between the car and the IPC program could be reused from the old version of the IPC with slight modification.

The IPC was programmed in Visual Studio [Microsoft Corporation, Visual Studio] using the C# programming language [C, www.ne.se]. After compilation, which transforms source code written in programing language into computer language [Kompilering, www.ne.se], the program could run on the IPC computer and be displayed on the screen in the car.
Phase I - Test and Evaluation of Existing IPC

6 Method
The overall purpose, which is defined in chapter 2, acted as the foundation for choosing which methods to use for the testing and evaluation process [Jordan, 1998]. Quick and cost efficient methods are used first to narrow down which areas require more thorough testing.

6.1 Heuristic Evaluation
A heuristic evaluation (HE) is one of the easiest and most inexpensive methods of evaluating a system. The goal is to identify usability problems in the design of the user interface. This method only requires a few evaluators and no user testing which makes it time and cost effective. More evaluators find more of the problems in a system, but only up to a certain number. By three to five evaluators the gain of more evaluators subsides, see Diagram 6.1. [Heuristic evaluation, www.useit.com]

![Diagram 6.1. Curve over how many problems are found by an increasing number of evaluators.](image)

During the HE, the biggest errors and design flaws in a system are discovered before the user testing. The HE on the IPC in ZE was conducted by two evaluators according to Nielsens heuristics. [Nielsen, 1993]
6.2 Hierarchical Task Analysis

Tasks tend to have a complex hierarchical structure, why the data is best represented graphically. In a Hierarchical Task Analysis (HTA), Figure 6.1, the tasks are organized as sets of actions used to accomplish higher level goals. HTA does not represent detailed cognitive information processing or decision making but rather defines the preferred order of execution and the conditions that must be met [Wickens, 2004].

![Diagram](Image)

**Figure 6.1.** The structure of a HTA sheet used when analyzing tasks.

6.3 Cognitive Walkthrough

In a Cognitive Walkthrough (CW) a user interface is evaluated focusing on the first time user experience of a user without any formal training of the system. A HTA is walked through with the cognitive aspects in mind. As prerequisites a general description of the user is used to estimate what problems that might occur when the user performs the tasks from the HTA [Rieman, 1995]. For each task four steps are examined;

1. Will the user try to achieve the right effect?
2. Will the user notice that the correct action is available?
3. Will the user associate the correct action with the effect that the user is trying to achieve?
4. If the correct action is performed, will the user see that progress is being made toward the solution of the task?

If the answer is “No” to any of the questions above, the reason for the problem is described in a “fail story”, and the usability problem is stated. This method helps to pin point exactly where in a task the usability problem lies.
6.4 Ishikawa diagram

Ishikawa diagrams, also known as fish bone or cause and effect diagrams, show the effect of an event, Figure 6.2. It helps identifying which factors are the cause of an overall effect. When the causes are determined they are tracked back to their roots and questions can be asked why they occurred.

![Ishikawa Diagram]

**Figure 6.2.** A Ishikawa diagram illustrates the causes of a certain problem (effect).

6.5 User Testing

Before performing user testing careful preparations were done. Based on the results from the previous methods a scenario to be run in the simulator was put together. A test scenario, where the potential problem areas could be tested on a user, was formed. Apart from the simulation section the test contained questionnaire before and after the test.

6.5.1 Think Aloud

During the simulation the think aloud method was used. The method is used to collect mental processes used during a task [Wilson, 1995]. A think aloud test involves having a test participant think out loud while using the system. This enables understanding of how the user views the system and makes it easy to identify misconceptions. During the test the observer does not answer any questions. The observer only talks when instructing what the next task is or asking probing questions such as “What are you thinking now?” or “What do you think this message means?”. Questions like the latter should only be asked if the user has noticed the message in question. [Nielsen, 1993]

When using the think aloud method the verbal report from the session may be distorted due to the surrounding settings. Having to give a verbal protocol may change the way the user performs a task, to a method which is more easily described. Thoughts can also pass through the mind to fast and be forgotten before they are reported and people may select to say what they think is appropriate rather than what they actually are thinking. [Wilson, 1995]

6.5.2 Questionnaires

When using questionnaires and interviews to gather information it is important to ask the questions in a way that does not influence the answers in any direction. It is important that the questions are specific and easily understood in order to get parative answers. Never ask more than one question at a time and do not use long and complex sentences. Generally it is also good to avoid negations in the questions. The negation can be missed by the person taking the questionnaire. [Trost, 2001]
6.6 KJ analysis
A KJ analysis is used to structure data masses from studies. The aim is to compile a holistic view over large amount of verbal data. This is a bottom up method where one starts with the details and move on to the higher levels. The result is a picture that illustrates connections between different parts. [Karlsson, 2008]

6.7 Severity rating
Using the groups created in the KJ-analysis the problems were listed and rated based on the severity of the problem. Both a higher occurrence and a higher impact of a problem leads to a larger severity [Nielsen, 1993]. A high severity problem is to be prioritized in the next phase.

6.8 Diagrams
The quantitative data was evaluated using pie charts, histograms and pareto diagrams. From these different representations of the data, conclusions could be drawn as to which parts of the IPC was user friendly and which that had potential for improvements.
7 Execution and Results Phase I

The testing and evaluation took place in the testing facility at Saab in Trollhättan, Sweden. All testing and evaluation was performed by the same team, except for the user testing where the test participants were people who had no previous affiliation with the study.

7.1 Heuristic Evaluation

Several flaws were discovered both in the system and layout as well as inaccuracies in the way the simulator simulated the system. A summary is presented below, and the full heuristic evaluation document can be viewed in Appendix I.

7.1.1 Possible Usability Flaws

The menu structure in the DIC was at some times inconsistent. Most of the problems were issues that would be difficult for the first time user, but fairly easy to learn. The auxiliary load gauge had a scale that could be misinterpreted because it had two conflicting indicators. When the consumption rose, the needle in the gauge went up, but the scale got narrower. This was to indicate “less green” behavior. The DTE gauge had a fairly dense scale, and it was hard to read out exactly how far the cars range was. When the battery level reaches below 15 percent the telltale is fairly discrete was not accompanied by a chime sound. Further more it has the same size and is located next to the symbol that indicated the SOC gauge. This is a case of low discriminability. The popups triggered by interaction in the DIC menu that indicate errors or in other ways alert the driver are three seconds long. This is too short for the driver to be able to see, read and perceive the message.

7.1.2 Simulator Inaccuracies

Initially some parts of the IPC in the simulator was not correct according to specifications of Saab ZE. These inaccuracies included spelling errors, wrong menu hierarchy, wrong color on symbols and settings options that will not be available. Some of the needles on the gauges did not respond accurately. These issues were corrected before the user testing.

7.2 Hierarchical Task Analysis

The HTA was done on three tasks; Start the car and drive off, operate the heater and change the “allow fuel heater” setting. These task were chosen because they contribute to many of the user problems that were discovered in the heuristic evaluation. The HTA schemes on these tasks can be viewed in Appendix II. Every step in the HTA was analyzed using Cognitive walkthrough.

7.3 Cognitive Walkthrough

Before performing the CW a user profile was made where a fictional user’s general characteristics were portrayed:

- The user is considerate about the environment.
- 30-60 years old.
- He/she wants a clean and quiet transportation, mostly in urban areas.
- Experienced driver with who has had a license for several years.
- Living in major cities or surrounding municipals.
- Not afraid of new technology.
- Uses car mainly for commute to work.
When the CW was conducted a couple of tasks where the user might encounter problems were found. Examples of issues that were found during the CW are:

- Long press is used in one place (entering settings) and short press otherwise in the menu.
- Menu hierarchy may be confusing without references to previous and next option.
- There is no proper indication of whether selections are executed or not.
- Telltale for Propulsion System Active may be hard to understand or recognize for first time users.

The complete analyses of every step can be viewed in Appendix III.

### 7.4 Ishikawa diagram

From the Ishikawa diagrams, Appendix IV, the possible causes of the usability problems can be interpreted. The IPC usability problem derives from human factors or design factors. These can separately or in combination with other factors lead to problems in using the system. When building the Ishikawa diagram for the IPC the causing factors were grouped in three categories: human factors such as previous knowledge, habits, experience and anticipation; design factors such as lack of guidance, discernibility, inconsistency and labeling; and consistency of the user interface.

The following four effects were studied:

- Difficulties understanding the auxiliary load gauge. Caused by labeling, scale and lack of knowledge from the user.
- Hard to comprehend that braking is inefficient. Caused by that braking is considered a good behavior and lack of positive braking zone on the gauge.
- Hard to notice when the propulsion system is active. Caused by previous experience of the user, placement, low distinction of the symbol and lack of sound.
- Hard to know when long press should be used. Caused by inconsistency, lack of guidance and previous experience.

### 7.5 User Testing

A general goal for the test was set, and then based on previous testing and evaluation a user test was formed. The outline for the test was first drawn, and then specific questions were tried out and revised until they were ready for pilot testing. The test procedure consisted of one part in which the car was stationary, and one where the car was driven through a mix of highway and urban environment. In the first part the menu navigation in the DIC was tested and in the second part, awareness of pop-ups and gauge movement recognition, was observed. Some adjustments were made during pilot testing until the test was ready. The test procedure protocol can be read in Appendix V.

#### 7.5.1 The Goal of the Test

The goal of the test in the driving simulator was to determine the performance of parts and features of the existing prototype of the ZE IPC. The test would help to decide which parts should be kept for the new version, and which features should be redesigned. The test was designed for discovering how intuitive the system was, and how easy the system was to “learn by doing”. In addition the test participants general wants and wishes regarding an EV were gathered, such as if the driver wants the interior of an electric vehicle to feel like a regular car or showcase the electric features.
7.5.2 Test participants
The participants were selected from Saab staff who had no connection to the ZE project. The reason for the “in house” selection was that test participants with previous experience in the simulator were known not to suffer from motion sickness. There was also a lot to gain in logistic, compensation and confidentiality matters.

The people in the test group were not randomly selected. The selection was a quota sampling, a method used when a certain representation of the population is wanted [Trost, 2001]. In this case the group of ten people were chosen to represent average drivers. Since the test was small scale, the extreme ends of the spectrum of possible drivers were not selected. Half of the group was male and the other half female with ages ranging from 27-59 years of age. All the test participants had driven a Saab vehicle before the test, making the car environment familiar and the instrumentation unique to the electric vehicle the only variable.

7.5.3 Structure of the User Test
The procedure of the test was constructed so that many of the specific matters of driving an electric vehicle would be involved. This includes task performed with the car being stationary as well as when driving. Preparing the car before a ride, turning on a heater and starting the car up all have differences from a fuel driven car worth testing. Though there are many peripheral tasks with an electric vehicle, such as charging, only interactions with the IPC were included in this test. The tasks for the driving simulation were chosen to be a part of a larger general task. This way transitions between functions are tested as well [Lewis, et al. 1994].

7.5.4 Test protocol
A test protocol was made for the test leaders to use during the test to ensure a high reliability. The protocol gave the instructor step by step instructions through the entire test including all the questions to be asked, which hints to give the participants and how long to wait before giving those hints. Since an audio link had been set up between the car and the control room, the test participants reflections when talking out loud were written down in a protocol both by the instructor in the car as well as the test leader in the control room. Questions regarding the users subjective opinions were primarily asked after they had tried the tasks, to avoid answers with low correlation [Nielsen, 1993].

7.5.5 Questionnaires
Questionnaires used before and after the simulation were formed using the guidelines from section 6.5.2 and can be viewed in Appendix VI and Appendix VII.

7.5.6 Pilot Testing
Before the test was carried out, two pilot tests were performed to make sure everything ran as planned and the testing procedures did not take too long. After the first pilot test, some questions in the questionnaire were clarified and one of the symbol for a popup messages was moved to fit on the screen. After the second pilot nothing had to be revised, and decisions were made to move forward to proper testing.

7.5.7 Walkthrough of Test Procedure
The test participant enters a room were he or she gets a brief walkthrough of what the test will consist of, both in speech and in writing. The test participant signs a consent form allowing the collected data to be used in the study. Before entering the simulator the test participant fills out a
form about age, sex and previous experiences of electrical vehicles. The form is presented in Appendix VI.

In the simulation vehicle, the test participant first has a few minutes to get aquatinted with the car and the feel of driving in the simulator since it can take some getting used to. At this stage questions about the car, regarding the parts that will not be tested (e.g. setting up the seat position), are answered. When the test participant feels comfortable with the car, the test begins using the “think aloud” method.

During the test the participant is asked to perform certain tasks related to driving and handling an electrical vehicle. In this part of the test the participant is encouraged to ask questions, however, no questions will be answered. The observer only gives instructions as to which task is to be performed and prompt the participant to keep on talking if he or she is silent for a long period.

After the simulation the participant is asked to fill in a questionnaire about the features of the car and some of the symbols used in the instrument panel. The form is enclosed in appendix VII. The entire test is expected to take approximately 60 minutes including the time for filling out the forms and questionnaire.

7.6 User Testing Evaluation
The data collected from the test was stored digitally and on paper after every session. The data was analyzed and evaluated using several methods.

7.6.1 KJ analysis
The fairly large amount of verbal qualitative data collected during the simulator tests was compiled with a KJ analysis. The analysis resulted in a grouping of the problems into five areas; Readability, Design, Attention, Usability and Placement, see Appendix VIII. Relations between problems in each area could then be identified. For instance: Sound confirmations draws attention to popup messages; Normal driving behavior should be displayed as green on the ecometer; Complementary numerical values clarifies gauge indications.

7.6.2 Severity rating
The problems, issues and the good things found in the testing were rated regarding its severity, according to Figure 7.1.

<table>
<thead>
<tr>
<th>Impact of problem on the users who experience it</th>
<th>Proportion of users experiencing the problem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>Few</td>
</tr>
<tr>
<td>Proportion of users experiencing the problem</td>
<td></td>
</tr>
<tr>
<td>Few</td>
<td>Low severity</td>
</tr>
<tr>
<td>Many</td>
<td>Medium severity</td>
</tr>
</tbody>
</table>

*Figure 7.1. The severity of the problems, issues and good things were evaluated regarding its impact and the proportion of users experiencing them.*
If a high proportion of the test participants experience a problem and it causes high impact on the task they are trying to perform, the severity is regarded as high, Table 7.1. A problem with high severity has high priority to get addressed in a later stage.

<table>
<thead>
<tr>
<th>Issues</th>
<th>proportion</th>
<th>impact</th>
<th>Severity</th>
</tr>
</thead>
<tbody>
<tr>
<td>The meaning of the A-gauge is vague</td>
<td>high</td>
<td>large</td>
<td>high</td>
</tr>
<tr>
<td>The icon for “Propulsion System Active” is vague</td>
<td>high</td>
<td>large</td>
<td>high</td>
</tr>
<tr>
<td>The need of a Long press in the menu</td>
<td>high</td>
<td>large</td>
<td>high</td>
</tr>
<tr>
<td>Short time limit of the popups</td>
<td>high</td>
<td>large</td>
<td>high</td>
</tr>
<tr>
<td>The left side (brake) of the Ecometer is hard to comprehend</td>
<td>low</td>
<td>large</td>
<td>medium</td>
</tr>
<tr>
<td>Lucidity of the menu</td>
<td>high</td>
<td>small</td>
<td>medium</td>
</tr>
<tr>
<td>No confirmation to the user on choices</td>
<td>low</td>
<td>small</td>
<td>low</td>
</tr>
<tr>
<td>Scale/gradation of the A-gauge</td>
<td>high</td>
<td>large</td>
<td>high</td>
</tr>
<tr>
<td>Lack of sync between DTE and SOC</td>
<td>low</td>
<td>large</td>
<td>medium</td>
</tr>
<tr>
<td>The design of the low battery symbol</td>
<td>low</td>
<td>small</td>
<td>low</td>
</tr>
<tr>
<td>The menu structure</td>
<td>low</td>
<td>small</td>
<td>low</td>
</tr>
<tr>
<td>Heater settings in the trip computer (DIC)</td>
<td>high</td>
<td>small</td>
<td>medium</td>
</tr>
<tr>
<td>No visual difference between menu and popup items</td>
<td>low</td>
<td>small</td>
<td>low</td>
</tr>
<tr>
<td>“Charge now”-warning when only 10 km left</td>
<td>low</td>
<td>small</td>
<td>low</td>
</tr>
<tr>
<td>No info on how to save electricity</td>
<td>low</td>
<td>small</td>
<td>low</td>
</tr>
<tr>
<td>Ecometer shows orange when cruising in 90 km/h</td>
<td>low</td>
<td>large</td>
<td>medium</td>
</tr>
<tr>
<td>The symbols only work with a description.</td>
<td>low</td>
<td>large</td>
<td>medium</td>
</tr>
</tbody>
</table>

**Table 7.1.** Severity of problems. High proportion of problem experience and large impact is rated as high severity and needs to be addressed.

The same disposition was made with the positive features of the IPC. A good feature with high severity is not in need of change. The positive features are presented below in Table 7.2

<table>
<thead>
<tr>
<th>Positives</th>
<th>proportion</th>
<th>impact</th>
<th>Severity</th>
</tr>
</thead>
<tbody>
<tr>
<td>The content of the IPC is good - generally</td>
<td>many</td>
<td>large</td>
<td>high</td>
</tr>
<tr>
<td>DTE gauge is easily understood and relevant</td>
<td>many</td>
<td>large</td>
<td>high</td>
</tr>
<tr>
<td>IPC is based on the present 9-3, makes it familiar</td>
<td>many</td>
<td>small</td>
<td>medium</td>
</tr>
<tr>
<td>The popup warnings are noticed</td>
<td>many</td>
<td>large</td>
<td>high</td>
</tr>
<tr>
<td>The ecometer is clear and relevant</td>
<td>few</td>
<td>large</td>
<td>medium</td>
</tr>
<tr>
<td>The placement of the display (DIC)</td>
<td>many</td>
<td>small</td>
<td>medium</td>
</tr>
<tr>
<td>Sound confirmation to the popups</td>
<td>many</td>
<td>large</td>
<td>high</td>
</tr>
<tr>
<td>The information from the auxiliary load-gauge is relevant</td>
<td>many</td>
<td>large</td>
<td>high</td>
</tr>
</tbody>
</table>

**Table 7.2.** A feature with high severity is favorable to keep.
7.6.3. Compilation of Statistics

All the questions in the questionnaire were compiled and illustrated in diagrams. The diagrams summarizes of all the answers and helps pin pointing the problem areas. Due to confidentiality the reasons exact numbers and diagrams from the results are not enclosed.

One of the areas with problems was the auxiliary load gauge, as most of the test participants did not, or did not fully understand what the gauge represented. The gauge is not normally found in cars, meaning users lack previous experience. The Labeling “A” is also quite vague. On the other hand, when the gauge’s function had been explained the test participants perceived the information from the gauge relevant and useful when driving an EV.

The intent of the ecometer was fairly easy for the participants to understand. How to read the meter however, was not clear to everyone. There were some misinterpretation about what the different directions on the indicator meant.

In the question about how easily navigated the menus were, the answers were very scattered across the entire scale. Some of the participants found them quite easy while others rated them as very difficult to understand. To find out what the biggest contributor to the problem was a Pareto diagram was made, Figure 7.2.

![Pareto diagram](image)

*Figure 7.2. The long press accounts for a substantial part of the problems.*

The problem that has most occurrence is located to the left and the rest in falling order on its right. If the problems are fixed, starting from left, the accumulated value shown how many percent are fixed. The diagram shows that a substantial amount of the total accumulated problems derive from “Long press” which is when the user has to press and hold the SET button to enter the settings menu. Removing the long press feature would reduce the struggle rate significantly.
An electric vehicle does not make any noise when turned on like a car with a combustion engine. Therefore there is a need for another signal that alerts the driver about the active state of the propulsion system. In the IPC a symbol for “propulsion system active” was lit when the key was cranked, but only roughly a third of the participants noticed it during the test. The low detection rate might be a result of the size and placement of the symbol in combination of not knowing what to look for. The combination of expectations not being met and the lack of experience as to know what the look for, is why the propulsion system active symbol is not that effective.

There are more than one ISO symbol to indicate “propulsion system active”, and after the simulation each of the test participants were asked which symbol they thought best represented that the car was active and ready to drive. The three symbols are shown in Figure 7.3. The symbol used in the old IPC, a car with a double sided arrow under it got the lowest rating. The test favorite was the symbol of a car with the text “READY” underneath it.

![Figure 7.3. The combination of a green car and “READY” best represents that the propulsion system is active.](image)

When the state of charge reaches below 15 percent the IPC displays an amber battery symbol next to the state of charge gauge. During the simulation only half of the test participants noticed the symbol while driving.

The popups in the menu disappeared too quickly, according to the majority of the test participants. The warning popups about low battery level and limited performance are cleared manually. This gave the user time to both register and understand them.
8. Conclusion Phase I

According to the test participants, all the necessary features for a IPC in an electric vehicle is present in the Saab ZE IPC, however, some of the features were hard to interpret and could be improved with more detailed information.

The way the menu structure was navigated through was at some times inconsistent. Long press is used in one situation (entering settings) and short press otherwise. The menu hierarchy may be confusing without references to previous and next option. There is no proper indication of whether selections are executed or not. Most of the problems were issues that would be difficult for the first time user, but fairly easy to learn.

The telltale for Propulsion System Active is hard to understand or recognize for first time users and only a few of the users even noticed the symbol during the test. The low detection rate might be a result of the size and placement of the symbol. According to the users in the test the symbol used is not the best of the available ISO symbols.

The time limit on the popups that indicate errors or in other ways alert the driver are three seconds long. This is too short for the driver to be able to see, read and perceive the message.

The auxiliary load gauge had a scale that could be misinterpreted because it had a raising indicator needle but a decreasing scale. Most of the test participants did not, or did not fully understand what the gauge represented. On the other hand, when the gauge’s function had been explained the test participants perceived the information from the gauge relevant and useful when driving an EV.

The intent of the ecometer was fairly easy for the participants to understand. How to read the meter however, was not clear to everyone. There were some misinterpretations about what the different directions on the indicator meant.

When the battery level reaches below 15 percent the tell tale is fairly discrete. A chime would attract more attention. Further more the DTE gauge has a somewhat dense scale, which makes it hard to read. Especially when the level is low.

On a positive note the general structure of the IPC was appreciated and the DTE gauge was good, and in many of the test participants eyes more important than the SOC gauge. The sound confirmations on the popups were good at catching the users attention and the Auxiliary load gauge was relevant to the user once the function had been explained.
9. Discussion Phase I

The downside of using cognitive walkthrough and heuristic evaluation although being effective methods is that they ignore contextual factors that affect HMI in the real world [Gabrielli et al., 2005].

Using colleagues as participants in the test needs to be done with precaution. [Jordan, 1998]. They should not be involved in the project and should not have any previous knowledge of the system. Although the IPC was new, the heritage from the 9-3 IPC made some impact on the answers from the test persons. The effect from comparison with the old IPC is unclear, and this must be considered when studying the results.

The simulation almost covered a complete discharge of the battery, but took place in under 30 minutes, it only gave the test person about a minute to notice the amber battery symbol before it was regarded as them not seeing it. In real life it would be considered satisfactory if the symbol is noticed within about five minutes. On the other hand the test participants were asked specifically to focus on the IPC and observe changes.

The propulsion system active symbol on the other hand was active from the moment the ignition key was cranked until the test was over, yet some of the participants did not notice it at all. A separate test should be done to evaluate what kind of symbol should be used to indicate the propulsion system is active. Is an icon on the IPC the best solution or are there other kinds of notifications that surpasses it? If an icon is the most suitable, a survey should be done to investigate which icon best represents that the vehicle is active and ready to be driven.
Phase II - Redesign of IPC

10 Method
Information gathered in phase I was used to redesign the IPC to better support the wants and needs of the driver of an EV. As earlier stated the redesign had fewer limitations than the previous IPC since the new version does not have to use the gauges and displays that are already in the Saab 9-3. This enables a more purpose build solution.

10.1 Concept Generation
Initially all the different gauges and functions of the IPC were separated into individual units. These units were then redesigned separately to modify the areas in need of improvement. The reason for doing so was to make sure limitations such as previous size and placement of gauges where not a distraction in the design process. Concepts were generated using brainstorming with iteration. First a number of ideas where generated and visualized using hand sketches, Photoshop and After Effects [Adobe Systems Incorporation, After Effects]. The focus in the concept generation was to correct the problems that were discovered in phase I. Secondly, usability design principles such as the “13 principles of display design” [Wickens, 2004] were taken into account, not to cause new problems. When several concepts for each unit where ready, another round of brainstorming took place where ideas where transferred between the different concepts.

Alongside the development of the different units, general layouts for the entire cluster were designed. Some of the layouts using mostly analog gauges, and some consisting of big digital displays. The various units could then be placed in different combinations in these layouts to form complete solutions.

10.2 Concept Selection
As mentioned earlier, during the design phase some almost complete IPC solutions were made. When it was time for final selection of a concept, the general layout was chosen first, then the different gauge units were selected and put into that layout to form a complete IPC design. The final design was chosen using a Pugh matrix [Pugh method, www.enge.vt.edu], all the components were then tuned to fit together coherently in the chosen design.

10.3 Designing the Visuals
The graphics in the simulator IPC was completely remade since the layout was new. Key aspects in the design were that visual objects on the screen had to be designed with high contrast colors to stay visible even in sunny conditions. The key objects, such as battery indicators etcetera, had to be distinguishable from the rest of the graphics. The graphical objects were primarily made in Adobe Photoshop and then exported to Visual Studio to animate them according to the design.

10.4 Simulation Programming
As much programming code as possible was reused for the logic and communication with the simulator. The rest of the programming was custom made for the new graphical interface.
11 Execution and Results Phase II

When several ideas and designs of each part was complete these were put together to form IPC layouts. In Appendix IX, sketches of various solutions are presented.

11.1 Redesign of IPC Layout

Since there is some information not usually present in cars powered by a combustion engine, additional information is desired in the IPC of an electric vehicle. Showing all information at the same time, however, leads to a cluttered panel making it hard for the driver to distinguish important values form each other.

To choose a layout, four design proposals were weighed against each other in a Pugh matrix, Figure 11.1. The designs were compared by how well they matched the following four criteria that were put together as the most important in dialog with Saab: Saab Identity, personalization, feasibility of production, display size.

<table>
<thead>
<tr>
<th>Saab identity</th>
<th>Feasibility</th>
<th>Personalization</th>
<th>Display size</th>
</tr>
</thead>
<tbody>
<tr>
<td>- - (Not Saab)</td>
<td>✓</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>++</td>
<td>✓</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>+↑?</td>
<td>✓</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>-↑?</td>
<td>✓</td>
<td>++</td>
<td>++</td>
</tr>
</tbody>
</table>

*Figure 11.1. Pugh matrix used to evaluate the IPC layouts.*
The highest scoring design is shown in Figure 11.2. The design has an analog speedometer on the left and a seven inch display to the right which houses all the other instruments.

![Figure 11.2. A schematic layout of the new IPC.](image)

At the bottom of the display a cell, the general information area, contains informations from the radio, time, temperature, trip, odometer and turn signal indicators. These are information that is frequently used when driving. The area, also shows pop up messages after they have been activated.

Above the general information cell are five cells containing DTE, SOC, menu, ecometer and Electrical usage. The information is visible at all times, at the specific location, minimizing access cost. One of the areas is expanded, making it show more detailed information. Switching the expansion between different cells is done by pushing buttons on the steering wheel.

### 11.2 Redesign of DTE

There were no predominant issues with the DTE gauge discovered in the testing phase, apart from a few test participants who mistook it for a tachometer. The new design was made with effort to enhance the user experience. When the DTE is in its standard mode, the cars range is displayed with a vertical bar which is filled up with the corresponding height, see Figure 11.3. The range is also presented in text underneath the bar, adding redundancy and helping the driver in judging the absolute level. When the DTE cell is expanded additional information can be brought in from the GPS (Global Positioning System) unit to show “Distance to Home”. This way the driver knows if the car has enough charge to reach home. Other preferred destinations could also be set in the same way.
The distance to home is represented by the house above the horizontal bar that indicates DTE. If “home” is farther away than the cars range the house will change color from green to orange indicating that the car will not reach the goal without charging, Figure 11.4. The same principal is used if an other goal than “home” is selected in the GPS. The house symbol, however, will be replaced with a symbol representing the goal.

Figure 11.4. When the set goal is beyond the range of the car the symbol turns orange.
11.3 Redesign of SOC

The SOC gauge was easy to understand for all test participants. The traditional state of charge gauge was replaced with a large battery to emphasize the electric propulsion, but also to fit the new layout and add pictorial realism, Figure 11.5. The battery symbol, filled when charged and outlined when empty, is familiar to most people from other electrical devices such as cell phones and lap tops.

![Figure 11.5. The SOC cell in its standard view (left) and its expanded view (right) with examples of possible additional information.]

The battery has a green bar that decreases in height when the charge is lowered. This new design exhibits double redundancy since it in addition to displaying the battery level in height and text, also turns the bar orange when the state of charge drops below 15 percent. Possible additional information in the expanded view is battery health and temperature.

11.3.1 Sync between SOC and DTE

Some of the test participants pointed out that it felt strange that the SOC gauge and the DTE gauge did not turn orange, indicating a low level, at the same time. This was due to the fix scales on the analog gauges in response to the raised issue, the DTE and SOC are synched and both switch from green to orange when the SOC reaches below 15 percent.
11.4 Redesign of Ecometer

The ecometer is a representation of how energy efficient one is driving, with the aim to help the driver learn to save energy. It is not a representation of a physical quantity or how much electricity currently is leaving or entering the battery.

Since some of the participants in the test were a bit confused about the different needle positions on the ecometer the gauge now only displays different levels of green as seen in Figure 11.6.

![Eco Ecometer](image)

*Figure 11.6. The Eco cell in its standard view (left) and its expanded view (right).*

When the driver exhibits driving behavior which gives low energy consumption many of the green light will be lit. If the driver accelerates hard, drives very fast or displays other uneconomic driving behavior the lights switch off in coherence with the driving. The stack of green light shows the instantaneous level of economic driving. If the driver chooses to expand the ecometer cell, the gauge will also show a histogram of the drivers eco history. This is intended as a friendly reminder of earlier driving and a help to reflect on different driving styles.

11.5 Redesign of Auxiliary Load

The auxiliary load was the hardest gauge for the test participants to understand initially. The purpose of the gauge is to help the driver visualize how much electricity is wasted by electrical consumers, not part of the propulsion system. The test participants did not understand that the gauge indicated electrical consumption, nor which electrical consumers were active and therefore could be switched off to save electricity. It was also hard to read out what effect the electrical consumers have on the cars range.
To improve the comprehension of the gauge a number of changes and additions were made resulting in the gauge shown in Figure 11.7. The name of the gauge was changed to the layman’s term Electric Consumption. The quantity of electricity is shown with a unit. In the expanded mode the different consumers are displayed with a pictorial representation of the consumer, and next to this symbol the amount of electricity they are using. To clarify the active consumers effect on the cars range, the estimated range loss is displayed at the bottom of the bar.

**Figure 11.7.** The Auxiliary load cell in its standard view (left) and its expanded view (right).

### 11.6 Redesign of DIC

There were two main problems with the DIC. As the Pareto diagram shows in section 7.6.3, many of the test participants had trouble with the use of long press on the SET button to enter settings, making it the most predominant issue. An easy adjustment to avoid this was simply to remove this requirement and use normal press. As there is no hazard in navigating through the settings, no extra precautions (e.g. long press) is needed to enter them.

The second issue with the DIC was that the test participants had problems knowing where they were while navigating in the menu. To address the problem the display showing the menu was made larger to contain more text and graphical aids to help guide the user.

#### 11.6.1 Menu Hierarchy

Having the options for the preheaters under settings in the DIC, puts it rather deep in the menu structure. Settings can also be interpreted as “system settings” which preheaters are not a part of, hence making it harder to find. Under settings one finds options for rain sensor sensibility and choice of unit, generally things that are changed very rarely. Setting a timer for a preheater is something that during the winter season might be done on a daily basis.
As a result the electrical and fuel driven preheaters are now visible higher up in the hierarchy under the label *Comfort Preheater*, see Figure 11.8.

![Figure 11.8. The old (left) and the new (right) menu placement of the heaters in the hierarchy.](image)

11.6.2 Setting Timers on Preheaters
When setting timers for the preheaters in the old version, one started from present time and scrolled up to a preferred time. This was done every time a timer was to be set. In the new DIC one timer of the old kind is available under the name “Timer” and a new entry for “Set Presets” is added to allow the user to add persistent timers called “Presets”. These timers keep their value ones set, and can be activated using both the electric and the fuel driven heater.

11.6.3 Graphical display for DIC
The DIC is incorporated in the cell structure and is called menu. To make it easier to find the right way around in the menu, previous and next coming menu item are shown over and under the current one as a predictive aid. The previous and next items are colored in the same color as the bounding boxes to make them blend in with the background, and not to confuse them with current options, see Figure 11.9.

![Figure 11.9. Current selection of the menu written in white. The previous and next menu items in green to make them blend in with the background.](image)

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When navigating up and down, the respective arrows light up to confirm the press on the button with a visual feedback, Figure 11.10.

![Menu](image)

**Figure 11.10.** The up button has been pressed and the respective arrow lights up as a confirmation to the user.

### 11.6.4 Pop Up Messages

The pop up messages are no longer confined to the space of the DIC. Along with a chime sound the entire screen can be used to alert the driver. The popups appear in a box in the center of the screen, and the area around the box is faded, Figure 11.11. This reduces the information access cost to a minimum when looking for the important message.

![Attention](image)

**Figure 11.11.** The pop up message in the center of the display.
The box stays in this state for four seconds and is then animated down to the general information cell, Figure 11.12. If the driver presses the clear button during the four-second period while the pop up covers the screen, it will move down to the general information cell immediately.

![Figure 11.12. After four seconds the pop up message moves down to the general information cell in the lower left corner.](image)

### 11.7 Final Design

The final design has a large analog gauge on the left hand side, displaying the vehicle speed. The scale still measures to 160 kilometers per hour but it is only spread over an angle of 155 degrees as opposed to the old one which spread across 210 degrees, Figure 11.13. The are two reasons for not using the full spread. First it takes up less space, allowing the large display to fit comfortably next to it. The second reason is that the maximum speed of the EV is lower than an average combustion engine vehicle. Therefore if the scale had been spread across the full 210 degrees, the position of speeds such as 70 kilometers per hour would make the needle point straight up.

![Figure 11.13. Speed scale spreading over 155 degrees.](image)
Next to the analog gauge is a seven inch, full color display with a standard resolution of 600 by 800 pixels. The display houses all the other instruments, Figure 11.14.

The information is grouped according to its compatibility. The two leftmost cells contain energy status in the form of distance left and state of charge. The two rightmost cells contain current consumption. Possible locations for telltale not shown on the screen are above and on the right side of the screen, and some, including the propulsion system active symbol, in the speedometer. The propulsion system active symbol has doubled in size in order to grab the drivers attention.

11.7.1 The 13 principles of display design
All of the parts were designed with the display principles in mind. In some parts many of the principles were incorporated, in others only a few. Below is a some examples of in which parts the principles were used.

1 The legibility of the display is obtained by its position right in front of the driver and uses previously tested fonts and font sizes.

2 Absolute judgement limits are avoided since only a few colors are used and the contrast between them are high. For example the State of charge indicator changes from green to orange when the level is low.

3 The colors also uses top-down processing since all “good” states of the gauges are green, and when levels are low, the gauges are orange, a convention used in most situations. The only exception is the ecometer which is always the color green. This because while inefficient driving shortens the range of the car, it is not a critical state that needs to be reported to the driver.

4 The state of charge indicator has redundancy since it has a bar that shows the charge level in high accompanied by text which displays the level in percentage. It can also be said to have dual redundancy because the bar changes color from green to orange when the level drops below fifteen percent. The DTE gauge has the same redundancy as the SOC; bar, text and color change.
5 The *discriminability* of the different gauges came to focus since four of them are bars that display a value by changing height. From the first draft when the bars essentially looked the same, adjustments were made to make it easier to distinguish them from each other. The changes can be viewed in Figure 11.15.

![First Draft and Final Design](image)

**Figure 11.15.** The first gauge concepts (left) and the redesigned gauges for better discriminability (right).

6. To ensure *pictorial realism*, high and low levels should be shown on a vertical scale. Horizontal scales should primarily be reserved for lengths and distances if no other reason indicates otherwise. The DTE is by necessity vertical in its standard state, but horizontal in its expanded state. The SOC gauge is also horizontal in its expanded view, but since it is in the form of a battery it is not mistaken for a length or distance.

7. The *Principle for Moving parts* on the IPC is that it increases in area or number when the wanted effect increases. The ecometer for example should show more dots when the driver uses a eco friendly driving style.

8. To *minimize information access cost*, the display area always shows the most frequently used information at all time in five cells. The driver then has the option to expand one of these cells and show more about the information in that particular cell. The small cell of the state of charge for example, displays a battery symbol which is filled up with the corresponding amount, and the charge level stated in percentage. When the cell is enlarged more detailed information about the battery, such as battery temperature and health, is displayed. If all the information from all the cells in their large state would be presented at the same time, there could be a case of information overload, making it harder for the driver to find desired information.

9. To make it easier for the user to build a mental model, items that derive from a common source or have the same purpose are preferably displayed closer together. This is called *the proximity compatibility principle* and is implemented in the IPC as the electrical usage gauge and the ecometer representing current consumption is on the right side of the display. On the left side of the screen information about how much energy/distance is left is shown in the DTE and SOC cells.
10. When the driver needs to be notified about the status of the vehicle the principal of *multiple resources* is used, meaning a visual as well as an auditory notification is used to grab the driver's attention. This is used in the popups where a box with text and symbol, accompanied by a chime, appears on top of the normal interface.

11. The battery symbol indicating the state of charge uses the notion of *replacing memory with visual information*. By showing something that resembles what is happening, in this case draining the battery, the information is easier for the user to decode.

12. The menu structure in the car uses something called *predictive aiding*. When the user is browsing through the menu the previous and next alternative is displayed to show the user about the possible future.

13. According to the *principal of consistency*, commonly known elements or symbols should be used for information that they are usually known to indicate. For instance the battery symbol is used to indicate the state of charge.

### 11.8 Programming the New IPC for the Driving Simulator

When the functionality and the layout of the new IPC was determined the process of programming it to run in a Windows environment began. As many objects as possible where created using programming, to be able to modify them dynamically during program runtime. These where primarily bounding boxes and text strings for the menu and the different cells of the cluster, Figure 11.16. The methods for communication between the car and the IPC program could be reused from the old version of the IPC with slight modification.

![Figure 11.16](image.png)  
*Figure 11.16. Many object were drawn using programming rather than image editing.*
11.8.1 Changes to Navigation Buttons in Simulator

The original IPC used four buttons to navigate the menus: up, down, set and clear. These were located on the steering wheel and maneuvered with the driver’s right hand. The new IPC required two additional buttons: right and left. The right and left buttons are used for switching which cell is expanded. The new buttons are placed next to the existing ones to form a directional pad. The configuration of the old and the new set up of buttons are presented below in Figure 11.17.

![Figure 11.17. Old (left) and new (right) schematic layout of navigation buttons on steering wheel.](image)

This configuration is commonly known from game controls and remote controls for television and DVD players [D-pad, en.wikipedia.org].
12 Conclusion Phase II
The new IPC design has been completely redesigned apart from speedometer that only has a few changes. The rest of the gauges are now shown on a large color display. The display enables more dynamic gauges with more versatility.

The display allows for more information to be displayed simultaneously, but also allows for a higher degree of customization, allowing the user to choose which information to display. This results in a more detailed IPC without overloading the driver with information.

The distance to empty gauge’s functionality has been increased with GPS connectivity, allowing it show points of interest such as “home”.

The ecometer is simpler in its design but displays the intended message to drive gentle more effectively.

The sources of electric consumption can be distinguished to help the driver decide if its worth turning off functionality to get a longer range.

Pop up messages can remain visible while the driver continues to use the menu.

These changes leads to improvements of the IPC regarding an electric vehicle, but much of the modifications could be used in fuel driven car as well.
The choice of having the speedometer as an analog gauge was done partly to preserve a bit of the Saab feeling in the IPC. Saab vehicles have a large speedometer dominating the IPC, as supposed to other brands who usually have a speedometer and a tachometer which are the same size. The speedometer, being the only analog gauge now still makes it stand out in Saab fashion. It was also done with production cost in mind. If the speedometer had been presented on the digital display, the display would have had to be very wide. A wide display with unusual measurements has to be custom made, something which raises costs significantly. A digital display housing the gauges, without the speedometer, could be a standard resolution seven inch display, 600 pixels high by 800 pixels wide in the standard aspect ratio 4/3. This is a common type of display on the market and should be fairly low cost. The only factor that may raise the price a bit is that the contrast and brightness of the screen has to be high for the screen to be visible in bright ambient conditions.

If one should draw conclusions from the second test and the input from co-workers, a few things can be noticed. First of all the clarity of the information on some of the gauges has been improved, but the layout is less familiar to the user. The fact that the new IPC is less familiar requires it to have a lower threshold for new users or have a wow factor which engages and invites the user to use and explore the new design and features.

Doing a heuristic evaluation on an interface that one self has designed is hard because of difficulties to stay objective and see faults. The user testing would be easier to conduct, but the test participants might be intimidated to criticize if they know that the test leaders are the designers of the system. Since the designer knows exactly how to use the system it is difficult to evaluate the user friendliness. Therefore many of the evaluation methods would best be done by someone else.

The vocabulary in the IPC should be positive for all the functions that are not dangerous. The driver must not be discouraged to use a function or do a maneuver because of its label or description. The new functionality for electrical usage makes an estimation of how much range is lost by the use of electrical equipment like seat heater and defroster. This is labeled "Estimated range loss", but it might be better to refer to how much range one could gain. Since orange is used to indicate low levels in the SOC and DTE using another color on the electrical usage bar might be more appropriate.

The additional information in the expanded view of the cells can be adjusted to conform with customer wishes. Since the average user might not know at what temperature a battery performs best the labeling could be good, warm or cold instead of a temperature in numeric values. There is also the possibility to let the user customize the view of the expanded cells according to their own preference.

No full scale test, like the one made with the first IPC was made with the new panel. One person did the simulation test, and several people involved with the interior HMI of Saab ZE tested the IPC. This means that no conclusions can be made from the result.
14 Overall Discussion

The methods used were chosen because heuristic evaluation is a quick and low cost way of finding the most problematic areas. The HTA and CW were then used to narrow down to exactly which task or process the reason for the issue. These issues then served as a base for the user testing. The choice to perform user testing with the think aloud method was to gather as much information from each test participant with as little influence as possible.

Before the simulator test the software was programmed to register each button press and time the test participants performing certain tasks or responding to signals. This data was collected during the test, but not used in the evaluation due to lack of relevance. The part of the test that is in the simulator was completed in roughly 30 minutes which means many processes in the car were accelerated. The time it took for the participants to react to a certain event would not give any reliable data in itself. It does not matter if it takes ten or thirty seconds for the user to see the symbol, making the fact if they saw it or not the interesting data.

At the user testing, all the participants had previous experience with the interface and IPC layout of the Saab 9-3. If this gave a familiar feeling, it can have affected the test results of the original ZE IPC. The effect would be a slightly higher score in the area of user friendliness compared to if the users had never set foot in a Saab before. The users already had the knowledge in their head to perform the tasks, that they in a new IPC needs to obtain from the surrounding world. [Wickens 2004]

Since no proper testing has been done with the new design, the first step for future work would be to perform the same or similar test with the new design as the original ZE IPC. The result from the two tests could then be compared to draw conclusions about the changes.

As a part of a larger evaluation of the produced Saab ePower, the IPC will undergo more evaluation in a PhD thesis. The thesis will focus on driver behavior, but the IPC will play its part as a possible improvement.
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Visibility of system status: The system should always keep users informed about what is going on, through appropriate response within reasonable time.

- When the key goes from RUN to OFF the Tell Tale for “vehicle ready” should disappear. It does not go away until the key is turned to the “LOCK” position.
- The indicator for low battery level is too discrete. Maybe it should be accompanied by an audio signal and text in the DIC e.g. “Low Battery Level”.
- Maybe the DIC should display “System Ready” or “Ready to Drive” after the systems check.
- It is a bit hard to see how many km left on the DTE when it’s close to zero. It’s the same all the way around, but it might be good to have a larger scale when the SOC is nearing empty.
- The time of the popup messages displaying errors are a bit too short.
- Maybe there should be a symbol for the car NOT being ready to drive, rather than the other way around. The cars main purpose is to be driven, meaning that an equivalent light should be active when the car is not ready to be driven.

Match between system and the real world: The system should speak the user's language, with words, phrases and concepts familiar to the user, rather than system oriented terms. Follow real-world conventions, making information appear in a natural and logical order.

- When the user sets a timer on the heater, after pressing set to confirm the time, the DIC displays “START 08.45” to show when the heater will start. This, however, could be perceived as a question “Do you want to start the Heater 8.45?”. Pressing SET at this time will make the DIC show the option to turn the heater off. A better phrasing would be “STARTING 08.45”. This will be perceived as a statement rather than a question, avoiding the confusion.
- The Auxiliary Load gauge is too vague. Scale looks backwards, the indicator goes up but the scale decreases. The meaning of the “A” may not be clear to everyone.
- kWh should be changed to a comprehendible unit. Perhaps % of battery (%Battery/km).
- “INST BATT Ø” should be clarified/spelled out. Instantaneously battery average is confusing. Should be named something like “consumption”.

User control and freedom: Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.

- “CLR” always works to leave settings without changing anything (good).

Consistency and standards: Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.

- The long press to access “SETTINGS” is inconsistent to the rest of the menu.
- After pressing SET when choosing a speed in ”Speed Average” the DIC then displays ”Distance” (the option after ”Speed Average” in the menu). When pressing SET int the other options, the DIC stays at that setting displays the option set by the user.
• The menu structure is inconsistent. When “SETTINGS” is chosen the “>” symbols show that you’re in a deeper level in the structure, but in the next level (e.g., “COMFORT HEATER”) no additional info shows that you are in an even deeper level. Deeper level no longer exists.

• All settings options should be put together under “SETTINGS”. Alternatively they should all be under its respectively function. Only reset options outside “SETTINGS”.

• The language should not be mixed Swedish/English.

• You should be thrown out from the settings menu if not active for a long period of time.

• DTE should be spelled out in the gauge.

**Error Prevention:** Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.

• A warning should be shown when DTE is low

**Flexibility and efficiency of use:** Accelerators -- unseen by the novice user -- may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.

• Limited area to contain text automatically calls for short messages.

• There is double battery symbols on the panel when SOC is low. They could be combined but it adds redundancy if not.

• It should be displayed somewhere in the Auxiliary load gauge which electric consumers are active.

• Ecometer does not react enough to give sufficient response to driver on his or her way of driving. It should react stronger to fast acceleration and hard brakes.

• When the user tries to turn “Allow fuel heater?” to “no”, when it is active, a message appears. The user should be asked to turn the heater off in the very same dialog.
Things to be changed before simulation.

- Spelling errors.
- Remove functions which will not be available in the real car.
- Change the text and symbols on the buttons on the steering wheel to match their function.
- No settings can be made with the left lever. Conceal buttons.
- Audio signals should accompany the visual!
- DTE meter and SOC are not fully visible because the screen is covered. Resize content if possible.
- When the key goes from RUN to OFF the Tell Tale for “vehicle ready” should disappear. It does not go away until the key is turned to the “LOCK” position.
- When the user sets a timer on the heater, after pressing set to confirm the time, the DIC displays “START 08.45” to show when the heater will start. Change to “STARTING 08.45”.
- Set correct time on error popups.
- Remove set functionality on “SPEED AVG”.
- Calibrate ecometer.
- Amber battery symbol should be lit at SOC 15%.
- ”CHARGE NOW” is to be displayed when DTE is at 15 km.
- Calibrate the maximum value of DTE.
- Correct the menu hierarchy.
- When charging: DIC displays “Laddat 10% 5,7 tim kvar” Will not fit, change “tim” to “h!”
- The popup messages that appears when switching between 10 A and 16 A should be 10 seconds long.
Appendix II - Hierarchical Task Analysis

Start the Car and Drive Off

Start Car

Insert Key

Drive Car

Crank Key

Release Key

Check "El. motor ready"

Select Gear

Drive

Allow Fuel Heater

Enter Setting

Select Allow Fuel Heater

Select Yes or No

Exit Menu

Press CLR twice

Navigate to el. or Fuel Heater

Press SET

Navigate to Yes/No

Press SET

Press and Hold SET

Navigate to Setting
Enter Setting

1.1

Navigate to Setting

1.2

Press and Hold SET

Navigate to el. or Fuel Heater

1

2

Choose Heater

Operate Heater

Press and Hold SET

2.1

Press SET

2.2

3

Set Timer

Choose Timer (A, B or C)

3.1

Select Time

3.2

Press SET

3.3

Exit Menu

Press CLR twice

4.1

Choose Timer

Navigate to el. or Fuel Heater

Press and Hold SET

Press SET

Press CLR twice

Exit Menu
Appendix III - Cognitive Walkthrough
The same questions (1-4) are asked for all the subtask. If the answer to the question is Y (yes) the row is left blank.

<table>
<thead>
<tr>
<th>Operating Heater</th>
<th>Sub task: Enter Settings (1)</th>
<th>Y/N</th>
<th>Fail/Success story</th>
<th>Usability Problem</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Y/N</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Will the user try to achieve the right effect?</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Will the user notice the correct action is available?</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Will the user associate the correct action with the effect that the user is trying to achieve</td>
<td>N</td>
<td>Eventually after browsing through the menu (but the long press might still be tricky).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. If the correct action is performed, will the user see that progress is being made toward solution of the task?</td>
<td>Y</td>
<td></td>
<td></td>
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</tbody>
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<thead>
<tr>
<th>Sub task: Navigate to Settings (1.1)</th>
<th>Y/N</th>
<th>Fail/Success story</th>
<th>Usability Problem</th>
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</thead>
<tbody>
<tr>
<td>1.</td>
<td>Y</td>
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<tr>
<td>2.</td>
<td>Y</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>3.</td>
<td>Y</td>
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<tr>
<td>4.</td>
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<tr>
<th>Sub task: Long Press Set (1.2)</th>
<th>Y/N</th>
<th>Fail/Success story</th>
<th>Usability Problem</th>
<th>Notes</th>
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<tbody>
<tr>
<td>1.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Will the user notice the correct action is available?</td>
<td>N</td>
<td>Short press will be tried, long press may need to be learned.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Y</td>
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<table>
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<tr>
<th>Sub task: Choose Heater (2)</th>
<th>Y/N</th>
<th>Fail/Success story</th>
<th>Usability Problem</th>
<th>Notes</th>
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<tbody>
<tr>
<td>1.</td>
<td>Y</td>
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<td></td>
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</tr>
<tr>
<td>2.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Will the user associate the correct action with the effect that the user is trying to achieve</td>
<td>Y</td>
<td>May try to use long press to select the heater</td>
<td></td>
<td></td>
</tr>
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<td>4.</td>
<td>Y</td>
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<table>
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<tr>
<th>Sub task: Navigate to Fuel Heater (2.1)</th>
<th>Y/N</th>
<th>Fail/Success story</th>
<th>Usability Problem</th>
<th>Notes</th>
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<tbody>
<tr>
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<td>2.</td>
<td>Y</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>3.</td>
<td>Y</td>
<td></td>
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</tr>
<tr>
<td>4.</td>
<td>Y</td>
<td></td>
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</tr>
<tr>
<td>Sub task: Press Set (2.2)</td>
<td>Y/N Fail/Success story</td>
<td>Usability Problem</td>
<td>Notes</td>
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<tr>
<td>-------------------------</td>
<td>-----------------------</td>
<td>------------------</td>
<td>-------</td>
<td></td>
</tr>
<tr>
<td>1. Y</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Will the user associate the correct action with the effect that the user is trying to achieve</td>
<td>Y</td>
<td>May try to use long press to select the heater</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Y</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Sub task: Set Timer (3)</th>
<th>Y/N Fail/Success story</th>
<th>Usability Problem</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Will the user notice the correct action is available?</td>
<td>Y</td>
<td>Probably by scrolling down</td>
<td></td>
</tr>
<tr>
<td>3. Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Y</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sub task: Choose Timer (3.1)</th>
<th>Y/N Fail/Success story</th>
<th>Usability Problem</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Will the user notice the correct action is available?</td>
<td>Y</td>
<td>Probably by scrolling down</td>
<td></td>
</tr>
<tr>
<td>3. Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Y</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sub task: Press Set (3.2)</th>
<th>Y/N Fail/Success story</th>
<th>Usability Problem</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Y</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sub task: Select Time (3.3)</th>
<th>Y/N Fail/Success story</th>
<th>Usability Problem</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Will the user associate the correct action with the effect that the user is trying to achieve</td>
<td>Y</td>
<td>Could be done with a numeric keyboard</td>
<td></td>
</tr>
<tr>
<td>4. Y</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sub task: Press Set (3.4)</th>
<th>Y/N Fail/Success story</th>
<th>Usability Problem</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. If the correct action is performed, will the user see that progress is being made toward solution of the task?</td>
<td>Y</td>
<td>Popup clarifies that the heater is on timer.</td>
<td></td>
</tr>
</tbody>
</table>
### Exit Menu (4)

<table>
<thead>
<tr>
<th>Sub task</th>
<th>Y/N</th>
<th>Fail/Success story</th>
<th>Usability Problem</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Will the user try to achieve the right effect?</td>
<td>N</td>
<td></td>
<td></td>
<td>It's not necessary to exit the menu, it will jump back to the “temp” position after 30 seconds. If the user wants to exit the menus though, it's not a problem.</td>
</tr>
<tr>
<td>2.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Will the user associate the correct action with the effect that the user is trying to achieve</td>
<td>Y</td>
<td></td>
<td>Back might be better than clr, but that will require an extra button.</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Press "Clr" (4.1)

<table>
<thead>
<tr>
<th>Sub task</th>
<th>Y/N</th>
<th>Fail/Success story</th>
<th>Usability Problem</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Will the user associate the correct action with the effect that the user is trying to achieve</td>
<td>Y</td>
<td></td>
<td>Button should be named Back for best usability.</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Press "Clr" (4.2)

<table>
<thead>
<tr>
<th>Sub task</th>
<th>Y/N</th>
<th>Fail/Success story</th>
<th>Usability Problem</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Will the user associate the correct action with the effect that the user is trying to achieve</td>
<td>N</td>
<td></td>
<td></td>
<td>Pressing Clear to reach the top of the list might not be what first comes in mind for everybody, however, since there is a &quot;clr&quot; click before this one, the user might just continue pressing int until he reaches the First page (without really looking on where in the menu he is).</td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Driving

#### Sub task: Start Car (1)

<table>
<thead>
<tr>
<th></th>
<th>Y/N</th>
<th>Fail/Success story</th>
<th>Usability Problem</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Y</td>
<td>Start key is at conventional place (for a Saab)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>N</td>
<td>User dose not notice that the “Ready Telltale appears after “ignition”</td>
<td>No engine sound. User might not see the Ready symbol.</td>
<td></td>
</tr>
</tbody>
</table>

#### Sub task: Insert Key (1.1)

<table>
<thead>
<tr>
<th></th>
<th>Y/N</th>
<th>Fail/Success story</th>
<th>Usability Problem</th>
<th>Notes</th>
</tr>
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<tbody>
<tr>
<td>1.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Y</td>
<td>The key will fit in the lock.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Sub task: Crank Key (1.2)

<table>
<thead>
<tr>
<th></th>
<th>Y/N</th>
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<th>Usability Problem</th>
<th>Notes</th>
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<tbody>
<tr>
<td>1.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>N</td>
<td>First time user does not notice the symbol/does not understand what it means.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Sub task: Check “Ready” symbol (1.3)

<table>
<thead>
<tr>
<th></th>
<th>Y/N</th>
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<th>Notes</th>
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<tbody>
<tr>
<td>1.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Y</td>
<td>User not accustomed to EVs does not know to look for ready telltale.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>N</td>
<td></td>
<td></td>
<td>Maybe not first time users, but once you know, there is no problem location the telltale</td>
</tr>
<tr>
<td>4.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
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</table>
### Sub task: Drive Car (2)

<table>
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<tr>
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<th>Fail/Success story</th>
<th>Usability Problem</th>
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<tbody>
<tr>
<td>1.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
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</table>

### Sub task: Select Gear (2.1)

<table>
<thead>
<tr>
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<th>Fail/Success story</th>
<th>Usability Problem</th>
<th>Notes</th>
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</thead>
<tbody>
<tr>
<td>1.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Y</td>
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### Sub task: Press Down Throttle (2.2)

<table>
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<tr>
<th></th>
<th>Y/N</th>
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<tbody>
<tr>
<td>1.</td>
<td>Y</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>2.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Y</td>
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</table>

### Allow Fuel Heater

### Sub task: Enter Settings (1)

<table>
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<th></th>
<th>Y/N</th>
<th>Fail/Success story</th>
<th>Usability Problem</th>
<th>Notes</th>
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</thead>
<tbody>
<tr>
<td>1.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>N</td>
<td>Eventually after browsing through the menu (but the long press might still be tricky).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

### Sub task: Navigate to Settings (1.1)

<table>
<thead>
<tr>
<th></th>
<th>Y/N</th>
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<th>Usability Problem</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sub task: Long Press Set (1.2)</td>
<td>Y/N</td>
<td>Fail/Success story</td>
<td>Usability Problem</td>
<td>Notes</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-----</td>
<td>-------------------</td>
<td>-------------------</td>
<td>-------</td>
</tr>
<tr>
<td>1.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Will the user notice the correct action is available?</td>
<td>N</td>
<td>Short press will be tried, long press may need to be learned.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Y</td>
<td></td>
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<table>
<thead>
<tr>
<th>Sub task: Select “Allow Fuel Heater” (2)</th>
<th>Y/N</th>
<th>Fail/Success story</th>
<th>Usability Problem</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sub task: Navigate to “Allow Fuel Heater” (2.1)</th>
<th>Y/N</th>
<th>Fail/Success story</th>
<th>Usability Problem</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Y</td>
<td></td>
<td></td>
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<tr>
<td>3. Will the user associate the correct action with the effect that the user is trying to achieve</td>
<td>Y</td>
<td></td>
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<td>4.</td>
<td>Y</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Sub task: Press SET (2.2)</th>
<th>Y/N</th>
<th>Fail/Success story</th>
<th>Usability Problem</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Y</td>
<td></td>
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<tr>
<td>2.</td>
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<td>Y</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Sub task: Choose &quot;Yes&quot; or &quot;No&quot; (3)</th>
<th>Y/N</th>
<th>Fail/Success story</th>
<th>Usability Problem</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Y</td>
<td></td>
<td></td>
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<td>2.</td>
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<td>4.</td>
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<table>
<thead>
<tr>
<th>Sub task: Navigate to &quot;Yes&quot; or &quot;No&quot; (3.1)</th>
<th>Y/N</th>
<th>Fail/Success story</th>
<th>Usability Problem</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Y</td>
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<td>2.</td>
<td>Y</td>
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<td>3.</td>
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<td>4.</td>
<td>Y</td>
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</tr>
</tbody>
</table>
### Sub task: Confirm by Pressing SET (3.2)

<table>
<thead>
<tr>
<th></th>
<th>Y/N</th>
<th>Fail/Success story</th>
<th>Usability Problem</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Will the user try to achieve the right effect?</td>
<td>N</td>
<td>User think he is done when he has browsed to “No” and does not confirm with pressing “SET”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Y</td>
<td></td>
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<td>4.</td>
<td>Y</td>
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</tbody>
</table>

### Sub task: Exit Menu (4)

<table>
<thead>
<tr>
<th></th>
<th>Y/N</th>
<th>Fail/Success story</th>
<th>Usability Problem</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Will the user try to achieve the right effect?</td>
<td>N</td>
<td></td>
<td>It's not necessary to exit the menu, it will jump back to the “temp” position after 30 seconds. If the user wants to exit the menus though, it's not a problem</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Will the user associate the correct action with the effect that the user is trying to achieve</td>
<td>Y</td>
<td>Back might be better than clr, but that will require an extra button.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

### Sub task: Press "Clr" (4.1)

<table>
<thead>
<tr>
<th></th>
<th>Y/N</th>
<th>Fail/Success story</th>
<th>Usability Problem</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Y</td>
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<td></td>
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<tr>
<td>2.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Will the user associate the correct action with the effect that the user is trying to achieve</td>
<td>Y</td>
<td>Button should be named Back for best usability.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Y</td>
<td></td>
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</table>

### Sub task: Press "Clr" (4.2)

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<thead>
<tr>
<th></th>
<th>Y/N</th>
<th>Fail/Success story</th>
<th>Usability Problem</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Y</td>
<td></td>
<td></td>
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<tr>
<td>2.</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Will the user associate the correct action with the effect that the user is trying to achieve</td>
<td>N</td>
<td>Pressing Clr to reach the top of the list might not be what first comes in mind for everybody.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Y</td>
<td></td>
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</tbody>
</table>
Appendix IV - Ishikawa Diagrams

**Cause**

- Labeling
- Scale
- Thinner when rising

**Effect**

- Difficulties understanding the auxiliary load gauge

**Cause**

- Human
- Knowledge
- No units

**Effect**

- Hard to comprehend that braking is inefficient

- Braking is considered a good behavior
- Opposite side from consuming acceleration on the gauge
- No positive braking zone
- Labeling
- Design
Hard to notice when the propulsion system is ready for take off

Experience
Anticipation
Size
Sound
Brightness
Contrast
Color
Low distinction
Design
Placement

Human

Effect

Hard to know if/when long press is to be used

Experience
Human

Cause

No guidance
Not distinguishable
Inconsistency
Design

Effect
Appendix V - Test procedure and protocol

At some of the tasks there are probing questions or hints. The test leader waits 30 seconds before using probing step one. If the test participant is still in need of assistance the second probing/hint can be used after an additional 30 seconds, and the third step 30 seconds after that.

Welcome and inform the test person

- The test person arrives and is escorted to the room
  - Welcome!
  - We will start off with a few questions and then you will drive the simulator. Finally we have some closing questions back in this room.

- Test person arrives and is escorted to the room
  - Welcome the test person
  - Introduce all involved staff
  - Give test person the welcoming document
  - Consent form signed by test person.
  - Tell the test person to speak freely about the system.
  - The system is confidential and should not by spoken of.
  - Questionnaire before the test.
  - Questions before the test.

Preparations before the test person arrives

- Forms printed and marked with the correct ID-number
- Notify the reception desk about the test persons arrival
- iNet Time cleared
- Projectors on
- ayeDrive started
- Computers started
- Projector computers started
- IPC started
- Center console started
- Matlab started
- Tolnet started
- DTLFunction.mdl started
- VNC connected till IPC-computer
- “Allow fuel heater” is “ON”!
- SOC on level 35%
- In vehicle speakers: on
- Room clean/ready
- Servo steering on
- Car start tested
Walk to the simulator.
Test person enters the car.

- Lights out in the room.
- “Are you comfortable in the seat?” (adjust the seat)
- Lights on in the car
- “The gauges are shown on a screen but symbolizes analog gauges”
- “The maneuvering of the car is similar to a regular car.”
- “90°-curves and hard braking can cause nausea”.
- “If you feel uncomfortable, take a break and close your eyes.”
- “The energy level will drop faster than normal to speed up the test”
- “Speak aloud about everything you thing and see.
- “We are interested about the inside of the car.”

Whats your first impression of the instrument panel cluster?

How do you interpreter the meaning of these gauges? (point to them)

- **DTE:**
- **Speedometer:**
- **A:**
- **Ecometer:**
- **Battery:**

- “DTE. means Distance to Empty.”
  (how far you can drive on current battery)
- “A means auxiliary load and shows electricity consumption.”
- “Ecometer show if you are driving energy inefficient.”
- “SOC means state of charge of the battery.”
“I would like you to put the fuel driven heater on a timer now.”
If help is needed: 1. Use the steering wheel buttons. 2. Inside the settings. 3. (extensive help)

Probing: How do you interpret the message?

“I would like you to turn off the possibility to use the fuel driven heater completely.”
If help is needed: 1. Use the steering wheel buttons. 2. Inside the settings. 3. (extensive help)

Probing: How do you interpret the message?

“You may now start the car (Do not forget to think out loud)” (Ready-symbol shows)

The test person get to drive a while without a specific task, other than thinking out loud.

SOC reaches below 20% (close to orange). (managed from the control room)

Reaction on the low battery level?  □ Yes  □ No
“Now I want you to brake hard and accelerate hard a few times”

Probing: What are your reflections on the ecometer?

SOC reaches below 15% (Low battery indicator is shown)  
(managed from the control room)

Test person reacts on telltale  
☐ Yes ☐ No

“Air conditioning, heated seats and defroster are also electrical. Try turning them on and off”.

DTE reaches below 15km (Charge car now) (managed from the control room)

Test person reacts on the message  
☐ Yes ☐ No

Probing: How do you interpret the message?

☐  Error message on reduced power (turtle).  
Test person reacts on the message  
☐ Yes ☐ No

Probing: How do you interpret the message?

☐  Error message on reduced power (turtle).  
Test person reacts on the message  
☐ Yes ☐ No

Probing: How do you interpret the message?

☐  End session.
Go back to the room.

☐ Final questionnaire
☐ “Now we will gladly answer any questions”

“Thank you. You have been very helpful, and contributed to a better system in the future”

☐ Follow the test person to the reception.
☐ Make sure all papers are marked with the correct ID-number
Appendix VI - Questionnaire Before the Simulation

Inledande frågor

Kön: ☐ Kvinna ☐ Man

Ålder: _____ år.

Du fick körkort år ____.

Bilmodell du kör till vardags: _______________________________ årsmodell________.

Har du kört en Saab 9-3 förut? ☐ Ja ☐ Nej
   • Om ja: Hur bekant är du med dess instrumentpanel?

1 2 3 4 5 6 7
   Inte alls hemma Som hemma

Har du kört en el- eller elhybridbil förut? (Du får kryssa flera rutor)
☐ Nej

☐ Elbil
   → ☐ Provkört ☐ lånat en längre tid ☐ Äger / har ägt

☐ Hybridbil
   → ☐ Provkört ☐ lånat en längre tid ☐ Äger / har ägt

Jag skulle väldigt gärna köra en elbil istället för den bil jag kör nu

1 2 3 4 5 6 7
   Håller inte med Håller absolut med
1. Vilken information tycker du är viktigast att den är lätt tillgänglig under körning?

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<thead>
<tr>
<th>1</th>
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2. Jag brukar tycka att instrument och information i bilar är lätt att förstå

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3. Jag brukar tycka det är lätt att navigera i menyer i bilen

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Vilken information tycker du är viktigast att den är lätt tillgänglig under körning?

4. Jag vill att det ska synas tydligt på utformningen av olika instrument och inredning att det är en elbil jag kör

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5. Jag vill helst att instrumentpanelen i en elbil ska vara så lik den i en vanlig bil som möjligt

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Appendix VII - After test

Jag gillar upplägget på instrumentpanelen.

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Jag tycker att menyerna är irriterande att använda.

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Det var lätt att hitta bland menyernas olika funktioner.

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Det var tydligt hur val och inställningar skulle utföras.

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A-mätarens innebörd var tydlig.

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</table>

Informationen från A-mätaren känns relevant när jag kör en elbil.

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</table>
Ecomätarens innebörd var tydlig.

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<tr>
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Jag skulle använda mig av ecomätaren i en elbil för att köra mer energisnält.

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D.T.E-mätarens innebörd var tydlig.

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Jag tyckte om menyknapparnas placering

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Jag tyckte om displayens placering

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</table>
Vad fick du för intryck av instrumentpanelen?

Saknades något instrument eller information?

Var det något instrument eller information du tyckte var överflödig?

Hann du läsa de meddelanden du såg i färddatorn?  ☐ Ja  ☐ Nej

Hur tolkade du funktionen av ”ecomätaren”?
Såg du denna symbol? Vad skulle du göra om den kom upp på instrumentpanelen?

Såg du denna symbol? Hur tolkar du den?

Såg du denna symbol? Hur tolkar du den?

Vilken av dessa symboler tycker du bäst visar att bilen är körklar?

☐  ☐  ☐
### Usability
- How does one know what can be done / turned off to extend range?
- Navigation buttons are hard to use.
- When is long press supposed to be used?
- Meaning of A?
- What does reduced power mean, practically?
- Menu structure hard to follow.
- Discrepancy between menu choices is vague (e.g. allow fuel heater and fuel heater).

### Design
- Scale on A is upside down and/or wrong colour.
- Ecometer is intuitive.
- Can one trust the DTE? How accurate is it?
- Symbols are vague without text.
- Impression of regeneration when braking hard.
- You should be able to avoid orange when cruising within speed limit.
- Vague if choices need to be confirmed or not.
- SOC and DTE should hit orange simultaneously.

### Attention
- Sound confirmation with messages are good.
- Late warning of low battery (10km).
- Discrepancy between menu and pop-ups.
- Vague indicator of propulsion system ready.

### Readability
- Messages regarding electricity are not clear.
- Low SOC-symbol should pop out more.
- A can be shown numerically.
- Pop-ups disappear to fast.
- Pop-ups could be cleared by user.
- Show DTE in numeric display.

### Placement
- Can some menu items be placed in the center stack?
- System electrical load on separate scale.
- Combine A - DTE.
- Combine SOC and DTE.
- DTE can be shown when needed, only.

**Meaning of A?**
Appendix IX - Concept Sketches

Concepts of the Ecometer gauge

Mek. broms
Motor-broms
Acc. & höög hast.

SOC A DTE
SOC A DTE

Battery

Eco
Concepts of the Electrical usage gauge