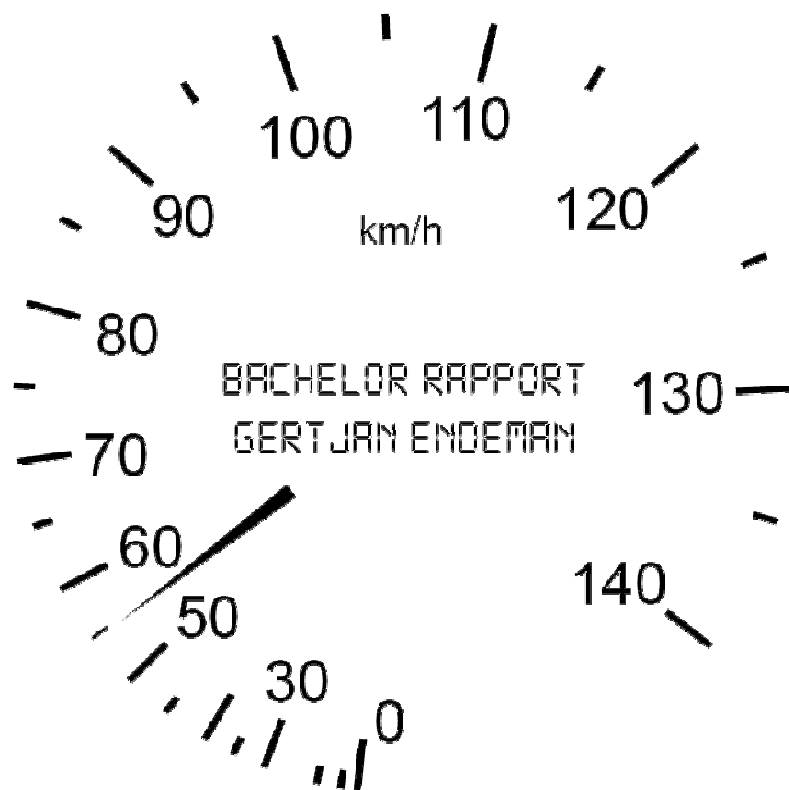


**The design of a user-interface for the powertrain of a car in the future
... in order to improve the acceptance of this powertrain.**



Rapport title:

**The design of a user-interface for the powertrain of a car in the future,
....in order to improve the acceptance of this powertrain.**

This rapport concerns the Bachelorassignment of Gertjan Endeman.

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Published: April 27th, 2007

Number of pages: 55
Supplements: 6
Number of copies: 4

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Abstract

Future powertrain

In the project "Car of the Future", two powertrain alternatives are developed. One is based on hydrogen powered fuel cells. This powertrain probably acts different compared to the powertrains of cars nowadays. Therefore, a user-interface has to be developed for this new powertrain, in order to let the driver understand and accept it.

In the new powertrain, the fuel cells produce electricity. Hydrogen is needed for this process. The electricity is used to power electro motors, which drive the wheels. These electro motors can also be used the other way around. When the motors are moved by something else, they generate electricity. This is called regenerative braking. Ultracapacitors are able to temporary assist the fuel cells in generating electricity. The capacitors are charged by the fuel cells or by regenerative braking.

An analysis of several car technologies, which were introduced in the past, was used to point out the factors, which could affect the acceptance of the new powertrain. These factors turned out to be for example performance, image and emotion.

The factors which could affect the acceptance were applied to the new powertrain to find its qualities and shortcomings.

Design considerations

When designing a user-interface, many aspects have to be taken into account. First, there is the project "Car of the Future". In this project the context, in which the car will be used and the system character of the car itself were stated.

Second, all kinds of information systems and display technologies are available and added to the interior of the car nowadays. However, it is very important not to overload the driver of the car with too much information.

Third, many design guidelines are available for in-vehicle information systems. They include guidelines about specifications of controls and how to present and prioritize information.

Fourth, the position is an important aspect when designing user-interfaces for cars.

These considerations, together with the obtained qualities and shortcomings, resulted in a list of functions and a list of requirements.

Design

The design of the user-interface consists of displays and controls. During an extended design process the primary display was developed. This display shows speed and energy consumption. Not all this information is displayed necessarily. The driver can choose whether to display the basic mode or the advanced mode. In basic mode, the speedometer and fuel gauge are displayed, and in advanced mode the energy consumption information is showed as well.

The information is displayed very clear and effective, according to the requirements that were a result of the design considerations.

The secondary display shows information on demand. This information is not necessary needed during a car drive. Therefore, it can be combined with other information systems like multimedia or traffic information.

Evaluation

A short evaluation was carried out. To check whether or not all the functions were fulfilled by the designed user-interface. This resulted in a list of recommendations and a final conclusion for the assignment.

Preface

The fact of this assignment having several interesting aspects, made me apply for it. First, the assignment itself concerned the design of a user-interface. This is a field of expertise of which I always wanted to learn more. Second, it concerned an investigation about acceptance matters. This is an issue I was not familiar with, until now.

Another interesting aspect was the participation in the national project "Car of the Future". In this project several students from Eindhoven, Delft and Enschede worked together to develop a car of the future. The c,mm,n goal increased the challenge of succeeding, together and individual.

Personally, I hoped to gain some good experience in setting up an investigation and using the conclusions for making an interface design. While doing this assignment, I found out that it was more complex than I thought it would be. Creating order in chaos and restructuring information turned out to be very important and difficult. Fortunately, I was supported by my tutors Kasper van Zuilekom, Robert Wendrich and Frans Tillema. They helped me to end up with a structured report and a decent design, presented in this document.

Gertjan Endeman

Enschede, 26 April 2007



Figure 1: Demonstration of the user-interface at the Amsterdam AutoRai, April 1st, 2007

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Introduction

We live in a world in which we have to handle our natural resources very carefully. This is not easy, because our entire industry uses energy which originates from these resources, for example oil and coals.

In order to lower the pressure on the natural resources, we are trying to change our energy consuming environment and researchers are trying to find alternative sources of energy.

Hopefully, this will result in a reduction of energy consumption and the use of alternative energy and new technologies to use our current energy sources more efficient.

Project Car of the Future

Stichting Natuur en Milieu, the Netherlands Society for Nature and Environment (SNM), is "*an independent organization committed to securing a vigorous and healthy natural environment. The Society is helping to build a sustainable society in which nature, the environment and the landscape are treated with care and respect.*¹"

They do this by starting discussions and influencing the policymaking process, and by conducting research and publishing the conclusions.

In order to encourage a huge industry to put a lot of effort in developing new technologies, SNM thought of a way to apply such an encouragement to the automotive industry.

They came up with a challenge for the three Dutch Universities of Technology (3TU) to participate in a project called 'Car of the Future'. The goal of this project: *Encourage the car industry to speed up the development of sustainable mobility solutions by designing a car for the year 2020*².

In this project, the strengths of SNM and the three universities of technology will be combined. Students of the University of Delft will take care of the vision creation and branding, and the design of the exterior and interior of the car. Students of the University of Eindhoven will take care of the design of the powertrain and the suspension. Students of the University of Twente will take care of a mobility scenario for 2020, the in-vehicle interface systems concerning vehicle status and the active safety systems.

The result of this project will be presented to the public, to car manufacturers and to the media at the 2007 AutoRai in Amsterdam, the Netherlands.

Assignment

In order to develop a car that should lead to a big step in making sustainable cars, it is inevitable to use unconventional technologies.

These technologies in the car of the future will cause different looks and behaviours compared to nowadays cars. Using current driver-powertrain interface solutions will therefore probably not be sufficient to let the driver understand the powertrain behaviour. In order to prevent problems on interfacing issues that could affect the acceptance of the powertrain in a negative way, the following assignment has been formulated in this project:

Design an interface for the car of the future to make the driver understand the working of the powertrain.

This rapport concerns this assignment.

To design such an interface, relevant research has to be done. Subjects of investigation includes literature investigation on powertrain concepts, research on important factors in user acceptance

¹ SNM, <http://www.snm.nl>.

² DHV (2005), "*Cars of the future*".

of powertrain concepts, research on the workload of the new system (using the new design) and an evaluation of the interface.

Preview

Chapter 1

In this chapter the aspects which probably are important for the acceptance of the powertrain of the car of the future are determined.

Therefore, the technical aspects and driving behaviour aspects of the powertrain of the car of the future are described first. Second, an investigation considering previous introductions of new powertrains and other technologies in cars is used to determine the aspects, which could play a role, in the acceptance process of the car of the future.

Chapter 2

In chapter 2, first, all kind of subjects are discussed, which are important when designing a user-interface for the powertrain of a car.

Second, a functional analysis is carried out to list all the functions the user-interface has to fulfill. Third, a list of requirements is created, considering all analyses and conclusions that were executed.

Chapter 3

Chapter 3 describes the process of design, together with a description of the designs themselves. First, the displays are described and second, the controls are described.

Chapter 4

In chapter 4 the user-interface is evaluated. A short evaluation is carried out considering the functions of the user-interface, which were determined in chapter 2.

Furthermore, a conclusion is given and recommendations are listed.

1. Acceptance of the powertrain

In this chapter, the powertrain, used in the car of the future, will be discussed. First, the technical working of the future powertrain will be explained, together with the driving behaviour that results from this powertrain. Second, a theory about the acceptance of technology will be presented together with some examples.

Third, this theory will be used to discuss the acceptance of the new powertrain. This will result in a list of factors that could affect the acceptance of the powertrain.

1.1 Fuel cell powertrain

The powertrain that is used in the project "Car of the Future" is a hydrogen powered fuel cell powertrain. Such fuel cells are often mentioned when future powertrains are discussed, but only few people know its working principle. Already, car manufacturers designed and produced advanced engines, based on fuel cell (FC) technology. These cars are tested to gain experience. Two examples are Toyota's FCHV and Honda's FCX³, both based on the "Proton Exchange Membrane"⁴ (PEM) fuel cell. In the *Car of the Future* project the PEM Fuel Cell technology will also be used, because of its useful properties.

Some general fuel cell technology aspects will be discussed, followed by a more detailed description of the essential parts of it.

1.1.1 The technology

Fuel cell technology is based on a chemical reaction which generates electricity. The electricity is used to feed the electro motors, which subsequently drives the wheels of the car. A battery is used to store electricity. This electricity can be used to assist the electro motors in certain driving situations.

The use of electro motors, instead of an internal combustion engine, provides different properties and possibilities in terms of driving behaviour and design of the car. This will be discussed in this chapter.

There are many different types of fuel cells. They can be distinguished by the materials where they are made of, the fuel used and the chemical reaction that takes place. Typical fuels used in fuel cells are hydrogen, ethanol, methanol and zinc. Their working principles are very similar. Usually, the reactants (fuel and air) flow into the fuel cell and reaction products (waste product and air) flow out. Below, the working principle for PEM FC technology will be explained.

PEM FC's

Every chemical reaction has reactants and reaction products. In the chemical reaction in the PEM fuel cell, the reactants are air and hydrogen (the fuel). The output consists of the reaction products, air and water. So the emission of fuel cells, running on hydrogen consists only of air and water, meaning that the tank-to-wheel pollution is zero.

During the chemical reaction, a transfer of positive protons takes place through a membrane. Water is needed for this. The transfer causes an accumulation of negative charge, this results in electricity (see Figure 2).

The distribution of water and air is done by 2 pumps. Therefore a water pump and an air pump are part of a fuel cell installation. In order to let the chemical reaction take place, the temperature has to be at 80° C. The temperature should not be much higher, because the water needed for the transfer of protons will start to

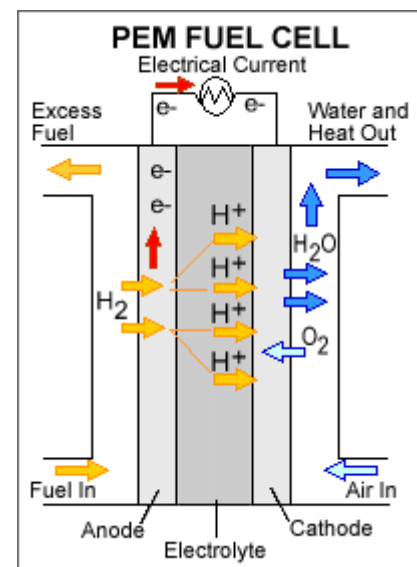


Figure 2: Working principle PEM fuel cell

³ Wikipedia, http://en.wikipedia.org/wiki/List_of_fuel_cell_vehicles.

⁴ Wikipedia, http://en.wikipedia.org/wiki/Proton_exchange_membrane_fuel_cell.

boil. The system will need up to approximately 5 seconds to reach the operation temperature. Several of these fuel cells together, are called a *fuel cell stack*, but often they are just called fuel cells. The fuel cell stack can produce 30kW of electricity.

When the chemical process is at its operational temperature, the power output can be increased or decreased by providing more or less air and hydrogen to the fuel cells. Thus, stepping on the gas will result in more chemical reactions, causing a higher electricity output. Unfortunately, providing more air and water to the fuel cells does not instantly result in a higher power output: It probably takes 1-2 seconds.

Ultracapacitors

The electricity is also used to charge the onboard ultracapacitors. Ultracapacitors are similar to batteries but differ in having a high energy density and short recharge time. They can provide up to 30kW of additional power on top of the power produced by the fuel cell stack. Because of the high power output, the ultracapacitor can only deliver the additional power for a certain, short, period of time.

The ultracapacitors, also called ultracaps, enable the car to instantly react during a power demand, either taking care of the starting-up time of the fuel cell stack or taking care of the respond time of the fuel cell stack (during a power demand).

It is not preferable to use the ultracaps when they are almost empty, because this will shorten the lifespan.

When the ultracaps are not used for a long time, they will get empty. This is a disadvantage nowadays.⁵ In 2020 this effect will probably be negligible.

Electro motor

The fuel cell car is actually an electrically powered car. The electricity provided by the fuel cell stack can be used by electro motors. In this project, every wheel has its own in-wheel electromotor with a capacity of 10 kW, making a total of 40 kW.

An electromotor can temporarily provide more power; this is called the 'overload' or 'boost' and it can be up to 100% of its normal capacity, providing a peak performance of 80 kW. This enables a 1000kg car to get from 0-100 km/h in about 10 seconds.

Not only do electro motors produce movement when they are connected to electricity, they also work the other way around. They produce electricity when they are moved by something else.

This is used during the brake process. During this process, the electro motors behave as a generator. Doing this, they consume a part of the brake energy; this will be converted to electricity and will be used to charge the ultracapacitors. This is called regenerative braking.

The electro motors can turn in both directions.

Fuel

The fuel used in the powertrain, is hydrogen. It can be made out of water, using an electrolysis process. This process requires electricity. Hydrogen can also be made out of fossil fuels. A huge disadvantage, in terms of sustainability is the carbon dioxide, created during the extraction of hydrogen from fossil fuels. When the electricity, needed for the electrolysis process, comes from a sustainable energy source, like solar energy, there is no pollution. Together with the zero-emission fuel cell powertrain, the total emissions for driving the car are zero!

Storage

Hydrogen is a fleeting gas. Therefore it has to be stored in a closed tank. This tank will be cylindrical and the gas is stored under a pressure of 700 bars. The tanks are made of enhanced stainless steel, including a carbon fibre casing. This is a very strong material. It is imaginable that the procedure for refuelling a hydrogen car is completely different compared to refuelling a conventional internal combustion engine car.

⁵ Toshiba, http://www.toshiba.co.jp/about/press/2005_03/pr2901.htm.
Europhysics News, <http://www.europhysicsnews.com/full/23/article2/article2.html>.

The filling up at the gas station takes about 10 minutes. This is longer than refilling a gasoline or diesel car. This process cannot be sped up because the huge changes in temperature of the fuel compared with its surrounding. They are caused by the pressure changes during refilling.

Transmission

The electro motors are integrated in the wheels. No transmission is used to bring the power from the electro motors to the wheels. The acceleration characteristic is in principle a continuous graph.

Assuming that most drivers are used to drive internal combustion engine powered cars, what does all this mean for the driver, in terms of driving experience and daily use of the car? Already, cars which use several of the above systems are produced. But there aren't cars, which use all of the above elements at the same time, yet. Still, several things can be said about the driving behaviour of the car. This is the subject of the next paragraph.

1.1.2 Driving behaviour

The first thing that will stand out when a user first drives a fuel cell powered car is the noise, because this is reduced to a minimum. The tires and pumps will be the main noise-producing elements of the car.

Operation

Some basic powertrain controls have to be operated by the user. The first is selecting a driving direction, the second is adjusting speed.

Stepping on the gas, results in two things. At first, the ultracapacitors will instantly deliver more power to the wheels. Secondly, more hydrogen and air is pumped into the fuel cell stack causing a higher power output. It takes a few seconds to reach this higher power output. As explained, this is fully compensated by the ultracapacitors.

Stepping off the gas pedal, results in no power output to the wheels and the car will slowly decrease speed. The remaining power output of the idle operating fuel cell stack is used to power the auxiliary systems and to charge the ultracapacitors.

Power output

The available power depends on a few aspects. The first aspect is the state of operation of the fuel cells. The fuel cells take a certain time (5-30 seconds) to get at its most efficient level of operation. This means that after a cold start the car cannot use the full capacity of the fuel cells. Once started-up the fuel cells stay turned on, even when the car has to stop for a short time. The procedure of turning off and starting-up again takes too much time.

The second aspect is the level of charge of the ultracapacitors. They might be empty after a long time of unemployment or when they are used intensively.

The third aspect is the condition of the electro motors. Their boost is only temporarily, so when the powertrain has just boosted, the electro motors have to cool down and cannot boost again for a certain period of time.

Transmission

The transmission ratio from the electro motors to the wheels will be 1:1. So no transmission system is needed. Not using a transmission will cause the car to behave different during acceleration compared to internal combustion engine cars, nowadays. In those cars the acceleration procedure is divided into 4-5 gears, each with its temporary power loss followed by a power boost, the electro motors will provide a more constant acceleration.

In comparison to an internal combustion engine an electromotor has different torque – engine speed relations. Where an internal combustion engine has a high torque at high engine speeds the electromotor has a more linear distribution of the torque. Compared to an internal combustion engine an electromotor has higher torque readings during low engine speed.

The transmission also takes care of the longitudinal driving direction, being forward or backward. This direction depends on the selected gear (forward/backward).

The transmission is also used to put the powertrain system into parking mode or in neutral mode. Parking mode results in a brake applied to all wheels. Neutral mode results in all wheels declutched from powertrain or brake forces.

Powertrain management

The onboard computer will decide to which extend a power source (fuel cells or ultracapacitors) will be used. It also decides when the fuel cells will charge the ultracapacitors and when the electro motors can be used to regain braking energy. All these decisions are taken, considering all kinds of efficiency and fuel consumption aspects. For example, the fuel cells have a certain level of operation in which they work most efficient. The management system will try to let the fuel cells operate as much in this range as possible, by letting the ultracapacitors take care of all the smaller fluctuations in the power output.

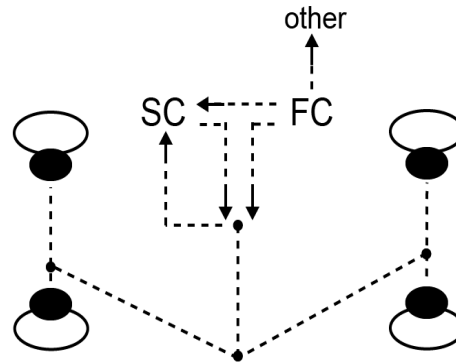


Figure 3 Wheels, electro motors, fuel cells (FC) and ultracapacitor (SC) in a scheme

Because the management system takes care of this, the possibility exists that the car does sometimes that doesn't seem logical to the user.

While the car is turned on, the fuel cells always produce an output, the idle output, even when you're standing still in front of for example a red light. This seems not logical, but it is more efficient to let them run instead of turning them off and let them start-up again.

Consumption

Thanks to the electro motors it is not necessary for the driver to watch the engine's number of revolutions in order to drive economic.

The actual fuel consumption depends on how much hydrogen the fuel cells are currently using. Keeping the level of operation of the fuel cells as low as possible results in a lower hydrogen consumption.

The electro motors change their functionality when the car is braking. They turn into generators generating electricity from the turning wheels. This electricity can be stored in the ultracapacitors.

Daily use

The capacity of the hydrogen tank will be 120 L. This results in a radius of action of about 450 km. Driving through the streets of an urban place the car barely produces noise; this means that this car is far quieter than cars nowadays. It could cause some dangerous situations for pedestrians.

Safety

Fuels always bring some safety issues with them. For example, everybody knows not to smoke at a gas station because of the highly explosive materials.

Hydrogen is also an explosive material. However, compared to gasoline it is less explosive. Only when hydrogen approaches levels of 4% concentration, the possibility of ignitions increases. This is a 4 times higher concentration compared to gasoline, igniting from concentrations of about 1%. Everybody also knows not to hang above the gas tank of a car because you will be poisoned otherwise. Hydrogen is not toxic at all. Besides, because of the high density hydrogen is lighter

than air causing it to rise when it is released in open air. Also, because of the high density the gas is very volatile causing the concentration to lower drastically as soon as it is released. The hydrogen is stored in the tank under a pressure of about 700 bars. These tanks are very strong and won't deform during a crash.

Image

The image of hydrogen in general is relative positive. There have been pilot projects to get the consumers acquainted with the use of hydrogen. For example the CUTE project in Amsterdam. In this project several buses driven by hydrogen operate in public transport.⁶ Reactions of passengers are positive.

In a certain way it is remarkable that consumers seem to accept the buses, while they are electrically driven. Apparently an electrical driven vehicle in public transport is acceptable but an electrical driven (personal) car is not.

1.1.3 Conclusion

In this paragraph the characteristics of the new powertrain system are discussed. It appears to be a relative unusual type of powertrain system. The fuel cell stack powers 4 electro motors which drive the wheels. Ultracapacitors are used to temporary provide extra power. The hydrogen is stored liquid and under pressure.

The main driving properties are the fuel cells taking care of the initial power supply, the ultracapacitor to take care of fluctuations in the power supply and the electro motors using braking energy to generate electricity.

Features:

- Range: 450 km
- Top speed: 135 km/h
- Fuel: hydrogen
- Regenerative braking
- Zero emission (local)
- 4 wheel drive

⁶ GVB, <http://www.gvb.nl/overgvb/projecten/brandstofcelbus.html>.

1.2 Acceptance of technology

New technologies concerning automobiles face a heavy job in convincing the consumers about their qualities. Consumers seem to need a certain amount of time in order to accept new technologies. They have to be able to get acquainted with the technology easily, especially when the technology is very advanced and when it takes over (control) tasks.

From the technology point of view it seems that a new technology has to gain confidence by good results. But when a 1st generation technology has some child diseases it seems that consumers allow the technology to try it again. So it is important that a 2nd generation is perfectly worked out and that it loses its negative image provided by the previously introduced version of the technology.

Acceptance matters were investigated in an extensive research that was carried out for this assignment⁷.

It concluded that the acceptance of products or technologies by user depends on a lot of factors. It is very hard to indicate which factors are most important and how these factors have to be met before a product will be accepted.

Despite the toughness of indicating exact which factors play a role in acceptance matters, it can be said that there are certain aspects that in all contexts play a role in acceptance processes.

- Costs
- Performance
- Image
- Usability
- Comprehensibility
- Emotion

Four examples will be mentioned here to illustrate this conclusion.

1.2.1 Robotic transmission

In a manual transmission gearbox the driver has to change gears by performing a few steps. First he has to push the clutch pedal with his feet. Second, he has to change gears by handling the gear stick. Third he has to release the clutch pedal by handling the clutch pedal again.

A robotic transmission performs these operations itself. Besides that, it also senses if the driver handles the accelerator pedal aggressively or calmly and reacts on this accordingly. The decision to change gears is made by the gearbox itself. It compares current engine speed, car speed and gas pedal position with pre-installed data and reacts according to it. Often a comfort mode or a sport mode can be chosen. Both modes cause different fuel consumption and performance behaviour.

Drivers have certain 'changing gears' behaviours. They are familiar with a car's development of velocity and know how to handle the gearbox in order to accelerate quick, economic or comfortable. An automatic robotic transmission takes away the ability to choose when to change gears. Drivers' expectations don't always match gearbox behaviour. So some robotic transmissions cannot satisfy the driver. For example the first generation sequential gearbox of the *Smart fortwo* has often been criticized for making slow and delayed shifts. Driving this car the driver rather changes gear himself.^{8,9}

⁷ The rapport of this investigation can be found in supplement 1.

⁸ Autowereld.nl, <http://www.autowereld.com/rijimpressies/detail.asp?artikel=2702>.

⁹ Autoweek.nl, <http://www.autoweek.nl/autotestrapport.php?id=1341&cache=no>.

Considering the user-interaction of the robotic transmission, the following can be concluded:

- According to the driver the robotic transmission does not always switch gears at the right time.
- The procedure to switch gears takes too much time.

1.2.2 CVT transmission

Another type of transmission is called the continuous variable transmission (CVT). Instead of the classical transmission in which 4-6 gears are used to increase speed the CVT does not work with a number of fixed gears. This transmission constantly changes the conversion between the engine and the wheels while speeding up. This enables the engine to constantly operate at its most efficient number of revolutions, causing this kind of transmission to behave different compared to transmissions using multiple gears. Those cars reach their top speed in 4-6 steps. During each of these steps the car accelerates when the driver steps on the gas.

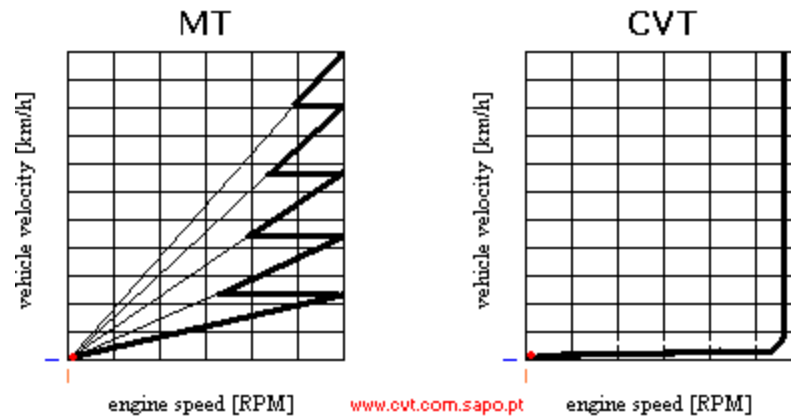


Figure 4 Comparison manual transmission vs cvt

In this transmission, the gearbox itself decides how the engine should provide the desirable car speed according to a certain pedal position and handling. The decision of the gearbox is based on a most efficient and economic engine performance. Often, user experiences on how to obtain an efficient and economic engine performance are not quite right, this results in a certain engine behaviour which is not understood by the user and leads to misjudgements. For example, the CVT sometimes puts the engine in a high speed while accelerating because at a high engine speed the engine is more efficient. But drivers may experience this behaviour as wrong because in a classical transmission a high engine speed indicates that you have to gear up. So others might think that you handle the transmission in a wrong way.

As explained above, the acceleration feels very smooth without the traditional 'jerks'.

The smooth performance of this type of transmission is very comfortable¹⁰. Furthermore, it gives a better fuel economy and less exhaust emissions.

Driving a car with a continuous variable transmission requires the driver to adapt its expectations. The transmission has to gain confidence on behaving different compared to cars with classical transmissions; it gives the same or a better performance and more comfort.

Some drivers, who were used to drive cars with gearboxes using several fixed gears, could not adapt to continuous variable transmissions. Because of the lack of 'jerks' they thought the engine could not provide enough power.^{11,12} So car manufacturers built artificial shifting points in the continuous variable transmissions.

The CVT emulates the traditional 'jerks' that should indicate the shift points during gear up or gear down.

¹⁰ See supplement 4.

¹¹ Automotive Design and Production, <http://www.autofieldguide.com/columns/0405euro.html>.

¹² AutoWire.Net., <http://www.autowire.net/2002-38.html>.

The following can be concluded considering user-interactions:

- Drivers find it difficult to accept a transmission that behaves itself like a transmission that is used wrongly.

1.2.3 Fuel alternatives

The main types of fuels used in cars are gas and diesel. Nowadays these fuels have an image of being suitable for engines. Engines running on gas or diesel are capable of propelling the cars we use. However, there are some alternative fuels available which can be used in the same engines.

One of them is LPG, it is gaseous fuel. An engine running on gas can (after a minor modification on the engine) also run on LPG. The initial costs of the LPG installation for the engine is high, but after driving 20.000 km on LPG these costs are earned back by the low LPG fuel prices. Using LPG is cleaner than using gas, but the LPG installation costs a considerable amount of space in the car. The first generation LPG installation faced a lot of failures. The recent generation LPG installation are very reliable, but they appear to suffer from the negative image which is created by the early generation LPG installations.

Other fuel alternatives are bio-fuels. These are fuels that come from living or recently living biological material. This material is called biomass. Mostly this is plant matter. This kind of fuel is more environmental friendly than conventional fuel. However, you need to go to the fill station more often and the availability of bio fuel is not very good. The image of bio fuel is that it is expensive and that the engine doesn't perform as well as it does on normal fuel. The biggest problem is that the government does not lower the duty of gas in correspondence with the lower impact on the environment.

The following can be concluded considering user-interactions of fuel alternatives:

- Fuels are sometimes judged by their image and not by their actual performance.
- Depends heavily on government policy.

1.2.3 Electrical

The most important characteristic of the electric car is that it has to carry batteries. These are heavy and can only contain a limited amount of energy. When the batteries are empty they have to be replaced or recharged. This causes the electric cars' performance to be moderate, resulting in a low top speed, acceleration and radius of action.

Recharging or replacing the batteries every now and then puts a high workload on the driver of the car, creating a huge disadvantage on the use of electric cars.

Many electric powered cars were introduced in the past century. They got never popular enough to start a revolution in the car industry.

One example is General Motors EV1. It is an electric car with a range of 120 – 140 kilometres per charge and a top speed of about 120 km/h. Together with a satisfying acceleration time, the performance of this vehicle was great. The car became available only for lease companies and it turned out to be a popular lease car. This car definitely showed that an electric car is capable of fulfilling consumers' demands. Unfortunately GM stopped producing this car, because development on this car was too expensive.



Figure 5 GM's EV1

The amount of noise produced by an electric driven car is totally different than the amount of noise produced by the classical internal combustion engine car. Furthermore the driving experience is totally different. The acceleration is very smooth since the powertrain does not need a gearbox.

The engine, safety and equipment of an electric car are all fine. But when it comes to comfort this car lacks to fulfil the need of the driver. Forgetting to charge the electric car at night should not lead to not being able to use it the next morning.

Newly introduced electric cars have to deal with the negative aspects which are derived from previous introduced electric cars. The design of electric cars is mostly very aerodynamical, to compensate the lack of power of the engine. Such an aerodynamic design gives the car a very futuristic look. This look is not liked by a lot of car drivers.

Electrical cars:

- Have to deal with a negative image.

1.3 Acceptance

The acceptance of the new powertrain depends on a lot of factors. It is difficult to indicate which factors and how they contribute to the acceptance process. The investigation of the acceptance matters of previous technologies resulted in a list that might be applicable when certain macro-conditions are not changed. The new powertrain is introduced in comparable macro-conditions as those technologies were, so this list of paragraph XX can be used to discuss the acceptance of the new powertrain.

Costs

It is assumed that the costs are comparable to the costs of current powertrains.

Performance

The performance compared with current powertrains is a little different. For example, the top speed is lower and the relation between power and speed is different: at lower speeds this powertrain is more powerful than a car with an internal combustion engine.

Image

The image for this powertrain does not really exist yet. Because the technology is very new, it is known as modern, innovative and ecological. These are all positive elements.

However, it is interesting how the reactions will be when users realise that this is in fact an electrical car. The image of this car is namely not positive.

Usability

The comfort of using this powertrain is not very high. The hydrogen fuel infrastructure will not be as extended as the current fuel infrastructure. So the refilling procedure asks for more effort by the driver.

Comprehensibility

The technology is quite complex. Therefore it will be hard for the consumers to understand it. This is caused by the fuel cell technology being unconventional and complex.

Emotion

Driving the car with the new powertrain requires less effort than driving nowadays cars with an internal combustion engine and a manual transmission. From that view the new powertrain lacks a 'racing' feeling.

1.4 Conclusion

In this chapter the new powertrain was discussed. It appears to be a relative unknown type of powertrain system. The main components are a fuel cell stack, an ultracapacitor and the electro motors. The main driving properties are fuel cells taking care of overall power supply, ultracapacitor to take care of fluctuations in the power supply and electro motors using braking energy to generate electricity.

Some technologies were discussed in order to point out how acceptance problems look like.

Considering these findings the following list of qualities and shortcomings of the new powertrain can be made. These items might play a role in the acceptance process of the new powertrain.

Qualities	Shortcomings
Always ready to run Smooth acceleration Regenerating energy Temporary extra power No local pollution No sound Image of comfort/reliability Safe Very economic	Not 100% power available during cold start Temporary peak power Radius of action No sound No fuel infrastructure No 'racing' experience Unproven technology "Complex" technology Possible association with electrical cars Dependent of government policy

Figure 6: Qualities and shortcomings of the new powertrain

2. Design considerations

In the previous chapters, the powertrain for the car of the future has been described. In this chapter, several aspects which are important when designing an in-vehicle interface for a future powertrain will be discussed.

We will start with discussing all kinds of user-interface design aspects which are relevant for the design of the user-interface for the powertrain of the car of the future.

To indicate exactly what the user-interface has to be able to do a list of functions is created. The result of this chapter is a list of requirements.

2.1 User-interface design aspects

2.1.1 Car of the future

Interior

The car of the future is developed by a multidisciplinary team. To work efficiently a decent planning is necessary. Unfortunately the development of the powertrain interface is already taking place, while the car interior, including several interface systems, has not been designed yet. This results in some assumptions that have to be made considering the characteristics of the interior. These assumptions are:

- The driver has to operate the car himself
- The driver seat is located front-left in the car, the driver faces in the forward driving direction.
- The driver has to use a control in order to change direction in lateral direction

Powertrain

In this assignment only the interaction between the system that propels the car and the user will be discussed. Therefore a clear definition of the powertrain part is necessary.

Definition of a powertrain:

"The vehicles powertrain comprises the entire system needed to propel the vehicle. This extends from the fuel tank, as primary energy source, to the tires, the elements that interact with the road."¹³

The description of the powertrain mainly concerned systems that affect the longitudinal driving direction. Therefore the interface will only concern these parts of the powertrain. So lateral and up and down direction powertrain systems will not be included in this interface. This means that suspension and steering wheel for example are not included.

About autonomous driving

In the year 2020, probably more and more driving tasks (all the tasks which have to be performed by the driver in order to drive the car) are moved from the driver to the car. In 2020, the technology even enables us to design cars which can drive completely autonomous. The computer in this car can combine the powertrain-control task with traffic information and fuel consumption information to arrange the most economic and efficient ride.

To which extend the car will be able to drive autonomously is not quite sure yet. It seems that there are a lot of acceptance issues considering this development. People are not ready to give control out of hands, because they are not confident that the car can handle the complex traffic situations properly.

There are two more aspects which prevent autonomous cars to be used (widely) in 2020. First, there are situations in the traffic which are not suitable for autonomous cars. For example, the busy traffic in the city. Secondly, even if the technology enables us to build autonomous cars in

¹³ Common, <http://www2.io.tudelft.nl/io1008595/>.

2020, not all cars in traffic will be autonomous cars, because millions of 'normal' cars exist nowadays which will still be used in 2020.

Therefore, we assume that the user of the car in 2020 will still have the option to drive the car himself. This means that in 2020, there still has to be a user-interface available for the driver, in order to be able to operate the powertrain.

User analyses

The development team of the car of the future stated a certain future vision in which they design this *Car of the Future*.

A future vision for the year 2020 has been formulated by the development team of the car of the future. Only with this vision a car can be developed that fits in this future, on technical, usability and design levels.

With this future vision a context has been created in which the car of the future will be used. In this context, the car is more seen as a part of the mobility solution, instead of being a mobility solution itself. For example: the mobility solution is to get from home to work in town. The car takes care of the part from home to the edge of the town, here; you leave your car on the parking and continue your trip by train.

In this context it is foreseen that the lead-users of the car of the future are the young adults. Their characteristics are that they want to be mobile, flexible, busy, and they are part of multiple social communities, like work, family and sports.

System character

A product character has been formulated for the entire car, based on the context of the car of the future. The character also accounts for the car interior and powertrain interface. This powertrain interface is in some ways the 'face' of the powertrain, because it is the way the driver 'communicates' with the powertrain. This should be considered when designing the interface.

The car of the future is¹⁴:

- Optimistically activating
- Challenging layered
- Dynamic balance
- Reactive
- Selective accessible

This implicates that the car is not a dull device anymore that only does what the driver imposes him. Instead the car will 'think' for the driver. This might be interesting for the driving task, like routing, watching energy consumption and watching safety systems.

There are some conditions that have to be kept in mind:

- Control about the degree of control. The driver should always be in control of the car and its behaviour.
- Modularity. Instead of buying a car, you buy a set of specifications that might be altered later.

Fuel economy

It seems that the market for fuel economy devices is rather limited. These devices give insight in the fuel consumption of the car and how this is related to the drivers driving style. Only new modern cars are equipped with such devices because car manufacturers integrated them in the car. The after market for such devices is very small.

However, when consumers are asked about such devices it appears that they are interested in using them¹⁵. Functions which have to be integrated in the information system when adding fuel economy information are:

¹⁴ Lammers, J; *Final Package_20060530[DRAFT].ppt*

- Display interpretable fuel economy information
- Give advice on how to influence fuel economy

It is remarkable that when fuel economy of a car is discussed, the energy consumption of the electrical systems in the interior of the car is never mentioned. Systems like air conditioning, heating, but also radio wipers consume a considerable amount of energy.

In the project "Car of the Future" an idea exists of what the car should look like and in which context it will fit. When designing the user-interface, this idea should be used to let the user-interface fit in the car.

2.1.2 In-vehicle interface developments

In this paragraph some developments of in-vehicle interface systems (IVIS) will be discussed. There might be developments which can be used for the design of powertrain interface of the car of the future

General

As already discussed, the basic concept of the automobile has not changed drastically during the last decades. Until about a decade ago, the same accounted for the user-interface of the powertrain. The early car-driver interactions existed of mechanical control devices, like the use of a steering wheel, a gas pedal, a brake pedal and a gear shift. However, they also existed of the output of the car, being speed, noise and pollution, which are noticed by the driver.

Soon, more information was needed by the driver while driving the car, so several interface devices were added to the car, some of them bringing some typical interfaces to operate them. For example a speedometer, a revolutions meter, an odometer, a fuel level meter and several engine indication lights.

The development of the past twenty years is that more and more electronic systems are added to the car, all bringing their interface systems with them, causing more and more information to be absorbed by the driver. For example, the radio, car phones, navigation systems and multimedia players.

To be able to accommodate these next-generation information systems, (touch) screens are often used to integrate several systems.

In this chapter we will discuss some developments concerning in-vehicle information systems.

Drive-by-wire

Until now, solutions for basic powertrain control problems were mainly mechanical solutions. For example, the gas and brake pedal in the car. The gas pedal used to be mechanically connected to the throttle valve. The throttle valve is a device of the engine which regulates engine speed. Development of electromechanical technologies made it possible to use an electrical signal to control the throttle valve, using a small actuator. The electrical signal comes from a sensor which senses the position of the gas pedal.

Using electrical interfaces in combination with actuators and sensors is called "by-wire", for example drive-by-wire to indicate an electromechanical interface for steering the car. By-wire can also be a solution for other mechanical interfaces, like the steering wheel, brake pedal, clutch pedal, hand brake and gear shift.

In the interactions between user and powertrain, the use of electrical interfaces, like the brake pedal, has huge consequences for the design process. The mechanical solution in conventional brake pedals caused a certain feeling for the user while handling it. This feeling is a direct result of how the braking force is translated from the brake pedal to the wheel. On a drive-by-wire solution the input device (pedal) only has to generate an electrical signal. So, the movement properties have to be designed as well.

¹⁵ Maarseveen, M.F.A.M. van, Voort, M.C. van der & Driel, C.J.G. van (2002).

This implicates that pedals do not have to be the most suitable solution anymore for certain driver-powertrain interfaces. However, drivers are still used to the mechanical devices like gas and brake pedals, so changing this to totally different solutions could cause acceptance and operating problems.

In-vehicle information systems

The powertrain information system, to be designed in this assignment, has to assist the driver in operating the powertrain, during the driving task. This information system will not be the only information system in the vehicle. In most modern cars, a variety of information systems are being used.

Existing theory about IVIS does not include the powertrain information systems. In the next overview the powertrain information systems will be added to "vehicle operation information systems" and listed next to existing information systems which are already defined by theory¹⁶.

1. **Vehicle operating information system.** For example powertrain information and vehicle speed.
2. **Safety and collision avoidance systems.** For example adaptive cruise control, rear-end collision avoidance and obstacle and pedestrian detection.
3. **Advanced traveller information systems.** For example navigation systems and vehicle status systems.
4. **Convenience and entertainment systems.** For example radio systems and mobile pc systems.

Considering the main function of the car, which is "transporting the passengers", the '*vehicle operating information system*' is the only system that is essential in order to fulfil this function.

All In-Vehicle Information Systems (IVIS) offer a huge amount of information, which is offered to the driver. Unfortunately, the driver's ability to observe all this information did not develop as fast as the development of IVIS itself. This results in the driver having to divide his attention over these different kinds of information in the car. For example, a driver driving a car with only a *driving task information system* uses all his available attention mainly for the driving task and once and a while for checking the *driving task information system* (e.g. a speedometer). However, when 3 systems are added and the driver wants to use all systems this goes with the expense of the available attention for the driving task, which can easily result in a possible dangerous situation.

For the design of the interface that has to be used by the driver, this means that a lot of effort has to be put in presenting the information on a most efficient way, causing a minimum distraction to the user, while accessing the information.

According to Kantowitz, integration is the solution for presenting the information generated by the non-essential IVI systems. A few requirements are obtained from literature, regarding IVIS design:

- In-vehicle information systems have to be integrated.
- IVIS interfaces must be intuitive and easy to learn.
- Do not let the interface bother the driver with information that is not needed at that moment.
- The driver has to be in control of the amount and detail of information that is offered to the driver.

A lot of research exists about the design of in-vehicle information systems and a lot of car manufacturers put their effort in presenting information at a most efficient and ergonomic way. Because of this, a broad consensus has originated, of design elements which have become standard in in-vehicle interface systems. For example the use of symbols or the use of positions for certain interfaces.

¹⁶ Kantowitz, B. H. et al, *Integration of driver in-vehicle its information*.

2.1.3 GUI design guidelines

A lot of instructions and guidelines exist about the design of graphical user interfaces for vehicles.

For example the “Human factors design guidelines for ATIS and CVO”. This is a report by the *Battelle Human Factors Transportation Center* in the U.S. It summarizes human engineering data, guidelines, and principles for use by creative designers, engineers and human factors practitioners during the ATIS design process. These summaries take the form of design guidelines for 75 distinct ATIS design parameters. These guidelines are intended to be used by anyone responsible for the conceptualization, development, design, testing, or evaluation of ATIS and CVO devices¹⁷.

Another example is the “Design guidelines for safety of in-vehicle information systems” by the Transport Research Laboratory. This is a research company in the UK. The report contains detailed guidelines about the use of controls, displays and auditory information

General concern

All design guidelines have something like a common general concern. This is obviously the same as the drivers concern, being a safe drive. To achieve a safe drive, the driving task should get all the attention of the driver. However, during the development of the car several ‘distraction’ systems like navigation and multimedia systems were added to the car and in the future there will be more systems added as well. The driver-system interfaces consist of several interactions which are necessary in order to operate these systems.

All in-vehicle interface design guidelines have an important thing in common: they all try to accomplish that the information and control systems distract the driver as less as possible, from his driving task.

This can be achieved by several means: (1) make the distraction as short as possible; there fore (2) the message from system to user has to be as clear as possible, to achieve an efficient transfer of the message. By taking into account guidelines about location, colour, lay-out, feedback, symbols and etcetera of the information and controls systems, this can be achieved. The guidelines are quite extended for these aids.

These guidelines will be taken into consideration when designing the interface. The guidelines are not entirely suitable to be used before the design process, because they will obstruct a creative design process. However, they can be used during the process as advisor on how to design certain interface elements. Afterwards they can be used to evaluate the interface.

A few general guidelines will be described here briefly.

Controls

The controls that are used by the driver of the car to operate the vehicle or the information systems within it, are called the input controls. All input controls have to be easy to reach from the normal driving position and should never interfere with other controls or displays, especially not with the ones that are necessary regarding the driving-task. Nor should an accidental leg or arm movement lead to accidental activation of a control.

Furthermore should be paid attention to location, handling consistency and effect on other controls while using the control. The design of the control should be suited to the function of it. For example pedals, buttons, slides and toggles.

Information

Information can be displayed using visuals, audio or haptic devices. Each of these modalities has some qualities which cause them to be suitable for different or common use.

¹⁷ US Department of Transportation, <http://ntl.bts.gov/DOCS/atis/index.html>.

Visual

Visual information presentation is especially recommended when information is presented continuously, complex, does not require immediate action and may need to be referred to again. The location of the information should be as close to the normal line of sight of the driver. The information with highest priority should be as closed to this line as possible. The priority of the information is based on relevance to driving, criticality, urgency and frequency of use of the information

Information on screens

Information for the driver used to be presented in the instrument cluster that is located behind the steering wheel. This cluster contained instruments like a speedometer and fuel gauges. Later, screens were added to the mid section of the dashboard to accommodate extra information like navigations systems and multimedia players

In the instrument cluster, screens are also used more and more. In modern cars, screens are used to accommodate what used to be positioned in the instrument panel. This screen is positioned where the instrument cluster used to be positioned.

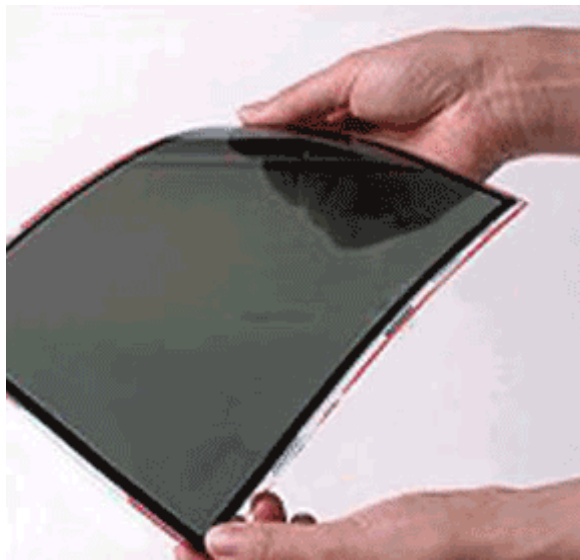


Figure 7 Flexible displays

The use of screens is getting common in modern cars. Car designers discovered the possibilities of using a screen in the car interface. The advantage of using (touch) screens is that information can be displayed in a lot of ways. The designer is not limited by a single button, symbol, colour or shape.

When using a screen to display the information the challenge is to which extend of detail the information has to be displayed to be as less distracting and interesting as possible in order to keep the driver busy with his driving task.

Furthermore, in 2020, flexible screens will be a common used product. This means that it will not be necessary anymore to put a screen on a straight surface.

The advantages and disadvantages of using a screen in short:

- Using a screen causes the information to be clustered.
- Screen lay-out is not restricted to fixed elements. The designer is free to come up with all kinds of shapes and colours.
- Several information systems can use a single display when the combine the different information or alternate the information.
- Current screens use a considerable amount of energy. Future screens are expected to use a minimal amount of energy.

- The change of adding too much information on the screen is increased, because it is able to present anything on the screen.

Information on Heads-up display

A heads-up display (HUD) is a display that presents information without the necessity for the driver to move his head. This can be done by projecting the information on the windshield for example¹⁸.

When using a HUD, the information displayed in it should also be available elsewhere. Because in some circumstance the information on the HUD is not available. For example: when there is a very bright sun light shining or when the driver has turned off the HUD himself.

Using a HUD provides some benefits, but this is not guaranteed. It seems very hard to design a HUD that can handle all viewing conditions. Furthermore, the way the information is presented and the amount of information is very important.

Auditory

Auditory information should be used when the driver's attention needs to be gained, when the message is simple and short and when it is not needed to be referred to later.

Spoken text and bleeps can be distinguished here.

Spoken text is used to present dynamic information. This information is subject of change, like routing information, so the message which has to be presented to the driving is never the same.

Bleeps are used to make the driver attentive about a certain situation which requires the attention of the driver. Accordingly the driver has to look at a visual display to find out what the urgent message is.

Audio can also be used as input modality. The interface then has to recognize spoken text by the driver. This can be used for dynamic information like routing information.

Haptic devices

The use of haptic devices is used a lot in internal combustion engine cars with an automatic transmission. A vibration, called 'kick-down', is felt in the gas pedal when the powertrain is boosting.

Further use of haptic devices is foreseen in future ADA systems. Like the lane departure warning system. This system gives vibrations in the left or right side of the chair to indicate that the car is deviating from the current lane.

2.1.4 Positions

In nowadays cars a few positions can be distinguished where information- and control systems can be positioned. In Figure 8 the following locations are formulated for information and communication systems.

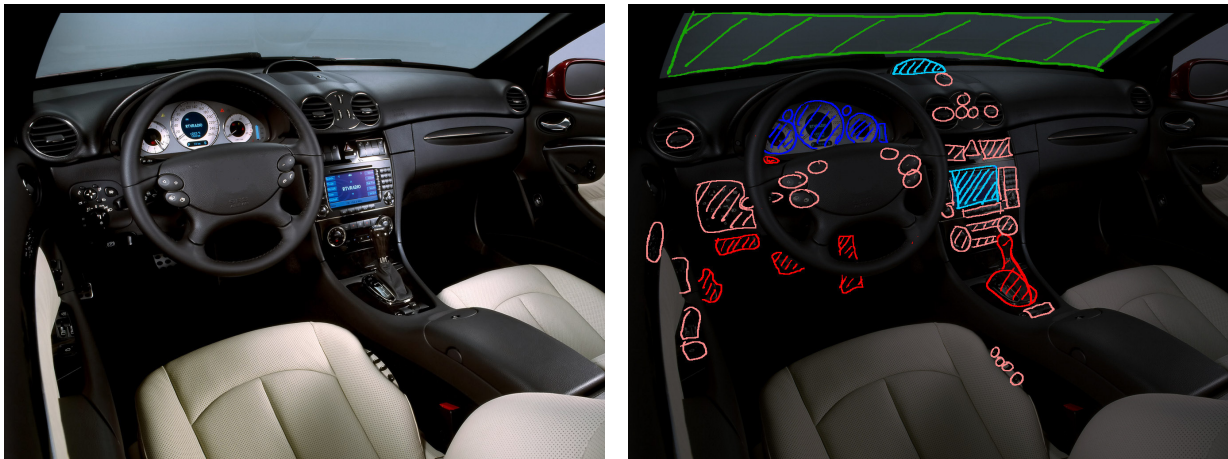


Figure 8 Position of controls and information systems in car interior

- Windshield
- Instrument cluster
- Dashboard
- Back seat compartment

This list is quite suitable for the information and communication systems in the car. However, it does not include (powertrain) control systems. Control systems are often found in some of the locations mentioned above.

To make the list workable for information systems, as well as for controls systems, general control and powertrain control systems are added and communication systems are deleted. This results in a slightly different list, containing information and control systems which can be used by the driver of the car.

- Windshield

The windshield is the closest place to the line of sight of the driver where information can be visually displayed. Modern cars sometimes contain devices that can display information on this shield. Such a projection device is called a Head-Up Display (HUD). No controls are accommodated here.

- Instrument cluster

This cluster contains some important information like speed and fuel levels. The cluster is located as close to the drivers' line of sight as possible. The driver has only to put his gaze a little away from the road scene. Only one control is mostly positioned on this location and that is the button to reset the trip counter.

Within this cluster the location of information is determined by aspects like the relevance to the driving-task, the frequency of looking at it and the complexity of the information.

- Dashboard

This place is used for all kinds of controls and information. The controls are for operating several systems in the car like the climate and the radio system. This location includes the left part of the dashboard, left to the steering wheel, and the mid part of the dashboard, including the vertical console. The mid section dashboard is also used when the front passenger has to have the possibility to have access to certain information and control systems.

- Steering wheel

The steering wheel is more and more used to accommodate several controls. Controls for climate systems and multimedia systems can by this be operate without taking the hands of the steering wheel. No information systems are found here.

- Mid tunnel

This place, as extension of the mid part of the dashboard, often accommodates several controls. Gear stick and handbrake can often be found here.

- Feet range

Here, important powertrain controls are located. Gas pedal and brake pedal can always be found here. In cars with a manual transmission the clutch can also be found here. Sometimes also a park brake pedal and hood opener can be found here. No information systems are accommodated here.

- Other

Among the 'other' locations is the left door. This often accommodates controls to adjust mirror positions or chair settings.

¹⁸ Wikipedia, http://en.wikipedia.org/wiki/Head-Up_Display.

There is a broad consensus that information systems have to be positioned on such a place in the interior of the car that the driver only has to direct his gaze very shortly away from the road scene. This is noticeable in car interiors because the instrument panel is positioned as close to the windshield as possible.

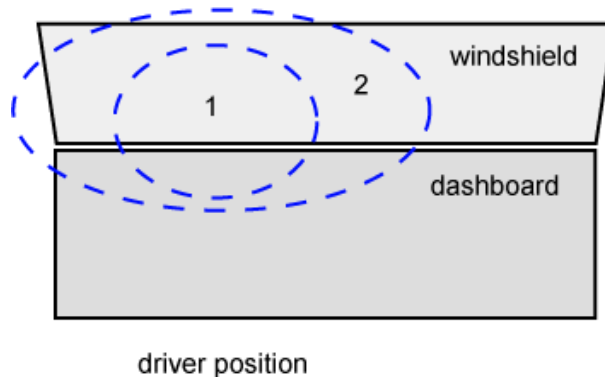


Figure 9 Location of information

Considering this, it is remarkable that locations like the A-style and roof-windshield edge are almost never used to accommodate information or control systems. In every A-style there is enough room for a small button and the driver can reach it with his arms without moving the rest of his body. The use of these locations will be considered later.

Use of the guidelines

The guidelines will be taken into consideration when designing interface. However, it is hard to meet every guideline that is available. This might slow down and obstruct the design process

2.1.5 Conclusion

The design of a user-interface for the powertrain will mainly focus on interactions that are relevant and necessary to operate the powertrain.

All kinds of developments are discussed and will be taken into account during the design process. This also account for the requirements and guidelines that come with these developments. After the design process these requirements and guideline will be used to evaluate the interface design.

2.2 Functions

The interactions between powertrain and user consist of controls and information flows. The powertrain is controlled by the user. The user accordingly uses different kinds of information flows to decide how to control the powertrain.

The interface has to accommodate the controls and information flows. The functions were analysed extended¹⁹. A storyboard was used for this²⁰. The functions of the interface therefore consist of these elements. In the list below, all the functions of the interface are listed. Some complex functions are divided in several sub functions.

Functions	Sub functions
Controls	
Change powertrain state	Turn powertrain "On" Turn powertrain "Off"
Change gear	Select P-gear Select D-gear Select N-gear Select R-gear
Change powertrain output	Increase powertrain output Maintain powertrain output Decrease powertrain output
Change brake force	Increase brake force Maintain brake force Decrease brake force
Information flows	
Indicate powertrain state	Indicate "On" state Indicate "starting-up" state Indicate "Off" state
Indicate which gear selected	Indicate "P-gear selected" Indicate "D-gear selected" Indicate "N-gear selected" Indicate "R-gear selected"
Indicate car speed	
Indicate critical fuel level	
Indicate critical level of available power for driving	
Indicate error	
Indicate current available power for driving	
Indicate total kilometres driven	

¹⁹ See supplement 2.

²⁰ See supplement 3.

by car	
Indicate trip kilometres driven by car	
Indicate current fuel consumption	
Indicate fuel level	
Explain the working of the powertrain	
	Explain the fuel-cell stack
	Explain the ultracapacitor
	Explain the electro motors
	Explain the energy flows in the powertrain
	Explain the start-up time
	Explain the available power
Indicate the regeneration of energy	
	Indicate when energy is regenerated
	Indicate how much energy is regenerated
Indicate extended fuel consumption information	
	Indicate energy regeneration
	Indicate historical powertrain fuel consumption
	Indicate fuel economy
Indicate range	
Indicate lack of sound	
Indicate fuel infrastructure	

Table 1: Functions and sub functions of the interface

During the concept design it will be tried to accommodate every (sub) function in the user-interface.

Conclusion

A workable list of functions for the interface systems has been derived from the interactions between powertrain and user. Some functions are divided into sub-functions because they are complex.

All (sub-) functions can be used to design an interface concept. Before that some boundary conditions have to be discussed. This is done in the next chapter.

2.3 Requirements

The powertrain user-interface has to fulfil all the functions that have been formulated during this research. But during this research also a lot of boundary conditions have been formulated. For example, the initiator of the project Car of the Future has started this project in order to let us develop a sustainable car. This means that the car has to be economical, but also that the car has to provoke a more economical driving style.

General

- The user-interface should enable the driver to operate the powertrain.
- The user-interface should be easily to accept.
- The user-interface should enhance the acceptance of the powertrain.

Functional

- The interface has to accommodate every function and every sub function as stated in chapter 2.2.
- The user has to be able to use the user-interface without explanation.
- The user has to be in control of the amount of information displayed. The use of multiple layers should be used to achieve this.

- Interface should enable an acquaintance with the powertrain technology.
- Interface should not shrink of displaying possible negative aspects. Doing this can help the user deal with.
- The interface has to support a sustainable solution.
- The interface has to be integrated in the car interior and with other user-interface systems.
- The interface should be able to use for different powertrains
- The interface should only display the information that is necessary at that moment.
- The interface has to be able to deal with more than one type of powertrain.

Ergonomics

- The user-interface should be able to use from the drivers position. This position is front-left in the car; the driver faces the forward driving direction.
- The user-interface should not present too much information to the user.
- Controls should be located in the reach of the arm or legs.
- Information should be easy to interpret.
- Information should be positioned as close the drivers line of sight as possible; the information with the highest priority should be positioned closest to that line of sight.
- The user-interface should not show superfluous information.

Safety

- The user-interface may not decrease driver safety during the driving task.

User

- The user-interface has to be suited for all drivers in the age of 18 to 80 years old.

Character

- The user-interface has to be simple, clever and effective.

Physical

- The user-interface has to fit in interior
- The impact of the use of the user-interface on the environment has to be as low as possible. (weight, materials used)
- It should be able to integrate with other in-vehicle information systems.

3. Design

In this chapter the designs of the user-interface will be discussed. They are presented together with a description of how the design process took place.

3.1 Introduction

The user-interface for the new powertrain consists of several parts, being controls and displays. These will all be positioned in the interior of the car. The exact location is not determined, because of the integration with other systems, which have to be accommodated in the interior of the car. However, basic requirements of the locations are yet determined.

The **primary display** contains important information, which is needed for the *driving task* and for the information regarding the *energy consumption*. The design of this display is quite elaborated. A lot of attention was paid to the presentation and ordering of information.

The **secondary display** contains information about *detailed energy consumption*, *historical energy consumption* and a *powertrain overview*. The contents of this display are only superficially elaborated.

The **controls** concern the basic powertrain operations, being: *powertrain state* and *driving direction*. These controls are also superficially elaborated.

<i>Part</i>	<i>what</i>
Primary display	Speed and energy consumption
Secondary display	Extended energy consumption
Controls	Start/stop button
	Gear selector
	Gas pedal
	Brake pedal

Table 2: The parts of the powertrain user-interface

Use of displays

Using digital displays offers a huge advantage over mechanical displays, because the displayed content is easier to change: First of all, the displayed content can be altered during a drive, when the driver needs to access various kinds of information. Secondly, the underlying software can be replaced or upgraded, without having to exchange physical components.

In chapter 2, it was already discussed that display technologies will have evolved in the year 2020. For example, it will be possible to display on a flexible material with sufficient contrast and color properties. These developments result in enough freedom in the positioning of the interface elements, because flexible screens can also be integrated in bended surfaces in the car interior.

The use of two displays instead of one has several reasons:

- The first display contains information which is necessary for the driving task. During a drive this information has to be accessed frequently, this could cause the driver to be distracted from his driving task. According to guidelines, the display should be located as close to the drivers' line of sight as possible, to make the glance at the display as short as possible.
- Other in-vehicle information systems in the interior of the car cannot use the first display, because the available space in that location is limited. Putting the information of the other systems here would result in a too high density of information.

- Other in-vehicle information systems could also be used by the passenger. Therefore the location of the display for these systems has to be different from the location of the first display.
- Other in-vehicle information systems will not be used all the time. So the display content can be made dynamical, this way the information can be alternated with other information. The user can control which information is showed in the display.

Character

For the user-interface it is tried to create a character that meets the following aspects:

- Effective
- Layered
- Simple
- Comprehensible

3.2 Primary display

For the design of the information elements, which resulted in the design of two digital displays, an extended design process took place. A lot of attention was paid to the presentation and ordering of the information. In this paragraph the design process and the designs are explained.

3.2.1 Design process

The starting point for the design process was the list of functions and sub functions in chapter 2 and the use of two digital displays. The primary display was located as close to the driver's line of sight as possible and the secondary display is positioned in the neighborhood of the driver and the passenger. In several steps, solutions were designed which are most suitable for fulfilling the functions. These steps will be explained below.

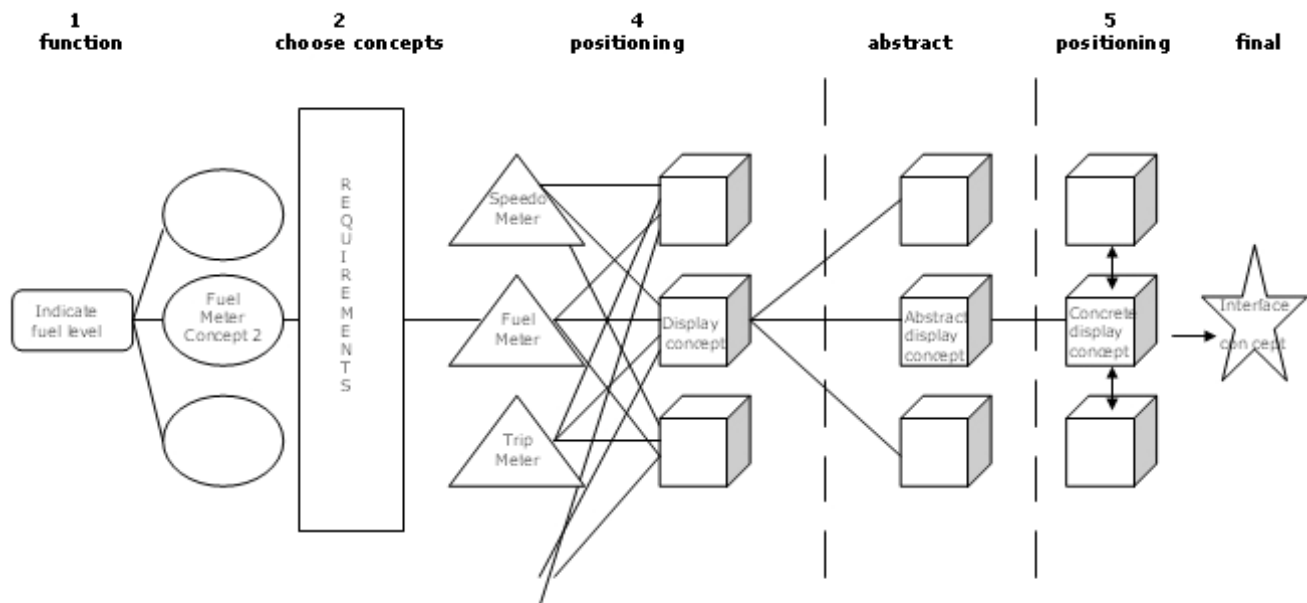


Figure 10: Overview design process

Step 1: Creating concepts for the information functions and sub functions. For example, for indicating speed and indicate available power. (See below and supplement 5)

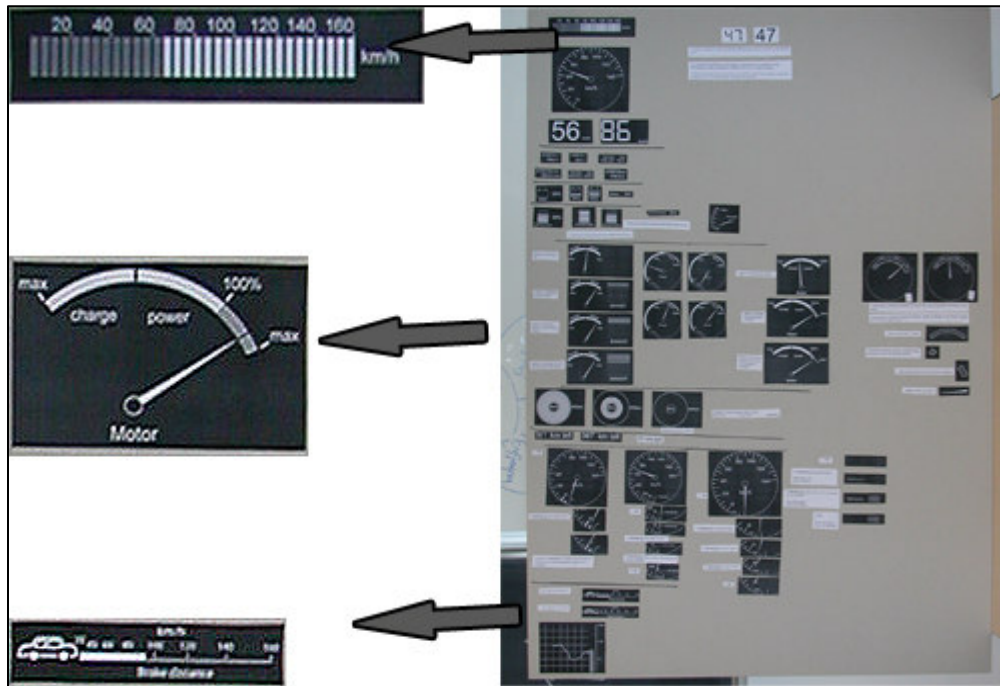


Figure 11: Concept development for information functions, resulting in information element concepts (left)

Step 2: Choosing information element concepts based on the list of requirements. This resulted in several information elements, which will be used for the interface concepts.

Step 3: It appeared that some of the information elements would be used frequently and quick and other elements would be used less frequent and more extended. Some elements required a complex design because they have to indicate some complex information. One of the properties of a digital display is that it can be switch on and off, even partly. With that property and the help of the storyboard²¹ a list was created in which the availability of information elements was pointed out. It lists, when which element appears in a screen. This list was upgraded later because new insights were obtained during the design process; the final list is presented here. To accommodate the more complex information elements, the use of a second display was also considered here.

²¹ See supplement 3.

		Interface element	Availability
Screen 1	Basic information	Textbox	On occurrence
		Speedometer	Always
		Odometer	Always
		Fuel gauge	Always
		Error messages	On occurrence
	Advanced information	Charge/assist meter	Always
		Fuel cells meter	Always
		Capacitor gauge	Always
		Fuel consumption indicator	Always
		Range Indicator	Always
Screen 2		Working of the powertrain	On demand
		Historical fuel consumption	On demand
		Fuel economy	On demand
		Other (settings, etc.)	On demand

Table 3: Availability of information elements

Step 4: All the information elements that had to be positioned in the primary display were placed. To find out the most optimal placing, the information elements were all abstracted. This way, only the general shape of the elements is used to judge the placing. An optimal placing is a placing in which the information elements are ordered simple, clear and logical. Several orders were considered. Some information elements were replaced by other concepts, until the optimal placing was found.

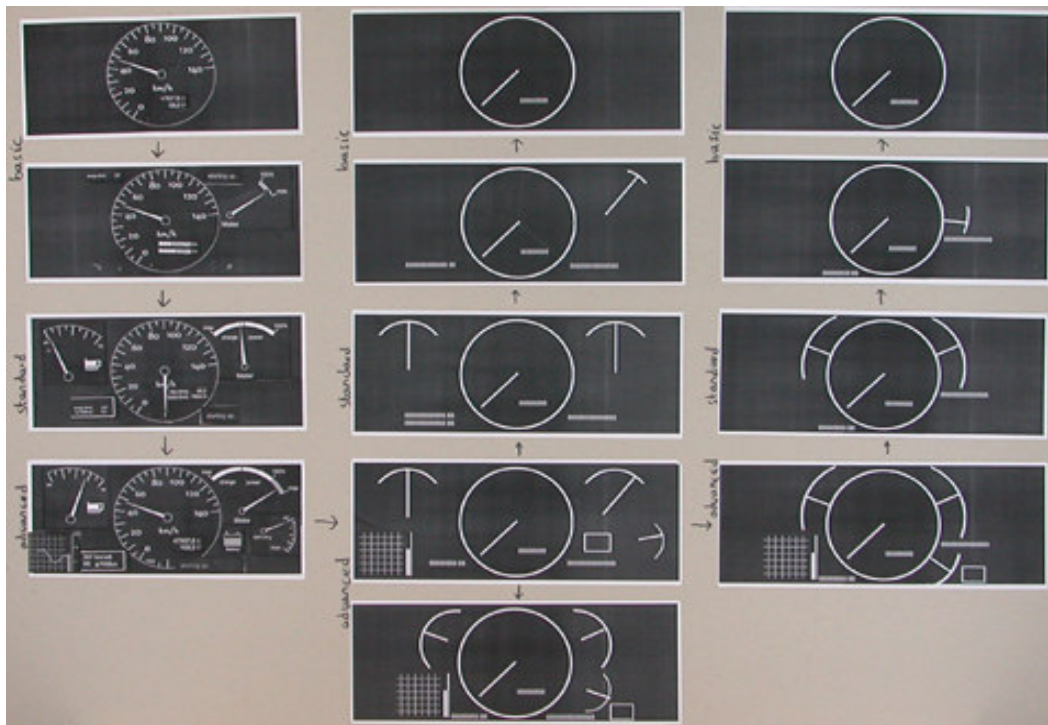


Figure 12: Interface concept development through assembly of information elements and abstraction.

Step 5: All information elements in the optimal placing were designed more detailed.

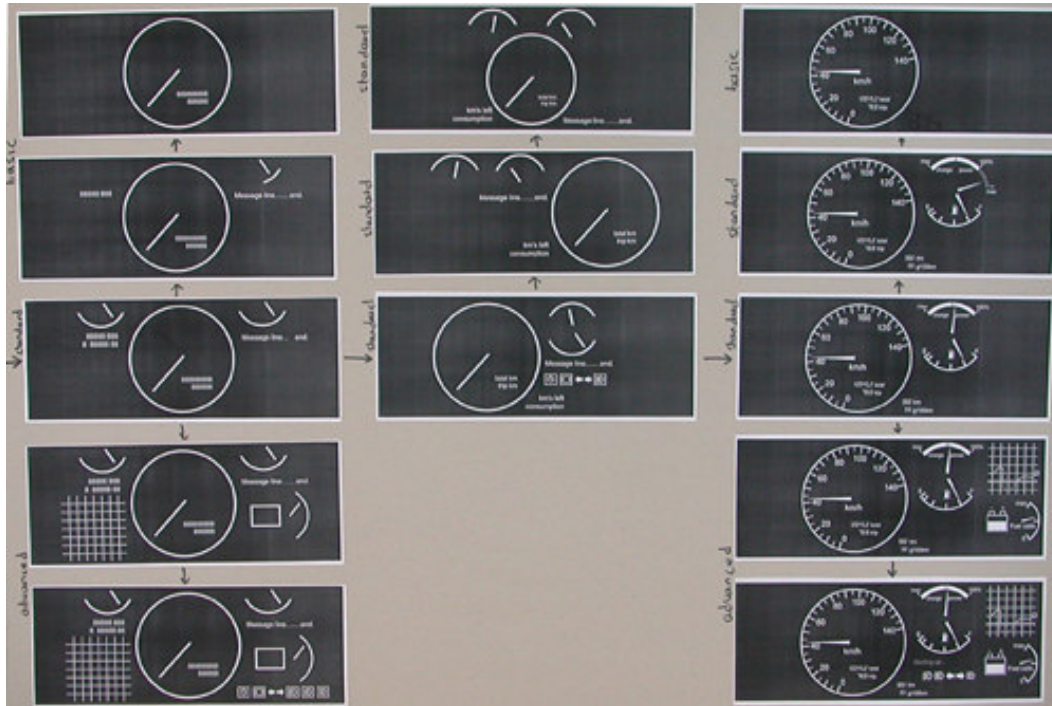


Figure 13: Interface concept development by making the abstracted concepts concrete again.

Step 6: This step concerns an evaluation of the designs. In this assignment, only a short evaluation is carried out, based on whether all functions will be fulfilled by the user-interface. A more detailed evaluation should be carried out as the next step in this design process. This should concern an evaluation, based on the design guidelines and requirements (see "Recommendations").

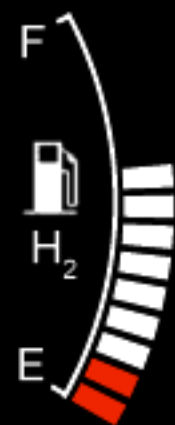
The steps in this design process were run through several times. During the entire design process several tools helped in creating suitable solutions. Like the use of pictures of several car interiors, but also train and plane cockpit interiors.

3.2.2 Specifications

The primary display will be positioned in the direct proximity of the drivers' line of sight, because this distracts the driver as less as possible from the driving task when he has to view the information. The dimensions of the display will be 361 mm x 135 mm. This is a little bigger than the space used in instruments clusters of current cars. Therefore it will provide enough space to accommodate the information elements. Not all the available space of the display is used, so the dimensions of the final design might be a bit different. This has to be found out when the display is evaluated, enhanced and integrated in the interior.

The background color is black and the primary color, used on the display is white, for a sufficient contrast. The primary font used is Arial, with a font size of at least 6 mm. For dynamic text, a digital font is used, also with a font size of at least 6 mm.

On the next page a screenshot of the primary display is presented on true size.



3.2.3 Basic mode

Initially, the primary display shows only the most basic information, being the odometer and the trip meter, because too much information could overload the driver. Basic information is the information necessary to be able to carry out the driving task safely:

- Speed (Speedometer)
- Fuel level (Fuel gauge)
- Text message (Textbox)
- Total driven kilometers (Odometer)
- Trip driven kilometers (Trip meter)

Speedometer

The design of the 'classical' speedometer is taken as base for the speedometer in this interface. A 'classical' speedometer is a round, clock-shaped meter with an equally divided scale. Mostly the speeds are indicated by a mark and a text every 20 kilometres. The advantage of using such an analogous meter instead of displaying a digital number is the readability¹. The difference of the change of speed between, for example a change of 1 km/h and a change of 20 km/h, will be clearly indicated in this speedometer by a bigger change of the angle of the pointer. In a digital number the change of the speeds is in both cases the change of a number. For the use of the speedometer in this user-interface, the 'classical' speedometer is modified by changing the scale.

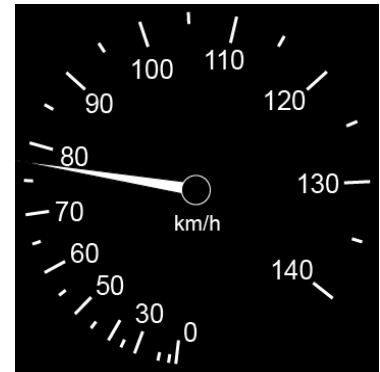


Figure 1: Speedometer

The scale of the speedometer of the new powertrain will be linear divided but quadratic divided, indicating that the amount of kinetical energy, saved in the car, increases quadratically as car speed increases only linear ($E_k = \frac{1}{2} * m * v^2$, E_k = kinetical energy, m = mass, v = speed).

Subsequently, this means that increasing car speed, increases energy consumption and braking distance even more. For example, for the braking distance it means that doubling the car speed means that this distance is four times as high ($E_b = F_b * x_b$, E_b = brake energy, F_b = brake force, x_b = braking distance).

The use of this unconventional scale should raise the awareness of the driver considering car speed in relation to energy consumption and braking distance. This will learn them that it affects environmental and safety issues.

The title "km/h" is added within the speedometer to indicate the unit for speed is kilometres per hour. No colour is used in this meter to make is as simple as possible.

Fuel gauge

The fuel level is indicated by a bar, which consists of several strokes. Each stroke represents an equal amount fuel in the tank. When the stroke is coloured white, it indicates that this piece of the tank is full. When the block is coloured red, it indicates that the available amount of fuel is critical. The blocks are ordered according to the downswing behaviour of the fluids in a tank.

The letters F on the top of the bar and E on the bottom of the bar indicate a Full or Empty tank. The symbol for a fuel tank is used together with the addition "H₂" to indicate that hydrogen is stored in the tank. This symbol is known worldwide

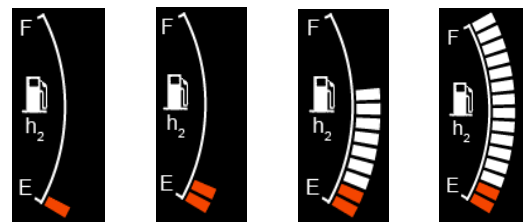


Figure 2: Fuel gauge at 5%, 10%, 60% and 100% level

¹ See supplement 5.

as filling station/fuel gauge symbol², and since this powertrain still has to be refilled on a regular base and on a similar way as we do nowadays with LPG, it would be obvious to use it in this user-interface, to improve recognisability.

When the tank is almost empty, this is indicated by two different behaviours of this interface items. First, the two last remaining blocks are coloured orange. Second, when the tank gets emptier, the last remaining orange bar starts to blink.

The bar is curved in order to make it possible to display some other information elements left of the fuel gauge, which are shaped similarly. These other elements will be discussed later, but some of those information elements use pointers. The use of too much pointers was avoided, too keep the interface orderly. Therefore, it is decided that a pointer in the fuel gauge is undesirable and strokes are used to indicate the available amount of fuel.

Textbox

In the design a text box is used. It can display limited number of text messages. A message is displayed for as long as the message is valid. When another message has to be displayed as well, the two messages are alternated in the textbox. A message is not valid anymore when the situation from where the message originated does not exist anymore or is passed by, by another situation. For example, a message indicating that the powertrain is starting up is not valid anymore when the powertrain has started up already. The message will disappear and another message is displayed, indicating that the powertrain has started up completely.

There are three types of messages, which are visually distinguished by their colour:

- A. Low priority information. Indicates a change regarding the powertrain system, no action by the user is required. These messages are coloured white in order to distract the driver as less as possible.
- B. High priority information. Indicates a change regarding the powertrain system, an action by the user might be required. These messages are coloured green to indicate that it is possible to proceed.
- C. High priority warning. Indicates a critical situation for which action by the user is required. These messages are coloured red, to indicate that the current drive needs to be interrupted as soon as possible and that an action is needed to prepare the car for further driving.

One of the functions of this interface element is to indicate the powertrain state.

The different **powertrain states** are *off*, *on*, *starting-up* and *'error'*. The change of states does not occur frequently and it occurs accompanied by the start of the trip or the end of the trip, except the error messages. The user usually knows when the change of state will occur. Therefore, the change of state itself will not be indicated by the interface.

During the state *off*, nothing is indicated on the interface.

The state *starting up* is indicated by a low priority information message (A) with the text "Starting up, please wait...".

The state *on* is indicated by the high priority information (B) message with the text 'System ready, start drive.'.

The messages below are also displayed in the textbox when necessary.

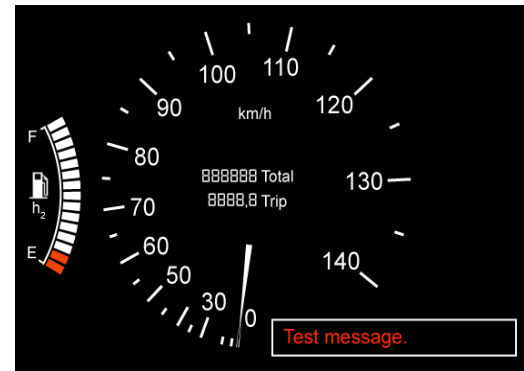


Figure 3: Screenshot showing the position of the Textbox (below, right)

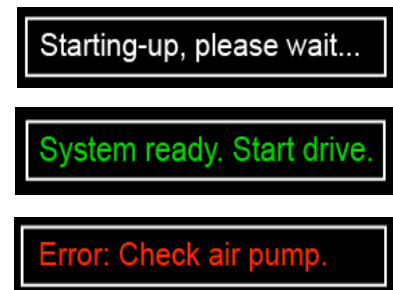


Figure 4: Screenshots of the textbox

² Dreyfuss, H. (1972), *Symbol Source Book*.

Type B

- "Warning: Low noise." The lack of noise is especially dangerous when the car drives through a busy residential area at low speeds. The driver will be warned for such situation by a message in the textbox.
- "Warning: Low fuel."

Type C

- Error messages
- "Warning: Low Power.". Indicating that the ultracapacitors are getting empty and that the current power demand cannot be fulfilled (anymore). This message is accompanied by an audio signal. A beep is played back to indicate that a warning message has appeared in the textbox.

Odometer and Trip meter

The odometer and trip meter are positioned within the speedometer. The number in the odometer is rounded off to a whole number. The word "Total" is placed next to the number to indicate that this number indicates the total driven kilometres. The number in the trip meter is rounded off to 1 decimal. The word "Trip" is placed next to this number to indicate that this number stands for the amount of trip kilometres.

Both numbers are not displayed in the Arial-font, but in a different digital font to indicate that these figures are dynamical. By consistently using this different font, the user will know that a figure or letter displayed in this font is subject of change.

The interface element for displaying the trip kilometres requires a control to reset this number. Resetting this number is required when a new trip is started. The accommodation of this control will not be discussed.

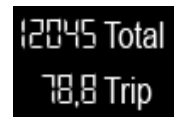


Figure 5:
Odometer and trip
meter

In the instrument clusters of current cars, these meters are often located in, or next to the speedometer. In this user-interface they are also located in the speedometer.

3.2.4 Advanced mode

The driver of the car has the possibility to let the display show more information than is displayed in the basic mode. This is done by means of a button or a switch; the controls for this are not designed in this assignment. The information available in this 'advanced' mode mainly concerns the energy consumption of the car.

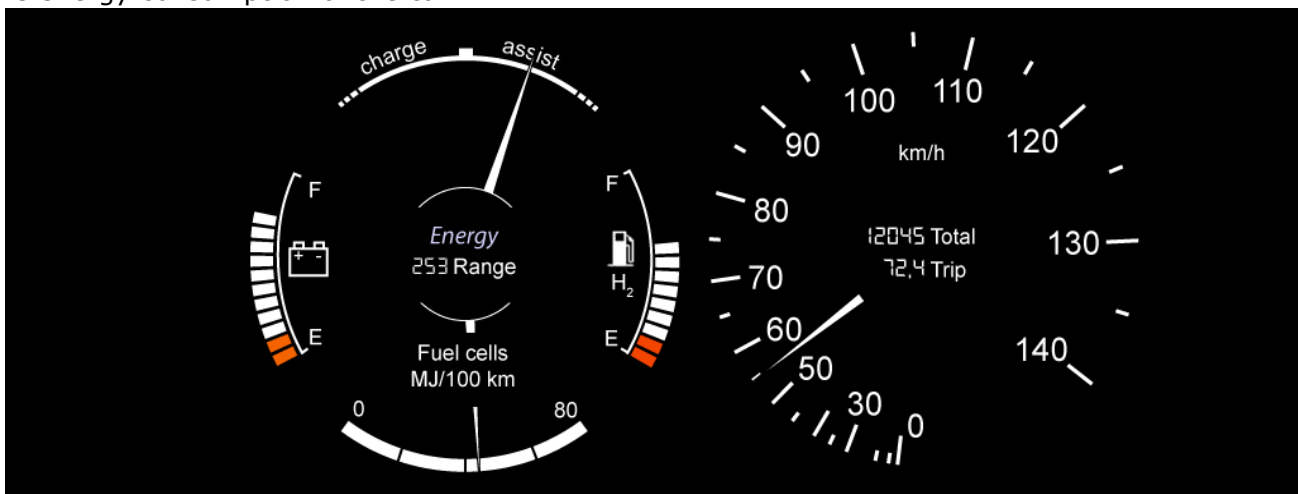
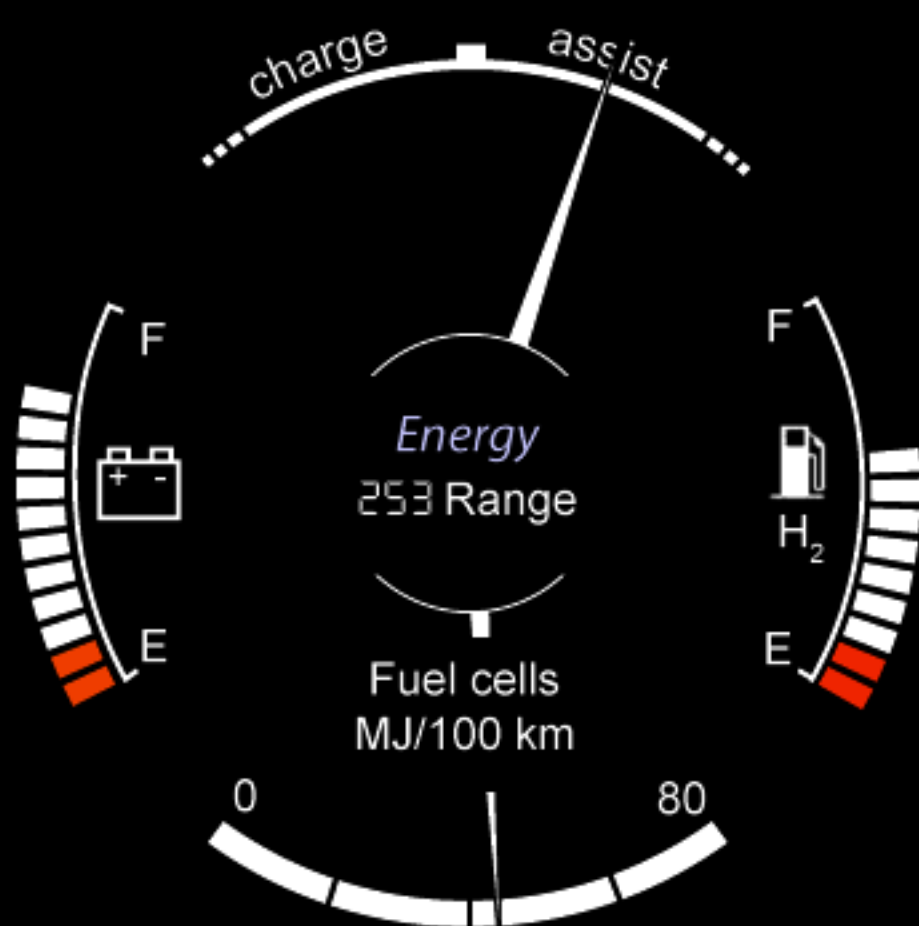


Figure 6: Screenshot primary display in advanced mode (scale 1:2)

On the next page a screenshot on true size can be found.



Not every driver wants to view the information of this advanced mode. But it is assumed that most drivers will be interested in this information, at least now and then.

This is encouraged by all kind of aspects of the car, which try to make the driver more aware of energy consumption and of the factors which play a role in that, for example the shape of the car and the design of the speedometer, but also the general background of the Car of the Future. The type of information and the behavior of the meters in this display require the same about the positioning of the information, as the information for the driving task does. Therefore they are positioned in this display and not in the secondary display.

The information elements concerning the energy consumption of the car are:

- Status ultracapacitor (Charge/Assist meter)
- Level ultracapacitor (Capacitor gauge)
- H₂ consumption (Consumption meter)
- Range indication (Range indicator)

Charge/Assist meter

The charge/assist meter represents the current operation of the ultracapacitor. The capacitor can be charged or can assist the fuel cells. Charging occurs when the fuel cells produce more electricity than needed for the powertrain or auxiliary systems and when braking regeneratively. Assisting occurs when the capacitor has to handle sudden changes in power demand. The amount of charging or assisting is indicated by a needle.

The use of a pointer for this meter is because a pointer indicates on a very quick and easily interpretable way the change in a situation. It is expected for the charge/assist situation to change a lot during a car drive. No numbers are attached to the meter because it is not important to know how much energy is used to charge or assist. Showing the exact amounts will not contribute to the comprehensibility of the meter.

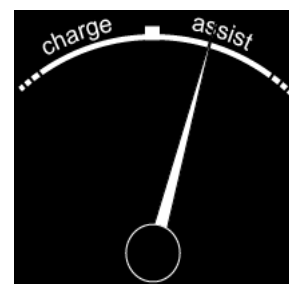


Figure 1: Charge/Assist meter

Capacitor gauge

This meter indicates how much energy is stored in the capacitor and thus, how much energy is available for the powertrain to use for driving operations. Just like the fuel gauge a curved bar of strokes is used for the same reason.

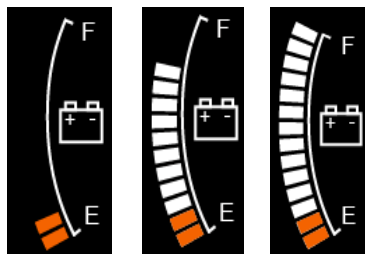


Figure 2: Screenshots of Capacitor gauge at empty, 75% and 100% level

When the meter reaches the two red strokes the message "Warning: Low Power" is displayed in the textbox and an audio signal is heard to indicate that the ultracapacitors are almost out of power.

The meter will indicate the two red strokes when the level of the ultracapacitor drops below the 50%. This is because in chapter 1, it was found out that using the ultracapacitors, when they are only charged for less than 50%, shortens the lifespan. The meter will also display the two red strokes when the electro motors have boosted and they reach the end of the current boost.

Consumption meter

The fuel currently consumed by the fuel cells is displayed by indicating the amount of used mega joules per 100km. The scale is from 0 to 140 MJ. A pointer is used to let the change in energy consumption appear very precise.

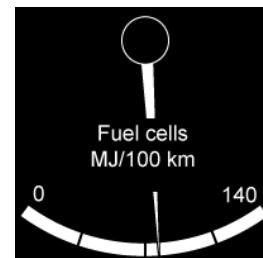


Figure 3: Consumption meter

Range indicator

This indicator displays the amount of kilometres that can be driven approximately, before the powertrain is out of fuel. The range is calculated based on of the current driving behaviour and current fuel level. The digital font is used for this.

A digital display showing the number '253' followed by the word 'Range' in a bold, sans-serif font. The text is white on a black background.

Figure 4: Range

3.3 Secondary display

3.3.1 Design process

The design of the secondary display is not as detailed as the design of the primary display, because of the limited time.

From the list of functions that the user-interface has to fulfill and the functions already fulfilled by the primary display several functions are derived which should be fulfilled by another display. These functions are described below and some conceptual ideas are presented of how these functions could be fulfilled.

3.3.2 Specifications

The secondary display will be positioned a little further away from the line of sight of the driver, because the information displayed here is accessed less frequent and should also be accessible for the passenger. The dimensions are 226mm x 169mm (4:3 aspect ratio).

As concluded from the discussion about other in-vehicle information systems it is assumed that more systems will use a screen in the interior of the car. Therefore this screen could be used in combination with other systems. For that reason, no background color or primary color is proposed for this display. The information elements will be discussed. The integration with the rest of the in-vehicle interface systems has to be done. This has to include:

- Common use of colors, fonts, backgrounds
- Creating a menu and information hierarchy

The following information elements were created to fulfill the remaining functions and were designed conceptually,:

- Working of the powertrain
- Fuel economy
- Historical fuel consumption

3.3.3 The screens

Working of the powertrain

When the user chooses to see the working of the powertrain, the main elements of the powertrain will be displayed by the means of a graphical representation. In this overview the main elements are the wheels, the electro motors, the capacitor, the fuel cells and the auxiliary systems. The energy flows between these main elements are also represented in this display. This will become an interface element giving a lot of information. It shows whether or not the fuel cells are operating, if the capacitor is charging or assisting and if the capacitors are charged with brake energy.

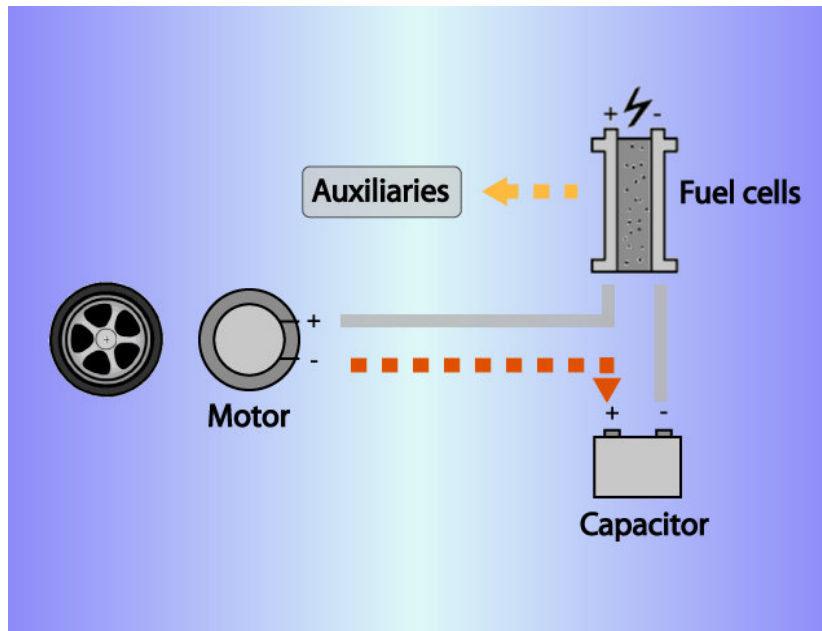


Figure 5: Screenshot secondary display (scale 1:2)

This interface element should only be displayed when the driver chooses to. The information is not necessary to drive the car, so this interface element has a low priority.

The information is not only interesting for the driver, but it could also be used to explain the working of the powertrain. For example, the salesman can explain it to the car buyer, or a car owner can explain it to its neighbour.

This screen is important in order to increase the acceptance of this powertrain by the driver.

Fuel economy

The fuel economy depends, among other things, on a lot of factors, being powertrain, suspension and several electrical interior systems.

The energy consumption of these systems can be displayed using a stacked bar. In this bar, each subsystem is represented by a colour. In an overview, an indication will be given of what systems consume which amount of energy in relation to the total energy consumption. The systems listed in this overview are:

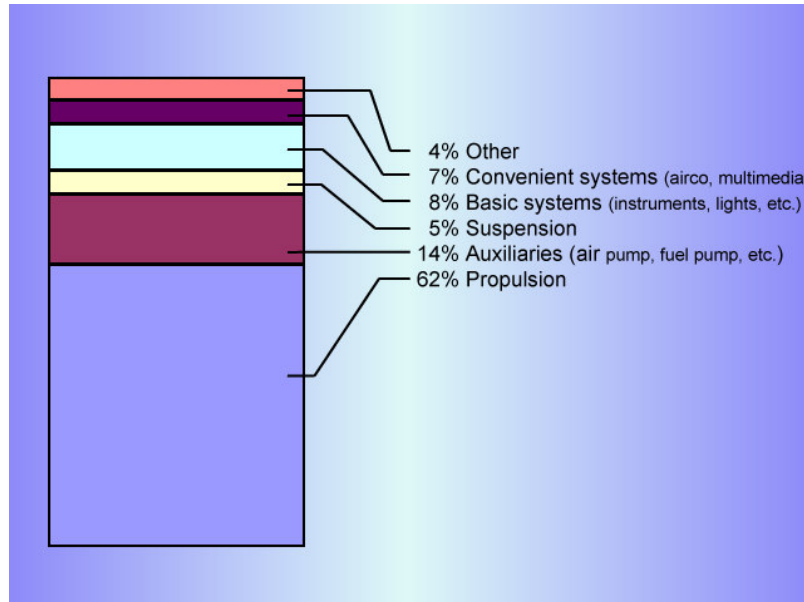


Figure 6: Fuel economy of electrical systems

- Propulsion
- Auxiliary (air pump, fuel pump, etc.)
- Suspension
- Basic systems (lights, instruments, wipers, etc.)
- Convenient systems (air conditioning, heating, multimedia, etc.)
- Other

The fuel economy screen will help to indicate what the energy consumption of the car depends on. This might increase the awareness of the driver about how his behaviour can affect fuel consumption. This will encourage the driver to drive more economic.

Historical fuel consumption

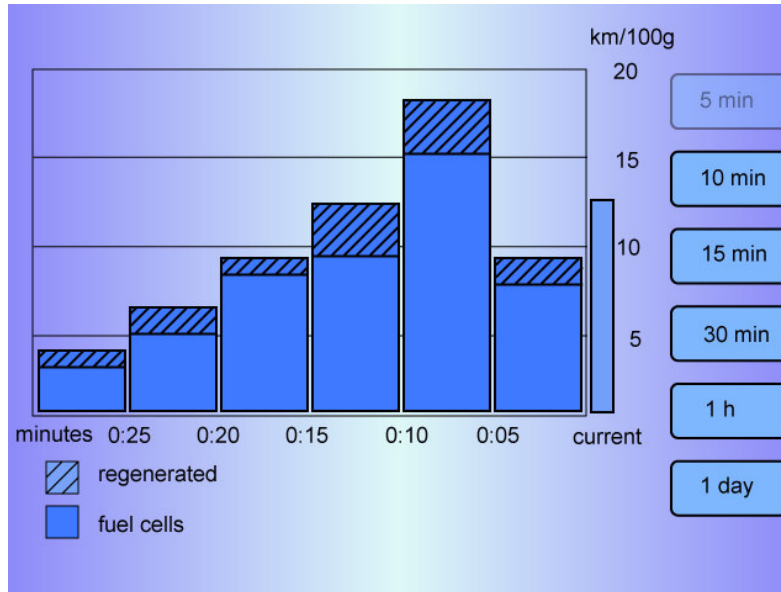


Figure 7: Historical fuel consumption

The historical powertrain fuel consumption can be indicated using a bar chart. Each bar represents the fuel consumption of the powertrain during a certain interval which can be set by the user. This bar includes how much energy was produced by the fuel cells to drive the car and how much energy is obtained by regenerative braking.

This interface element also has the ability to be downloaded on a personal computer. This way the data about fuel consumption can be viewed at home and shared with others like friends, employers and maintenance services.

This screen increases the awareness of the driver about the energy consumption of the car. It enables him to compare different driving situations in order to obtain the most efficient ride.

3.4 Controls

3.4.1 Design process

The controls for the designed interface are not designed very detailed, because of the limited time. The functions which have to be fulfilled are described below and some conceptual ideas are presented of how the functions could be fulfilled.

3.4.2 The controls

The controls should be located near the driver's arms or legs. All the powertrain controls have to be handled by the driver only and not by passengers. In the following paragraphs, all interface controls elements will be described.

Start/Stop button

The powertrain has two states, *on* and *off*. But before the state *on* can be used, the powertrain has to start up. When the start-up has completed, the *on* state is automatically entered. Starting-up lasts a few seconds.

The turning on of the powertrain probably takes place at the same time

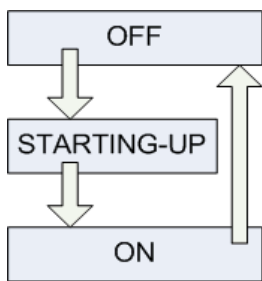


Figure 9 Powertrain states

as the switching on of the other systems in the car. These systems also have to be switched on by the user. Both controls can be combined in a single control. Handling this control initiates the switching on of the 'car', meaning that the powertrain and other systems are activated. The control has to be accommodated in the car interior. Since this interior has to be designed, it is difficult to design this control. For now, a push button is used to switch the car on. The button's diameter is 30 mm.

Integration with other in-vehicle systems is recommended for this control, because probably other in-vehicle systems probably also need an on/off button. This might be combined with the start/stop button for the powertrain.



Figure 8 Start/Stop button (scale 1:1)

Since turning on the powertrain is an important function (all kinds of driving controls become activated when the powertrain is turned on), it is important that the powertrain cannot be turned on by passengers like children.

Therefore, safety measurements should be taken. In order to turn on the powertrain when the button is pressed the driver has to be in his chair. This could be checked by a sensor in the seat which checks the occupation of the seat. Another solution is to let the driver wear a proximity sensor. Only when he is within a certain distance of the car, the powertrain controls become activated.

Gear selector (P/D/N/R)

Gear selection does not occur a lot in this car, but it is an important function, since it regulates the driving direction of the car.

The gear selection is accommodated in a set of four push buttons. Each button represents a single gear. When one of the buttons is pressed, this button will light up and the according gear will be activated. Only one button be active at the same time, meaning that only one gear can be selected at the same time. Pressing a button only results in a selection of the according gear when the car does not drive or drives very slowly (up to 3km/h).

The four buttons are positioned in a typical shape, indicating that the

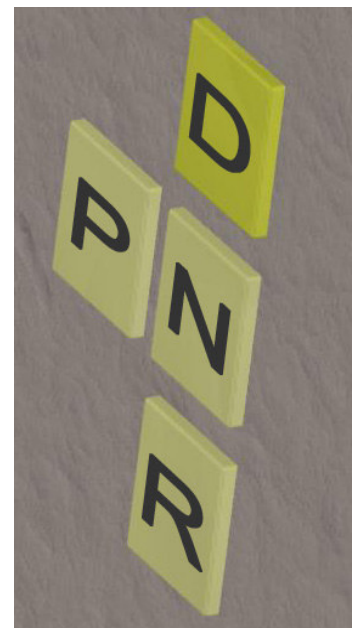


Figure 10: Gear selector (scale 1:1)

D and R gear result in a driving direction and P and N are used when the car stands still.

Gas pedal

Users can learn to operate pedals, for example to regulate car speed, as if the pedals were an extension of the human body. Therefore, pedals will be used in the car of the future as well. A 'gas' pedal regulates the amount of input for the electro motors. The input depends on the position of the pedal. The position can be altered using a foot. The further the pedal is pushed, the more input is delivered to the electro motors. Stepping on the pedal causes a spring attached to it to compress, so when the foot is removed from the pedal the pedal goes back to its 'rest' state. Matching the pedal position with the car speed has to be avoided, because the electro motors will react too immediately. When stepping on the gas, the position will be matched to the power output of the electromotor. When stepping off the gas, the power output will not be matched with the pedal position.

Instead, the electromotor will declutch from the wheels. Gliding of the car is the result. When the power output matched the current pedal position, the electro motors are clutched to the wheels again.

The increase and maintenance of the speed is done by pushing the 'gas' pedal more and more, and respectively maintaining the position of the gas pedal. The decrease of car speed is achieved by letting this pedal get more to its 'rest' position. The car then slowly decreases speed.

Brake pedal

Another pedal is used to decrease car speed more quickly.

This second pedal handles the brakes. Stepping on this 'brake' pedal results in a brake force delivered to the wheels resulting a decrease of car speed. Stepping off this pedal, results in less brake force delivered to the wheels.

3.5 Conclusion

The interfaces designed in this chapter concern displays and controls. The displays do not display all the information all the time, because the information depends on a certain condition of the powertrain or the amount of information the driver wants to display. Below, all the interface elements discussed in this chapter are listed:

		<i>Interface element</i>	<i>Availability</i>
Powertrain controls	Hand controls	Start/stop button	Always
		Gear selector	Always
	Feet controls	Gas pedal	Always
		Brake pedal	Always
Display controls	Hand controls	Trip reset button	Always
		Basic/advanced selector	Always
		Other display controls	..
Screen 1	<i>Basic information</i>	Textbox	On occurrence
		Speedometer	Always
		Odometer	Always
		Fuel gauge	Always
		Error messages	On occurrence
	<i>Advanced information</i>	Charge/assist meter	Always
		Fuel cells meter	Always
		Capacitor gauge	Always
		Fuel consumption indicator	Always
		Range Indicator	Always
Screen 2		Working of the powertrain	On demand
		Historical fuel consumption	On demand
		Fuel economy	On demand
		Other (settings, multimedia, etc.)	On demand

Figure 11: Availability of information and controls

4. Evaluation & conclusion

This chapter contains the evaluation and conclusion of the assignment. First, a short evaluation of the designs is carried out. Second, recommendations are listed. Third, an overall conclusion is given.

4.1 Functions

The next step in the design process would be to evaluate the interface designs. Unfortunately, due to limited time, such an extended evaluation is not included in this rapport. However, a short evaluation concerning the fulfilment of the functions and the sub functions is carried out and listed below.

Functions	Sub functions	Interface element
Controls		
Change powertrain state		
	Turn powertrain "On"	Start/stop button
	Turn powertrain "Off"	Start/stop button
Change gear		
	Select P-gear	Gear selector
	Select D-gear	Gear selector
	Select N-gear	Gear selector
	Select R-gear	Gear selector
Change powertrain output		
	Increase powertrain output	Gas pedal
	Maintain powertrain output	Gas pedal
	Decrease powertrain output	Gas pedal
Change brake force		
	Increase brake force	Brake pedal
	Maintain brake force	Brake pedal
	Decrease brake force	Brake pedal
Information flows		
Indicate powertrain state		
	Indicate "On" state	Text box
	Indicate "starting-up" state	Text box
	Indicate "Off" state	Text box
Indicate which gear selected		
	Indicate "P-gear selected"	Gear selector
	Indicate "D-gear selected"	Gear selector
	Indicate "N-gear selected"	Gear selector
	Indicate "R-gear selected"	Gear selector
Indicate car speed		Speedometer
Indicate critical fuel level		Fuel gauge/Textbox/Audio 1
Indicate critical level of available power for driving		Textbox/Capacitor gauge/Audio 2
Indicate error		Textbox/Audio 1
Indicate current available power for driving		Capacitor gauge/fuel gauge

Indicate total kilometres driven by car		Odometer
Indicate trip kilometres driven by car		Odometer
Indicate current fuel consumption		Fuel consumption indicator
Indicate fuel level		Fuel gauge
Explain the working of the powertrain		
	Explain the fuel-cell stack	Working of the powertrain
	Explain the ultracapacitor	Working of the powertrain
	Explain the electro motors	Working of the powertrain
	Explain the energy flows in the powertrain	Working of the powertrain
	Explain the start-up time	Textbox
	Explain the available power	Capacitor gauge/fuel gauge
Indicate the regeneration of energy		
	Indicate when energy is regenerated	Charge/assist meter
	Indicate how much energy is regenerated	Capacitor gauge
Indicate extended fuel consumption information		
	Indicate energy regeneration	Charge/assist meter
	Indicate historical powertrain fuel consumption	Historical fuel consumption
	Indicate fuel economy	Fuel economy
Indicate range		Range indicator
Indicate lack of sound		Text box
Indicate fuel infrastructure		

Figure 12: Functions and sub functions of the interface

The evaluation points out that only the function “Indicate fuel infrastructure” is not fulfilled by the user-interface. All the other functions and sub functions are fulfilled by the designed user-interface.

4.2 Recommendations

Evaluation

- The user-interface should be evaluated with the help of the requirements and design guidelines, in order to judge it on usability.
- The displays should be tested and evaluated by a representative target group. The usability has to be tested, for example by users with colour-blindness and concerning the comprehensibility of the interface.
- The user-interface should be tested with the real powertrain, order to find out if everything works the way it should.

Detailing design

- Solutions have to be designed for the controls that were encountered during this design process which are necessary to control the user-interface itself. For example, the design of

the trip reset button, the basis/advanced mode selector button and other (display) controls.

- The designed user-interface and other in-vehicle user-interface systems should be integrated.
- The function "Indicate fuel infrastructure" should be considered.
- The use of customization of the displays should be considered. Digital display offer enormous possibilities. One of those is that car manufacturers or drivers themselves could design the information elements and placing of the user-interface.

4.3 Conclusion

The use of the fuel cell powertrain in the Car of the Future as described in this rapport, can cause several acceptance problems, but can also accelerate the acceptance.

To deal with acceptance problems and to use factors which will increase acceptance, the user-interface for the powertrain offers opportunities.

The designed user-interface offers information to the driver to drive the car safer, more efficient and more ecological, by offering clear, unambiguous and useful information and providing effective controls.

The information educates the driver, by explaining the technology of the powertrain and indicating the possibility to influence the powertrain behaviour. This could stimulate the driver's awareness of the relation between the driver's driving behaviour and the energy consumption of the powertrain.

The design of the user-interface has to be used as a base for the development of a final design of the user-interface for the powertrain of the Car of the Future. The integration with other in-vehicle interface systems, the car's interior and the powertrain are the most important aspects to regard during the last design phase.

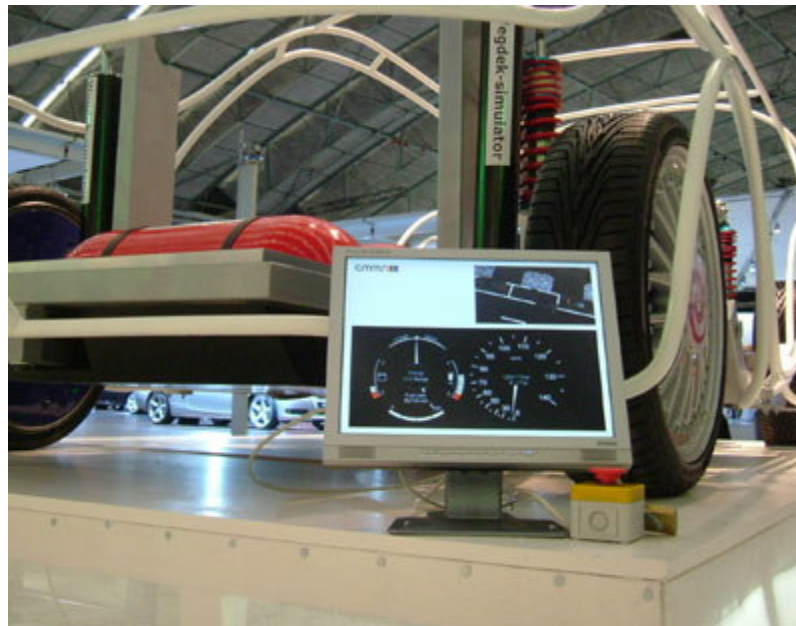


Figure 13: Demonstration of the user-interface at the AutoRai 2007.

Word list and abbreviations

Powertrain	The entire system needed to propel the vehicle. This extends from the fuel tank, as the primary energy source, to the tires, which are the elements that interact with the road.
Regenerative braking	Electro motors do not produce movement only. When they are connected to electricity, they also work the other way around. They also produce electricity when they are moved by something else. This fact can be used while braking. During this process, the electro motors behave as a generator. Doing this, they consume a part of the brake energy; this will be converted to electricity.
Well-to-wheel	Term to indicate the environmental impact of a given product or service throughout its lifespan, looking from the well, to the output, being the wheels when considering a car.
Tank-to-wheel	Term to indicate the environmental impact of a given product or service throughout a part of the lifespan, looking from tank to wheel.
Driving-task	All the tasks which have to be performed by the driver in order to drive the car.
Longitudinal	Length.
Lateral	Sideways.
GUI	Graphical user-interface.
SNM	Stichting Natuur en Milieu, English: The Dutch Society of Nature and Environment.
3TU	The federation of the three Dutch Technical Universities.
FC	Fuel cell.
UC	Ultracapacitor.
PEM	Proton Exchange Membrane.

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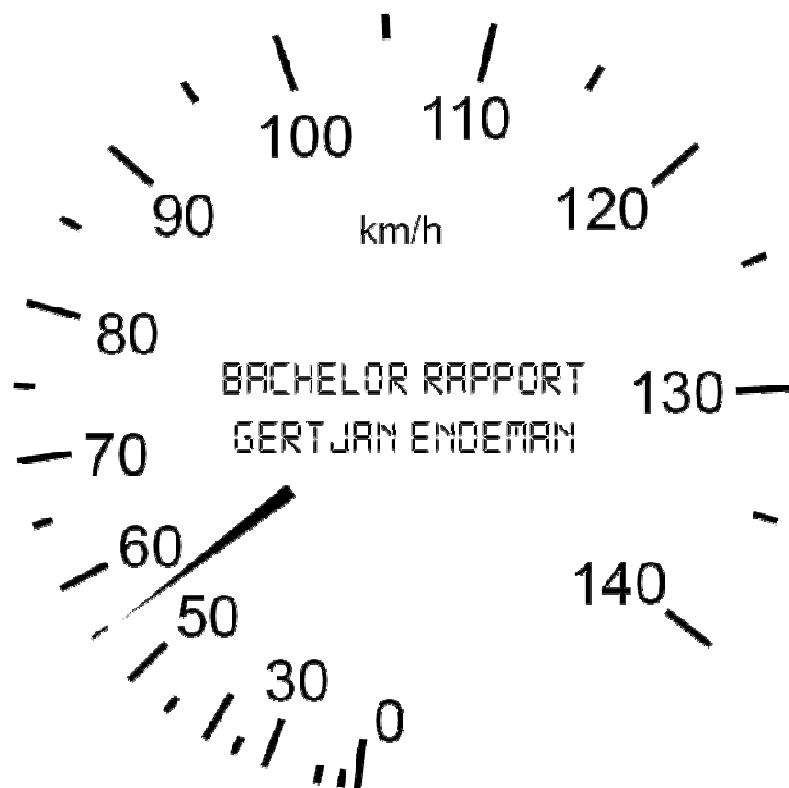
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**The design of a user-interface for the powertrain of a car in the future
... in order to improve the acceptance of this powertrain.**

Supplements



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1. Acceptance of alternative automobile technologies

1.1 Introduction

The use of alternative technologies (or parts or products) in the powertrains of automobiles means changes in the basic characteristics of the car. In order to let consumers accept these changes and to let them buy the new, different car, possible acceptance problems of the new powertrain have to be taken into account. Therefore, we take a closer look at previous attempts to introduce new technologies in powertrains.

Previously introduced new technologies, which affected the automobile, are discussed, like the use of different fuels, different transmissions and different engines.

The objective of this discussion is to point out the factors, which could affect the acceptance of new powertrains.

Approach

The use of different technologies, as mentioned above, results in a new powertrain. These new powertrains can be seen as alternatives for conventional powertrains.

Several powertrain alternatives will be distinguished on the bases of engine type, fuel type and transmission type. For example: a powertrain running on gas and a powertrain running on diesel are two powertrain alternatives.

To be able to distinguish more powertrain alternatives, a schematic overview is needed.

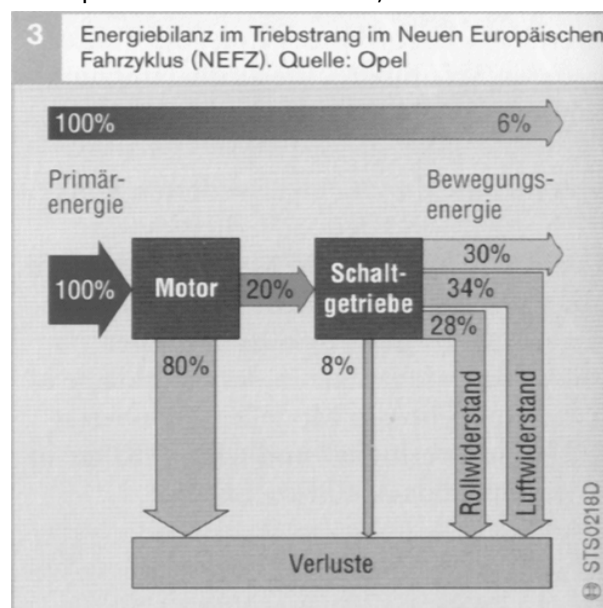


Figure 1 Efficiency diagram of energy (Bosch, *Sicherheits- und Komfortsysteme*, 2004)

The conversion of energy by the powertrain will be taken as base for the overview.

The powertrain's function is to propel the car, in order to let it move. The driver of the car controls the direction and speed of the movement.

Performing this function, the powertrain is nothing more than a device that converts energy in several steps. For example: it converts fuel (chemical energy) to engine speed (kinetical energy) and engine speed to wheel speed. Unfortunately, a lot of energy is wasted during the process of converting energy. This is inevitable in such energy conversion processes. (zie plaatje)

The -energy conversion- process is taken as the base for the description. Since different powertrain alternatives can use different types of fuel the -energy supply- is also discussed.

The overview is energy-based. Each powertrain alternative will be described, starting with a description of the energy supply. This description consists of *energy source*, *energy-carrier* and *distribution of carrier*. Second, the energy conversion is described. Described here are *energy storage*, *energy converter*, *transmission* and *motion*. Each of these aspects has a certain interaction with the driver.

These are the links between user and products/technologies. For example: during a car ride, the driver controls the powertrain, but his handlings are a result of his decisions, which he makes on base of the desired driving behaviour (related to the other traffic) and current vehicle conditions. The interactions which are necessary to achieve this will be added to the overview and discussed.

Not every element in the overview is different for each powertrain alternative. These elements are included in the paragraphs that will follow subsequently: *classical, transmission, liquid fuel, gaseous fuel, electrical propulsion* and *hybrid propulsion*.

1.2 Classical automobiles

The overview starts with the gas powered internal combustion engine car with a manual transmission gearbox. This 'classical' car will be used as starting point. Alternatives are compared with this classical powertrain, but also with each other.

Table 1 'Classical' car

Internal combustion engine running on gas and using a manual transmission gearbox			
	<u>Energy path</u>	<u>Technical solution</u>	<u>User interaction</u>
energy supply	Energy source	Fossil fuels: non-renewable energy	Vague knowledge
	Energy carrier	Gas. A liquid mixture derived from fossil fuels.	The substance smells, is dirty, toxic, ignitable and explosive.
	Distribution of carrier	Mostly fill stations are supplied by tankers which use public road infrastructure.	Extensive infrastructure of fill stations. Usually within a few kilometres of residence.
energy conversion	Energy storage	A storage room (tank) in the car is filled with the liquid fuel	Driver is warned on 'low fuel' and has to fill up the tank himself accordingly at a fill station. Filling takes a few minutes. Tank volume and weight affect package of the car and radius of action.
	Energy converter	An internal combustion engine burns the fuel generating kinetical energy. The burning of the fuel is done by exploding the compressed fuel.	Driver can start and stop the engine using a key. The burning process produces a lot of noise and vibrations. Driver has direct control in torque and power supplied by handling the gas pedal.
	Transmission	A gearbox uses multiple gear wheels to transmit the engine speed to the wheel speed at a most efficient relation. When engine speed and wheel speed are disconnected, gear wheels can be changed. After that, the engine speed and wheel speed can reconnect again.	The driver can choose gear using (1) the clutch pedal to disengage the clutch, (2) choose gears using the gear lever and (3) engage the clutch by releasing the clutch pedal. The choice of gear depends on the wishes of the driver with regards to the other traffic. The choice consists of accelerating, decelerating or maintaining speed
	Motion	The car is moved.	Driving-experience consists of acceleration, braking, gliding, noise, vibration, consumption and pollution.

Driver interaction

A car with this powertrain cannot be operated on an easy and intuitive way. For example, the interactions that are necessary in order to increase or decrease the car's velocity, are a direct result of the technology used in this car. The driver has to be aware of speed, revolutions and the current traffic situation, in order to make a decision about which gear to use. Subsequently, he has to operate a clutch, throttle and gear shift to change gears. These are a many factors which have to be considered and many operations that have to be performed by the driver, for only increasing or decreasing the cars' velocity.

From a human factors point of view we would rather see that the driver only has to handle a single input to indicate the powertrain to increase or decrease car speed.

Acceptance

The current technology is accepted because it is the only alternative available. A lot of effort has to be put in learning how to handle this machine. Because of this, changes on handling solutions are not desired.

Conclusion

The 'classical' car is totally accepted because it is a common product and the drivers know how to handle this car. However, the handling of the car requires many actions and practice. This has not changed a lot during the last decades while the technology did.

1.3 Transmission alternatives

The use of different transmission types will be discussed here. The technical solution will be mentioned, but now more extended than in the previous paragraph. Accordingly, the resulting driver interaction and acceptance will be mentioned. The "transmission" aspect from table 1 is used as starting point

1.3.1 Manual transmission using gearwheels

Introduction

As seen in the overview above, the transmission of a car has the task to transmit the power from the power source (the engine) to the road surface (through the tires). The engine's speed depends on how much the driver steps on the gas. An internal combustion engine has a certain engine speed where it performs at its optimum, in terms of power output or fuel economy. The gearbox tries to use this property as efficient as possible. The 1st gear converts the high engine speed to a lower number of revolutions for the wheels (wheel speed). When the driver steps on the gas the driving speed increases because of the increasing engine speed. When the engine has reached its top speed the driver has to gear up. The first step in doing this, is to declutch the gear from the engine by handling the 'clutch' and stepping off the gas bringing the engine to a lower speed, while the car keeps rolling. The second step is to change gear from 1st to 2nd, by handling the gear stick. The second gear has a different converting ratio compared to the first gear. It converts the engine speed to a higher wheel speed than the 1st gear does. Third step is to clutch the engine back to the gearbox again. Now the driver can accelerate again, by stepping on the gas.

Usually 4-6 gears are used in a manual gearshift in order to get from standing still to top speed.

Driver interaction

As mentioned already, the driver's input consists of handling the gas pedal, clutch and gear stick. This gear stick is used to shift to another gear. This shift comes with a feeling of a jerk because of the temporary lack of power. This is caused by the fact that the connection between the engine and the gearbox has to be interrupted for a short moment in order to change gears. This lack of power is typical for manually shifted cars (Figure 2).

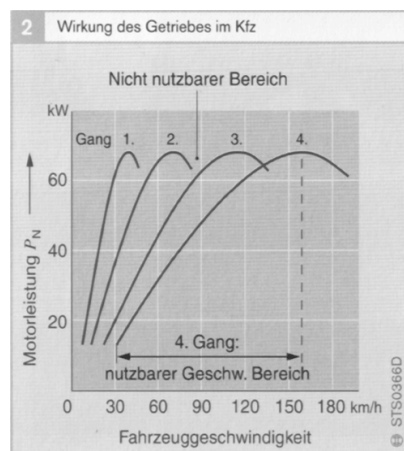


Figure 2 Velocity development with a manual transmission (Bosch GmbH, Sicherheits- und Komfortsysteme), 2004

When the driver steps off the gas and the wheels are still 'in gear', the situation is reversed: now the wheels propel the engine because the car is using its already obtained speed to continue to drive. The engine's inertia slows down the car's velocity.

Acceptance

As already mentioned, most people are familiar with this kind of transmission. There are a lot of alternative transmission types which may be superior in terms of driving experience and fuel consumption. However, manually switching gears gives a feeling of being in control.

1.3.2 Automatic robotic transmission

A robotic gearbox automatically changes gear. This includes taking care of handling the clutch to temporarily interrupt the connection between the engine and the transmission. The time this transmission needs to change gears is less than the time the driver takes for this operation. It can result in a more comfortable drive, because of a shorter and less fierce jerk. It also results to a more economic drive because the automatic transmission can be programmed when it has to shift gears, in order to be as economic as possible.

The gearbox decides when to gear up or to gear down. It also senses if the driver handles the accelerator pedal aggressively or calmly and reacts on this accordingly. The robotic transmission takes care of changing gear at the right moment. The decision to change gears is made by the gearbox itself. It compares current engine speed and gas pedal position with pre-installed data and reacts according to it. Often a comfort mode or a sport mode can be chosen. Both modes cause different fuel consumption and performance behaviour.

However, the right moment to change gears can still be variable; it depends on the current needs and wished of the driver. The gearbox does not know the drivers current mood. This is important because the driver will only put the transmission to the automatic mode when it will change gears according to his satisfaction. The driver will only be satisfied when the behaviour on changing gears is as good as or better than the driver's own behaviour on changing gears.

Driver interaction

The driver has to select the forward or backwards driving direction, the parking mode or the neutral mode.

The driver uses the gas pedal and brake pedal to accelerate or decelerate causing the transmission to change gears. The driver feels the jerks, indicating a gear shift. A display on the dashboard is sometimes used to indicate the currently used gear.

Acceptance

Drivers have certain 'changing gears' behaviours. They are familiar with a car's development of velocity and know how to handle the gearbox in order to accelerate quick, economic or comfortable. An automatic robotic transmission takes away the ability to choose when to change gears. Drivers' expectations don't always match gearbox behaviour. So some robotic transmissions cannot satisfy the driver. For example the first generation sequential gearbox of the *Smart fortwo* has often been criticized for making slow and delayed shifts. Driving this car the driver rather changes gear himself.^{1,2}

1.3.3 Manual robotic transmission

The robotic transmission can function as a manual gearbox but also as an automatic gearbox. In manual mode the driver can decide when to change gear by choosing to gear up or gear down. The gearbox takes care of the changing gear procedure. However, when the driver lacks to change gear the gearbox will change gear itself because otherwise the engine could suffer under the wrong handling of the driver.

¹ Autowereld: <http://www.autowereld.com/rijimpressies/detail.asp?artikel=2702>, accessed 4 july 2006.

² Autoweek: <http://www.autoweek.nl/autotestrapport.php?id=1341&cache=no>, accessed 6 july 2006.

Driver interaction

The driver can override the automatic mode of the robotic transmission by choosing the manual option using the gear stick. During manual mode the driver uses the gear stick or gear flippers at the wheels to shift gears. Like in automatic mode, the used gear is indicated in some cars.

Acceptance

The driver's decision to change gears is an improvement compared to automatic robotic transmissions. But since the procedure of changing gears is still done by the gearbox itself, this procedure can still be very slow, as already mentioned during the discussion of automatic robotic transmission.

1.3.4 Continuous variable transmission

A continuous variable transmission (CVT) does not work with a number of fixed gears. This transmission constantly changes the conversion between the engine and the wheels while speeding up. This enables the engine to constantly operate at its most efficient number of revolutions, causing this kind of transmission to behave different compared to transmissions using multiple gears. Those cars reach their top speed in 4-6 steps. During each of these steps the car accelerates when the driver steps on the gas.³

Driver interaction

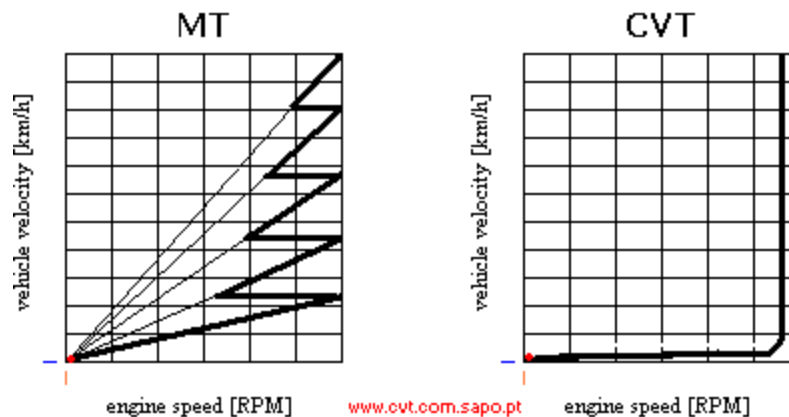


Figure 3 Comparison manual transmission vs cvt

In this transmission, the gearbox itself decides how the engine should provide the desirable car speed according to a certain pedal position and handling. The decision of the gearbox is based on a most efficient and economic engine performance. Often, user experiences on how to obtain an efficient and economic engine performance are not quite right, this results in a certain engine behaviour which is not understood by the user and leads to misjudgements.

As explained above, the acceleration feels very smooth without the traditional 'jerks'.

Acceptance

The smooth performance of this type of transmission is seen as very comfortable. Furthermore, it gives a better fuel economy and less exhaust emissions.

Driving a car with a continuous variable transmission requires the driver to adapt its expectations. The transmission has to gain confidence on behaving different compared to cars with classical transmissions; it gives the same or a better performance and more comfort.

³ Afbeeldingen vervangen?

1.3.5 Continuous variable transmission including emulated gears

Some drivers, who were used to drive cars with gearboxes using several fixed gears, could not adapt to continuous variable transmissions. Because of the lack of 'jerks' they thought the engine could not provide enough power.^{4,5} So car manufacturers built artificial shifting points in the continuous variable transmissions.

The CVT control unit emulates the traditional 'jerks' that should indicate the shift points during gear up or gear down.

Driver interaction

Although the shifting points do not have a function, the driver feels some 'jerks' during acceleration.

Acceptance

As already mentioned the integration of simulated shift points were a result from acceptance matters.

1.3.6 Conclusion

A transmission is a very sophisticated device that is necessary in order to move the car in an efficient, comfortable and economic way. Skills and training are needed when the driver wants to handle a transmission himself.

Automatic transmissions can take care of the changing gears procedure, resulting in a more efficient, comfortable and economic drive. However, in areas where a manual transmission was very common, automatic transmissions faced a heavy job in convincing the driver to give gearbox controls out of hands. This is caused by these transmissions behaving differently compared to the driver's expectations and by the fact that the driver prefers to be in control of the engine behaviour himself.

⁴ Automotive Design and Production: <http://www.autofieldguide.com/columns/0405euro.html>, accessed 24 July 2006.

⁵ Autowire.net: <http://www.autowire.net/2002-38.html>, accessed 24 July 2006.

1.4 Liquid fuel alternatives

Liquid fuels can be alternatives for gas. These liquid alternatives differ in some ways from gas.

1.4.1 Diesel

Introduction

The intention to make an engine that could run on a natural product led to the production of the diesel engine. The first fuel used in such an engine was peanut oil, a fuel that could be made by consumers themselves. Nowadays a different fuel (diesel) is used. This fuel is made in a factory and is a waste product created during the petroleum distillation process.

Up until ten years ago, diesel engines were not really popular. Several aspects caused diesel engines having an image of being slow and noisy. The truth is that diesel cars really were slow and noisy. This can easily be explained because a diesel engine has a compression ratio of about 20:1. This is quite more compared to a gasoline engine (8:1). A high compression ratio results in heavier explosions, producing a larger amount of noise and vibrations. Furthermore, more material is needed to accommodate this force. More materials mean more weight and more expenses.

All this led to diesel engines being slower in terms of acceleration compared to a gasoline powered engine.

On top of this, the injection of fuel, which is necessary for the diesel technology, caused the engine to be less reliable than gasoline engines.

Other negative aspects were diesel engines producing more smoke, a stronger smell and that they have to be 'preheated' to get started. This causes the driver to wait a few seconds for the glow plug to heat up the engine, in order to get it started. This is not necessary in gasoline engines.

Two big advantages of a diesel engine are a longer engine life and less fuel consumption. These advantages only show up after long use of the diesel engine. Together with the initial costs being higher than those of gasoline engines, diesel had never been a very popular fuel.

Modern diesel engines are much more developed. This led to several disappearing disadvantages.

Nowadays, diesel engines are powerful and affordable. Soot filters can reduce the exhausts of a diesel engine to a minimum.

Table 2 Diesel fuel

Powertrain technology: Internal combustion engine (using diesel)			
<u>Energy path</u>		<u>Technical solution</u>	<u>Driver interaction</u>
	Energy carrier	Diesel. A liquid mixture derived from fossil fuels with a higher energy density than gas.	The substance smells, is dirty, toxic, ignitable and more polluting than gas.

	Energy converter	See Table 1	See ice default, but the engine has to be pre-heated a few seconds in order to get it started.

Driver interaction

Comparing the scheme for a diesel powered car with the scheme for the 'classical' car, it is almost the same. Diesel fuel differs from gas in that it is dirtier and not explosive. Another important interaction issue is the fact that the diesel engine has to be pre-heated in order to get it started. This takes a few seconds between inserting the key and starting the car.

The image of the old diesel engines being slow, polluting and heavy is not forgotten.

Acceptance

Compared to a gasoline engine, the diesel engine is heavy and noisy, causing strong and slow performance. The comfort is noisy and rude. The fuel consumption is very economical but the image/status is rude, noisy and dirty. On old diesel engines the cons weighted more heavy than the pros. On modern diesel engines, the engine has developed well, but apparently modern diesel cars still seem to be bothered by their old image.

1.5 Gaseous fuel alternatives

1.5.1 LPG

Introduction

Car engines running on LPG were introduced in Australia in the 1970s. LPG was an alternative fuel during the fuel crisis. Although nowadays the price of fuel is often rising, the market for gas driven cars is still only about 10% of the total automobile market. LPG should be an attractive fuel because of its price and environmental friendly conditions. So why is it that people do not modify their gas driven car by installing a LPG installation?

One benefit of LPG is clear: after driving 20.000 km, LPG is cheaper than gas because the investment costs for the gas installation are earned back. Driving more than 20000 km means that money is gained compared with driving on gas.

Compared with petrol and diesel, LPG is a very clean fuel, which is another benefit. The exhaust of harmful materials is significantly lower than the exhausts of gas powered engines. However, modern gas engines also provide a minimum of emission, so the benefit of being clean is not that strong anymore.

A practical point is that the LPG-installation fits in every car and that it is an extra installation instead of a replacing installation. So, gas can still be used after LPG-installation.

The downside of driving on LPG is the tank taking away a considerable amount of space in the trunk of the car. The tank can only be filled up to 80% of its capacity because the expansion of LPG has to be taken in account.

Another negative aspect is the radius of action of a litre of LPG. This is 20% less than the radius of action of a litre of petrol.

The early LPG-installations were not as good as the current generation installations. Relatively high emissions and the lifespan of the engine being shortened while driving on LPG were negative aspects about those installations. This could be one of the reasons why nowadays driving on LPG is not that popular.

Remarkable is the fact that only a few car manufacturers produce cars with an LPG-installation already pre-installed.

So LPG was never really a popular fuel. The enormous tank in the trunk of the car could not be compensated by the financial profits after 20.000 km.

Experts think that 20.000 km is still too much to convince the consumer. Developments in technology should take care of this number to decrease.

Other factors which should make LPG more popular are the prices for oil and petrol. When the price for one litre of gas is twice as much as one litre of gas, then the difference is big, but everyone is familiar with it. But when the gas prices raise, consumers start thinking about it and realize that gas is more than twice as cheap.

Table 3 LPG fuel

Powertrain technology: Internal combustion engine (using LPG)			
Energy path		Technical solution	Driver interaction
energy supply	Energy carrier	LPG is a gas that is synthesized by refining fossil fuels	The gas smells, is dirty, toxic, explosive and ignitable.
	Distribution of carrier	Mostly fill stations are supplied by tankers	Infrastructure of fill stations available, usually within 10km of residence. Fill stations and tankers

		are known as dangerous.
Energy storage	A storage room (cylinder) in the car is filled with the gas.	Driver is warned on 'low fuel' and has to fill up the tank himself accordingly.

Driver interaction

LPG has a lower energy density than gas. Also, the LPG system is always an extra fuel system, so more space in the car is needed to accommodate this system. This mostly causes the LPG tank being not too big because no room for luggage is left in the car.

Acceptance

The investment for buying a LPG-installation which is only profitable after driving about 20.000 km is too high. Also the image of the older LPG-engines having less performance than gas engines and the clumsy procedure for refilling probably contributes to a negative opinion about modern LPG-engines.

1.6 Bio fuel

Introduction

Bio fuel is fuel that comes from living or recently living biological material. This material is called biomass. Mostly this is plant matter. It can be a waste product, like biogas, but it can also be the result of a breeding facility like Cole seed oil.

Bio fuel has lower energy contents per unit mass than conventional fuel. This means that compared to conventional fuel more bio fuel is needed to get the same performance of the engine. A huge benefit is bio fuel producing fewer exhausts than conventional fuels. Mostly bio fuel is added in a certain proportion to conventional fuel. The European government already commissioned the member states to introduce bio fuels. In Germany and France bio fuels are a huge success. This is caused by the government of those countries which deleted excises on bio fuel.

Table 4 Bio fuel

<u>Energy path</u>	<u>Technical solution</u>	<u>Driver interaction</u>
Energy source	Fossil fuels: non-renewable energy, or biomass: renewable energy.	Vague knowledge from both fossil and biomass fuels.
Energy carrier	A liquid mixture partly derived from fossil fuels and partly (or completely) derived from biomass.	See table 1. It has a lower energy density. Thus more bio fuel is needed to get the same performance as conventional fuel.
Distribution of carrier	See table 1	The infrastructure of filling stations is not as extended as conventional fuel fill stations.
Energy storage	See table 1	The radius of action is less than those of conventional fuel cars.

Driver interaction

The lower energy density causes the driver to visit the fill station more often to fill up the tank. Unfortunately those fill stations are not as available as fill stations for conventional fuels.

Acceptance

The problem of bio fuel is that the price is higher than the price for normal gas. This is caused by the government who doesn't want to lower the duty of gas while the bio fuel is far more ecological. Another problem is the fuel infrastructure for bio fuels. There not as filling stations for bio fuel as there are for normal fuels.

These two factors result in a high barrier to the consumer for using bio fuel.

1.7 Electric propulsion

Introduction

The first electric cars were involved in the birth of the automobile. Eventually they were beaten by the internal combustion engine car.

The most important characteristic of the electric car is that it has to carry batteries. These are heavy and can only contain a limited amount of energy. When the batteries are empty they have to be replaced or recharged. This causes the electric cars' performance to be moderate, resulting in a low top speed, acceleration and radius of action.

Recharging or replacing the batteries every now and then puts a high workload on the driver of the car, creating a huge disadvantage on the use of electric cars.

Many electric powered cars were introduced in the past century. They got never popular enough to start a revolution in the car industry.

One example is General Motors EV1. It is an electric car with a range of 120 – 140 kilometres per charge and a top speed of about 120 km/h. Together with a satisfying acceleration time, the performance of this vehicle was great. The car became available only for lease companies and it turned out to be a popular lease car. This car definitely showed that an electric car is capable of fulfilling consumers' demands. Unfortunately GM stopped producing this car, because development on this car was too expensive.



Figure 4 GM's EV1

Table 5 Electrical propulsion

Powertrain technology: Electrical propulsion			
<u>Energy path</u>		<u>Technical solution</u>	<u>Driver interaction</u>
energy supply	Energy source	Fossil fuels or sustainable energy: non-renewable or renewable energy	Vague knowledge
	Energy carrier	Electrical charge	Not visible, no smell, charge can be deadly.
	Distribution of carrier	Global infrastructure: network of wires.	Always and everywhere present. Daily used
energy conversion	Energy storage	A device for storing electrical energy can be charged (a battery)	Driver is warned on 'low energy' and has to charge the battery by connecting it to the infrastructure himself.
	Energy converter	An electromotor converts the electrical energy to kinetical energy	Driver has control in how much kinetical energy is produced, by using the gas pedal. The process is quiet and smooth.
	Transmission	No transmission is needed in an electric car	
	Motion	The car is moved.	The driving-experience is affected by the used transmission. Driving-experience consists of acceleration, braking, gliding, noise, vibrations, consumption and pollution.

Driver interaction

The amount of noise produced by an electric driven car is totally different than the amount of noise produced by the classical internal combustion engine car. Furthermore the driving experience is totally different. The acceleration is very smooth since the powertrain does not need a gearbox.

Acceptance

The engine, safety and equipment of an electric car are all fine. But when it comes to comfort this car lacks to fulfil the need of the driver. Forgetting to charge the electric car at night should not lead to not being able to use it the next morning.

Newly introduced electric cars have to deal with the negative aspects which are derived from previous introduced electric cars. The design of electric cars is mostly very aero dynamical, to compensate the lack of power of the engine. Such an aerodynamic design gives the car a very futuristic look. This look is not liked by a lot of car drivers.

1.8 Hybrid propulsion

Introduction

A hybrid vehicle uses a combination of technologies. For example: a combination of an internal combustion engine and an electric motor.

Previous introduced hybrids like the Daihatsu UFE2 were not really a success. The car looks very futuristic from the inside and the outside.

Before the introduction of the Prius, Toyota was known as a high-quality manufacturer. They never had been much of a pioneer. The top of the company was convinced of the fact that hybrids were becoming mainstream cars and they worked hard to speed up this process. One way was by making hybrids more affordable for consumers, this has become a key element in Toyota's strategy. The other way⁶ to speed up the process was by building a hybrid car themselves. The focus of Toyota was to build a car that is complete and can compete with conventional cars. This led to the first generation of the Prius. It was, unlike other 'green' cars, a modern car with 'green' technology instead of a bunch of 'green' technologies that should form a car. In other words: the Prius was a regular new car that should prove itself after its introduction just like other new cars. At the same time this car was ecological.

In 1997 Toyota introduced the 1st generation Prius on the Japanese market and sales were better than expected.

Toyota introduced the Prius in the U.S. in 2000. They already found out that extreme environmentalists were not interested in hybrids because of the technology. Stakeholders were sceptic about the design of the car which should not be extreme enough.

A newly introduced car sometimes comes with some imperfections. So did the Prius. The behaviour of the 1st generation engines was irregular resulting in an uncomfortable driving.

Apparently buyers did not care about the uncomfortable ride and premium price but did care about improved fuel economy, lower emission and advanced technology. Even the resale value was positive: after three years a Prius would retain 57% of its value. A very interesting aspect was that apparently, pride of ownership was that important, that only 2% of the buyers opted to lease.

In 2001 15.556 cars were sold and 20.119 in 2002. When the second generation of the Prius was launched at the fall 2003, the Prius appeared to become a fashion statement. Some Hollywood celebrities bought a Prius and they proudly showed themselves driving it. More attention was attracted to the Prius when five of them appeared at the 2003 Academy Award Show driving more celebrities to the red carpet.

The performance of this car in speed and acceleration was not inferior to those of concurrent combustion engine cars. Together with the rising gasoline prices, this caused a sales boost of 53.991 in 2004 and 107.897 in 2005. At June 7, 2006 500.000 Prii⁷ have been sold worldwide and in November 2006, 50.000 have been sold in the Netherlands⁸.



Figure 5 Daihatsu UFE2



Figure 6 Toyota Prius

⁶ Verschil tussen one and the other

⁷ Plural of *Prius*.

⁸ Bron?

Driver interaction table

The table is filled in for a hybrid propulsion vehicle.

Table 6 Hybrid propulsion driver interactions

	Powertrain technology: Hybrid vehicle (gas-electric)	
	<u>Energy path</u>	<u>Technical solution</u>
energy supply	Energy source	Fossil fuels: non-renewable energy
	Energy carrier	See gas or diesel.
	Distribution of carrier	Mostly fill stations are supplied by tankers
energy conversion	Energy storage	<p><u>Fuel</u>: A storage room (tank) in the car is filled with the liquid or gaseous fuel</p> <p><u>Electric</u>: A device for storing electrical energy can be charged (a battery)</p>
	Energy converter	<p><u>Fuel-to-kinetics</u>: An internal combustion engine burns the fuel generating kinetical energy. The kinetical energy is used to drive the wheels (through the transmission) or to drive the electro motor.</p> <p><u>Kinetics-to-electric</u>: The electromotor is driven by an internal combustion engine or by the wheels (during brake) and generates electricity, that is used to charge the battery.</p> <p><u>Electric-to-kinetics</u>: An electromotor converts the electrical energy to kinetical energy</p>
	Transmission	See chapter XX.

Driver interaction

Due to a total different engine lay-out, the car behaves totally different compared to internal combustion engine cars. The engine behaviour is more controlled by the car itself. The driver can still speed up by stepping on the gas and slow down by stepping off the gas or stepping on the brake pedal. In some cars a display is used to give some insight in the decision making process about which engine is currently used. This screen causes the driver to be more aware of fuel consumption and engine behaviour⁹.

⁹ See [supplement](#) (Bezoek Toyota-dealer) en gesprek prius rijder?

Acceptance

Unlike previous electric cars and hybrid cars, the Prius was not introduced with the message that it had a lack in some of its features, like limited radius of action or a short engine life.

The engine is very advanced giving the car a modern image. Fuel consumption is very beneficial and the equipment very complete. The design of the car is modern, not imposing its aerodynamic shape, like other revolutionary cars did.

1.9 Conclusion

The acceptance of products or technologies by users depends on many factors. It is very hard to indicate exactly which factors are most important and how these factors have to be met before a product will be accepted.

Probably, it also depends on the context in which the product is introduced. This context is constituted by all kinds of social, geographical and economical aspects.

Despite the toughness of indicating exactly which factors play a role in the acceptance process, it is concluded from the above that the following factors do certainly play a role.

- Costs
- Performance
- Image
- Usability
- Comprehensibility
- Emotion

Costs

While considering buying a product, the user always has to deliberate about the price, whether or not it is worth the product. This depends on a combination of the other factors mentioned in the list above. All these factors have to satisfy the needs of the user to a certain extend.

Performance

If something performs better than people are used to, they will to use it in favour of something that performs worse. In comparison with an older version or a competitive product, this means that the new, better, product will be accepted. Better could be faster, or longer living.

Image

If something has a negative image, it has a hard job to get rid of that image. Users seem to distrust something that didn't work out before. The product or technology will have to prove itself before it will be used and accepted.

Not only performance properties can affect an image, but charismatic properties also do. For example, a product with a sexy or sturdy charisma will be accepted sooner.

Usability

A product that is easy to operate will sooner be used than a product that is very difficult to use.

Besides, the product has to be comfortable. This means that the operation of it has to be simple and easy to learn.

Comprehensibility

It is important that people know how something works. If they understand what is happening, the barrier to using it is much lower, compared to when it is a magical black box that apparently does do something.

Emotion

If a product has a positive emotion than it is likely that it will be accepted and used. For example, the joy of driving a car with manual transmission, with its typical handling properties and sound production, is partly based on emotion, rather than performance.

2. Interface system

*We want to determine the interactions that occur and investigate the necessity of using an interface to accommodate these interactions. Now we will focus on the control of the powertrain during the driving task and the information that flows during this task.
The result of this chapter will be a list of functions for the interface system.*

2.1 Powertrain-user interactions

In this paragraph, the interactions between powertrain and driver are named. Therefore the interactions which occur between have to be pointed out.

2.1.1 Driving-task

To make the extraction of interactions between user and powertrain easier, a simplistic model is used for the powertrain. Later, the typical characteristics of the powertrain of the car of the future are discussed to find out if more interactions will occur between powertrain and user.
The powertrain characteristics in the simplified model:

- The powertrain propels the car in the longitudinal direction
- The powertrain runs on a fuel
- The powertrain operates according to some parameters set by the driver
 - The powertrain can be turned 'on' or turned 'off'
 - Car movement is achieved by the power output of the powertrain
 - A direction is achieved by putting the powertrain in a forward or backward gear

Interactions between powertrain and user consist of information and control. These interactions are necessary to operate the powertrain during the driving task. The following diagram is used to investigate the interactions which already take place or which have to take place in the interface that has to be designed.

In this diagram the driving task is represented as an ensemble between user and powertrain. They are

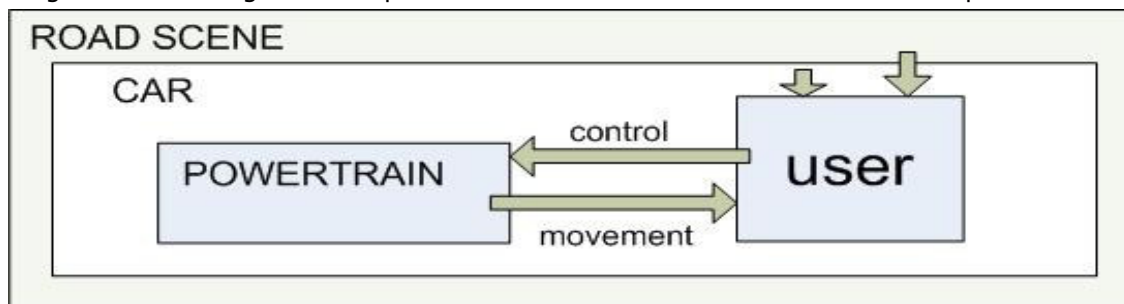


Figure 7 User driving a car

accommodated in the car and the car is part of a road scene. The driving task consists of the user observing the situation on the road scene. Accordingly, the user controls the powertrain and the powertrain creates movement.

The user is affected by several factors. They appear from powertrain, car and road scene and influence the decision making progress. For example speed and noise which are produced by the car; traffic and traffic lights which appear from the road scene and movement and noise which appears from the powertrain.

Since we are interested in the powertrain-user interactions we will take a closer look at this in another diagram.

2.1.2 User-powertrain

The condition of the powertrain, car and road scene appears from several factors. One of these factors is 'movement', as seen in the above diagram. This factor is a powertrain's output. Other powertrain's

outputs are for example noise and smell, these are natural available, because they are inherent to the powertrain's operation. Unfortunately, these are useless factors for the driver because he, for example, cannot smell or hear how fast the car is driving.

So, not all information is natural available for the user. The user might want to know something of the powertrain or the car that does not appear from things like movement, vibration, noise or smell. These factors somehow have to be obtained from the powertrain, car and road scene and presented to the user. This is done by several sensors attached to different parts of the powertrain and car. These sensors can read several outputs. For example, power output, level of performance or car speed. The readings of these sensors are processed and interpreted by a processor and accordingly presented to the driver in a user-interface.

The information flows and controls are visualized in the *powertrain-user interactions diagram*.

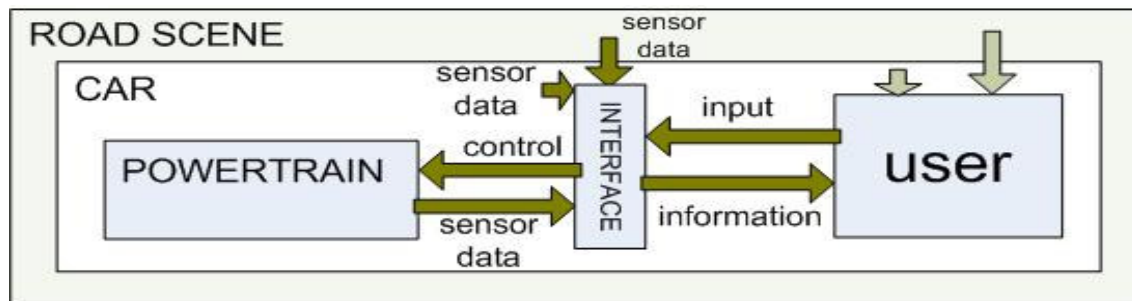


Figure 8 Powertrain-user interactions diagram

Looking at both diagrams we see that the information originates from the powertrain and that the controls are handled by the user.

Below, all information flows and controls that are used to operate the powertrain will be listed. A storyboard¹⁰ in which some typical car situations are visualized is used to come up with all possible information flows and controls.

2.2 Control

The controls control a certain aspect of the powertrain, the *option* says something about the amount of (sub) functions that control can fulfil.

Table 7 Controls

What does it do?	Control	Options
It turns the powertrain on or off	Powertrain state	ON/OFF
It puts the powertrain in the right direction	Powertrain gear	P/D/N/R
It controls car speed	Powertrain power output	Increase/decrease/maintain
	Brake force	Increase/decrease/maintain
It controls display settings	Several display controls	To be mentioned later

The difference between the controls above is that *powertrain state* and *powertrain gear* have pre-selected states. The driver can choose from a reduced amount of options. Based on a typical driving task, this parameter will probably not change a lot.

Because cars will not drive autonomous all the time in 2020, car speed will fluctuate as is does with current cars. Therefore, the *powertrain power output* control has to be handled continuously. The user observes traffic in relation to his own situation and handles the speed accordingly. A lot of changes in traffic condition occur during a single driving task so the speed has to be changed a lot during the same driving task.

¹⁰ See [supplement](#)

2.3 Information

The information flows in the car are divided into two categories. The first category is described as the information that is necessary to enable a car drive. Thus, without this *basic* information the car drive will not start or it will be interrupted.

The next level of information is the information that makes the drive more convenient. This *convenient* information is still directly related to the driving task. It enables a more comfortable drive which might also be more efficient and economic. An overview of the basic and convenient information is given below.

Table 8 Information flows

	Information flow	Message
basic	Powertrain state	Powertrain is ON, starting-up or OFF
	Powertrain gear	Powertrain is in P/D/N or R
	Car speed	The current car speed
	Insufficient power available	Power level for driving is critical
	Fill up the fuel	Fuel level is critical
	Errors	Error message concerning (sub)system
convenient	Available power	Current available power for driving
	Total kilometres	The total number of all driven kilometres
	Trip kilometres	The total number of the trip kilometres
	Fuel consumption	The current used fuel per time or fuel per distance
	Fuel level	The current fuel level
	Explanation	Technical working of the powertrain

These are the information flows that are derived from the simplified powertrain model. The next step is to take a look at the interactions that are typical for the powertrain systems of the *car of the future*, the hydrogen powered PEM fuel cell powertrain system. This is done by using the list of qualities and shortcomings from chapter three.

2.3.2 Future powertrain

In chapter three we determined some qualities and shortcomings of the powertrain system of the car of the future. This list is used to add more functions to the interface. It might be clever to use the qualities in the interface to raise the acceptance level of the car of the future. For the shortcomings we will try to add something to the interface that helps the user deal with that shortcoming. Hopefully this raises the acceptance level of the new powertrain.

The next table will indicate which information flows are needed to put in the interface, based on the list of qualities and shortcomings. For each quality or shortcoming is considered if the already obtained *information flows* from the table above are already sufficient. If not, the required information will be mentioned, and it is indicated that it is a new piece of information, compared to table XX, "*Information flows*".

Some items from the qualities and shortcomings become clear to the driver naturally. The driver has to experience that aspect, or after a while the driver will get familiar with it.

Table 9 h2 PEM FC powertrain specific information

		Information
qualities	Always ready to run	Powertrain state (see table X)
	Smooth acceleration	-natural output-
	Regeneration of energy	Indicate the regeneration of energy (new)
	Lack of local pollution	-natural output-
	Lack of a lot of noise	-natural output-
	Image of comfort/reliability	-natural output-
	Safe	-natural output-
	Economic	-natural output- Indicate fuel economy (new)
shortcomings	Not 100% power available during cold start	Current available power (see table X)
	Temporary power peak	Current available power (see table X)
	Radius of action	Indicate range (new)
	Lack of sound	Indicate lack of sound (new)
	Deficient fuel infrastructure	Indicate fuel infrastructure (new)
	No 'racing' experience	-no interface solution-
	Unproven technology	-no interface solution-

The shortcomings '*racing*' experience and *unproven technology* are not items which can be accommodated in a user-interface. There fore, they will not be considered when interface functions are being listed below.

2.4 Functions

The interactions between powertrain and user consist of controls and information flows. The powertrain is controlled by the user. The user accordingly uses different kinds of information flows to decide how to control the powertrain.

The interface has to accommodate the controls and information flows. The functions of the interface therefore consist of these elements. In the list below, all the functions of the interface are listed. Some complex functions are divided in several sub functions.

Table 10 Functions and sub functions of the interface

Functions	Sub functions
Controls	
Change powertrain state	Turn powertrain "On" Turn powertrain "Off"
Change gear	Select P-gear Select D-gear Select N-gear Select R-gear
Change powertrain output	Increase powertrain output Maintain powertrain output Decrease powertrain output
Change brake force	Increase brake force Maintain brake force Decrease brake force
Information flows	
Indicate powertrain state	

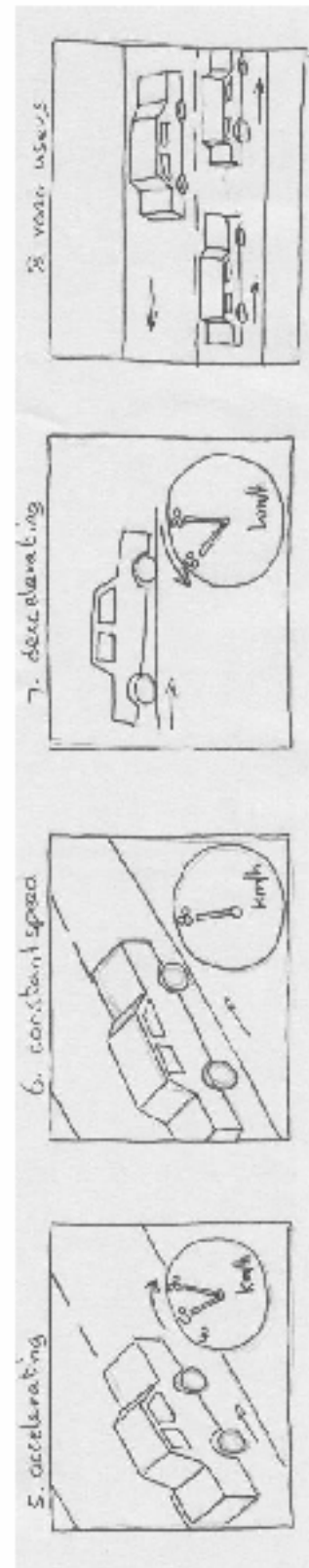
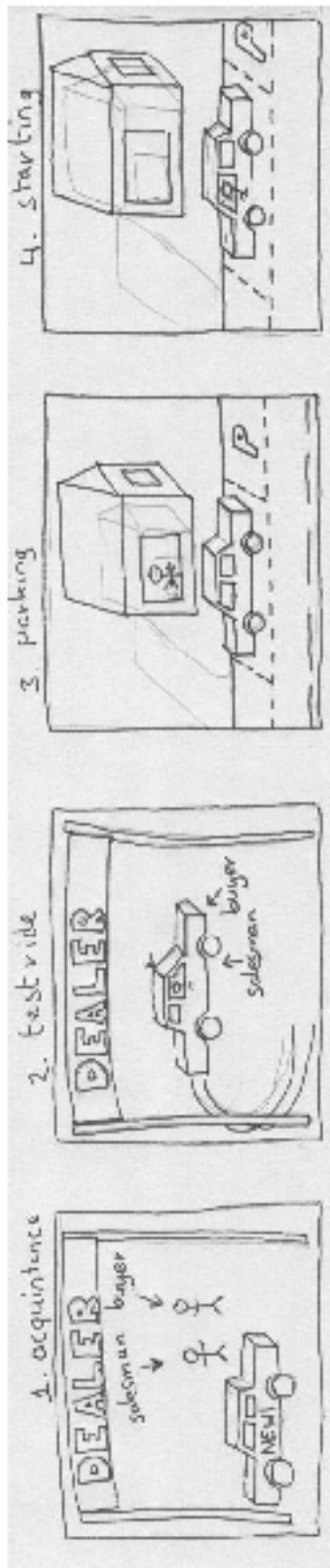
	Indicate "On" state
	Indicate "starting-up" state
	Indicate "Off" state
Indicate which gear selected	
	Indicate "P-gear selected"
	Indicate "D-gear selected"
	Indicate "N-gear selected"
	Indicate "R-gear selected"
Indicate car speed	
Indicate critical fuel level	
Indicate critical level of available power for driving	
Indicate error	
Indicate current available power for driving	
Indicate total kilometres driven by car	
Indicate trip kilometres driven by car	
Indicate current fuel consumption	
Indicate fuel level	
Explain the working of the powertrain	
	Explain the fuel-cell stack
	Explain the ultracapacitor
	Explain the electro motors
	Explain the energy flows in the powertrain
	Explain the start-up time
	Explain the available power
Indicate the regeneration of energy	
	Indicate when energy is regenerated
	Indicate how much energy is regenerated
Indicate extended fuel consumption information	
	Indicate energy regeneration
	Indicate historical powertrain fuel consumption
	Indicate fuel economy
Indicate range	
Indicate lack of sound	
Indicate fuel infrastructure	

During the concept design it will be tried to accommodate every (sub) function in the user-interface.

2.5 Conclusion

A workable list of functions for the interface systems has been derived from the interactions between powertrain and user. Some functions are divided into sub-functions because they are complex. All (sub-) functions can be used to design an interface concept. Before that some boundary conditions have to be discussed. This is done in the next chapter.

3. Storyboard



4. Bezoek Toyota-dealer

Een goed voorbeeld van het gebruik van een display om de werking van de motor weer te geven is te vinden in de Toyota Prius. Om dit zelf te ervaren is er een bezoek gebracht aan de Toyota-dealer te Enschede. Hier is eerst een uitleg gegeven door een verkoopmedewerker en vervolgens is er een proefrit gemaakt.

Hybride

De Prius is een auto met een hybride aandrijving. Deze aandrijving bestaat uit een elektromotor die gevoed wordt door accu's en een verbrandingsmotor die op benzine loopt. Beide motoren kunnen apart van elkaar en samen worden gebruikt. Het computermanagement van de auto regelt het samenspel van beide motoren, de bestuurder hoeft daar niets aan te doen.

In de praktijk zal de elektromotor zorgen voor aandrijving bij een lage belasting, bijvoorbeeld het met constante snelheid rijden binnen de bebouwde kom. De verbrandingsmotor zal bijspringen tijdens een hoge belasting zoals optrekken of berg opwaarts rijden.

Stroom opwekken

De elektromotor kan zich ook als generator gaan gedragen. De opgewekte stroom wordt dan gebruikt om de accu's op te laden. De elektromotor kan worden aangedreven door de verbrandingsmotor of door de wielen tijdens bijvoorbeeld het afremmen. In het kader van duurzaamheid is dit laatste, waarbij de opgebouwde kinetische energie gebruikt wordt om de accu's op te laden, natuurlijk interessante mogelijkheid.

CVT

De Prius heeft een automatische transmissie, maar wel een hele bijzondere. Het is een continu variabele transmissie. Dit betekent dat er tijdens het optrekken geen 'schokken' te voelen zijn tijdens de schakelmomenten, maar dat er heel geleidelijk wordt opgetrokken. Deze transmissie maakt het mogelijk voor de verbrandingsmotor om een hoog, vast aantal toeren te draaien tijdens het optrekken. Dit is gewenst omdat de motor bij een hoog aantal toeren efficiënter werkt. Dit resulteert in meer vermogen, een gunstiger brandstof verbruik en een betere verbranding van de brandstof waardoor er minder schadelijke stoffen worden uitgestoten.

De test

Wanneer de verkoper de auto start blijft het stil, blijkbaar vind het motormanagement het niet nodig dat de verbrandingsmotor gestart wordt. Het lijkt dus meer een kwestie van de auto 'aan' zetten in plaats van starten.

Wanneer de Prius het parkeervak uitdraait valt meteen op dat ook hier de aandrijving geen geluid produceert. Wanneer je er met de rug naar toe zou staan zou je, behalve wanneer de auto over een steentje rijdt of iets dergelijks, niet horen dat hij op je af komt.

We nemen zelf plaats in de auto en rijden rustig weg. Ook nu horen we nagenoeg niets. Nadat we de weg opdraaien trappen we het gaspedaal wat verder in. De verbrandingsmotor wordt binnen een tel gestart en gaat meteen hoog in de toeren zitten. Qua geluid lijkt het alsof er iemand veel gas geeft en vervolgens pas langzaam de koppeling laat opkomen. Dit is natuurlijk niet zo, want de auto accelereert meteen flink. Zodra er weer wat gas wordt teruggenomen om op de constante snelheid van 50 km/h te blijven schakelt de motor zich uit en neemt de elektromotor het weer over.

Gedurende de rit blijkt dat het motormanagement duidelijk een eigen wil heeft. Soms wordt de verbrandingsmotor namelijk ingeschakeld terwijl er geen reden voor lijkt te zijn, omdat we bijvoorbeeld op een lage constante snelheid rijden.

Wanneer we een zebrapad naderen waar een schooljuf met de rug naar de straat toe staat gekeerd om een schoolklas te verzamelen voor het oversteken, nemen we toch maar het zekere voor het onzekere en rijden er voorzichtig langs. Straks hoort ze ons niet en besluit ze toch om zomaar te gaan oversteken.

Display

Het touchscreen in het dashboard van de auto wordt gebruikt om allerlei informatie op weer te geven en om instellingen mee te kunnen regelen. Een van de schermen, de *Energy Monitor*, geeft het energieverloop van de aandrijving weer. In een schematische weergave van de auto zijn een aantal

onderdelen te zien zoals verbrandingsmotor, elektromotor, accu's en wielen. Met pijlen wordt aangegeven hoe de energiestromen lopen.



Op het scherm wordt tevens de buitentemperatuur en het actuele verbruik weergegeven. Het display geeft een goed beeld van wat er gebeurt onder de motorkap. Zo zou het plotseling aanslaan van de verbrandingsmotor tijdens het met constante lage snelheid rijden een gevolg kunnen zijn van een lege accu die opgeladen moet worden.

Er moet wel gezegd worden dat er zoveel gebeurt op het display dat het onverstandig is om er tijdens het rijden naar te kijken. Je zou er zodanig door geboeid kunnen worden dat het je afleidt van je rijtaak.

Na de rit bekijken we op het display wat het verbruik was tijdens het afgelopen half uur. Dit wordt overzichtelijk getoond in een aantal staafdiagrammen.

Toegift

De Prius kan geleverd worden met een automatische inparkeer hulp, Intelligent Park Assist genaamd. Dit systeem kan de auto achterwaarts inparkeren in een parkeervak en fileparkeren.

De verkoopmedewerker geeft hiervan nog een demonstratie.

We naderen een parkeerplaats met een leeg vak. Wanneer de parkeerhulp ingeschakeld wordt herkent het systeem een leeg parkeervak en geeft het vak op een videobeeld weer door een vak te tekenen met rode lijnen. Met behulp van pijltjes toetsen kan de plaats van het vak nog wat nauwkeuriger worden aangegeven. Nadat dit is bevestigd door de verkoper volgt nog een waarschuwingsbericht. Hierna begint de auto te rollen zodra de bestuurder de rem loslaat. Het stuur van de auto draait uit zichzelf en het systeem zet de auto achterwaarts in het vak dat door de gebruiker is bepaald. De bestuurder moet zelf remmen wanneer de auto ver genoeg in het vak staat. Het resultaat is dat de auto in het vak staat maar dat de inzittende aan de passagierskant niet kan uitstappen omdat de auto slechts 10 cm naast een andere auto staat. Niet helemaal perfect dus.

Ook het fileparkeren lukt niet helemaal. De auto wordt door de parkeerhulp met de 2 linkerwielen op de stoep gezet.

We denken dat het plaatsen van het vak op het videobeeld erg bepalend is voor hoe de parkeerhulp de auto parkeert. Het systeem werkt dus in principe wel, maar voor alsnog zouden wij het nog met de hand blijven doen.

Conclusie

- De stilte van de auto kan een probleem zijn in het verkeer
- De CVT transmissie is erg comfortabel, maar klinkt vreemd
- Het scherm is een welkome aanvulling om de aandrijving inzichtelijk te maken
- Het scherm mag niet teveel van de aandacht van de bestuurder vragen

Links:

www.toyota.nl

www.toyota-enschede.nl

cvf @ wikipedia

Afbeeldingen: www.toyota.com



47 47

1. Current is required to reach top distance. Reaching top distance results in a top distance of 0.

At a speed from [speed limit - 1] the speed is projected on the road ahead (0.0 km). For example, during a speed limit of 50 km/h, the car is 47 km/h or higher appears.

Auditory: The beep when speed limit is exceeded by 1 km/h. For example, a beep when going from 51 to 52 km/h during a speed limit of 50 km/h.



56 km/h 86 km/h

47507.8 km trip 108.2 km total

47507.8 km trip 108.2 km total

47507.8 km trip 108.2 km total

47507.8 km trip 108.2 km total

50% Battery

50% Battery

50% Battery



Fuel cell output: 60%



Fuel cells currently produce about 60% of their power.

Fuel cells currently produce about 90% of their power.



Battery is warning, level is active.



Battery is warning, level is active.



Battery is warning, level is active.



Battery is warning, level is active.



Motor is charging the battery.



Motor is tracking maximum power available.



Motor is tracking maximum power available.



1. Powertrain is currently charging. The lower that is left in reserve, the battery is also empty.

2. Powertrain is currently charging the battery. Battery is already full. Boost is empty and will slowly regain space.

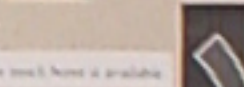
Battery status (full - empty)



Mechanical braking indicator. Indicates when mechanical brakes are used for braking.



Battery status shows how much power is available.



Powertrain which can sustain



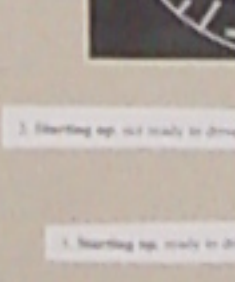
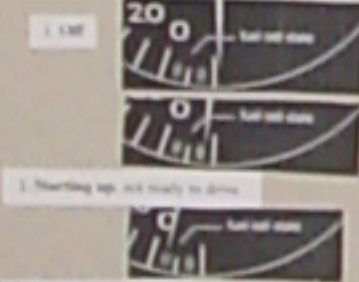
Auditory: 3 times beeping when critical. Beep beep. Beep beep.

367 km left 367 km left

10 km left



3. Starting up, not ready to drive.



3. The car is forced out. It might not be started up completely, or maximum power might not be available.

3. Starting up, not ready to drive.

3. Starting up, not ready to drive.

2. Starting up, not ready to drive. First error and beeping. Beeping.

starting up...

3. Starting up, ready to drive. Not maximum power available.

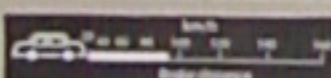
starting up... ready

4. On. First error, green. Beeping, not beeping.

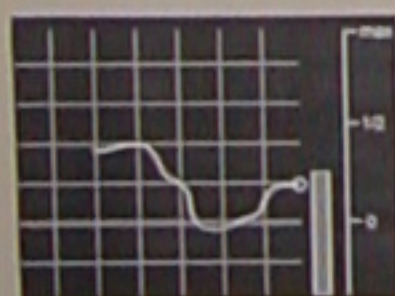
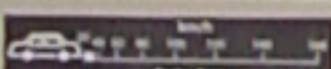
ready

Warning: Low Fuel. System ready, not done. Starting up, please wait.

Car velocity is 90 km/h



Car velocity is 75 km/h



basic



standard



advanced



basic



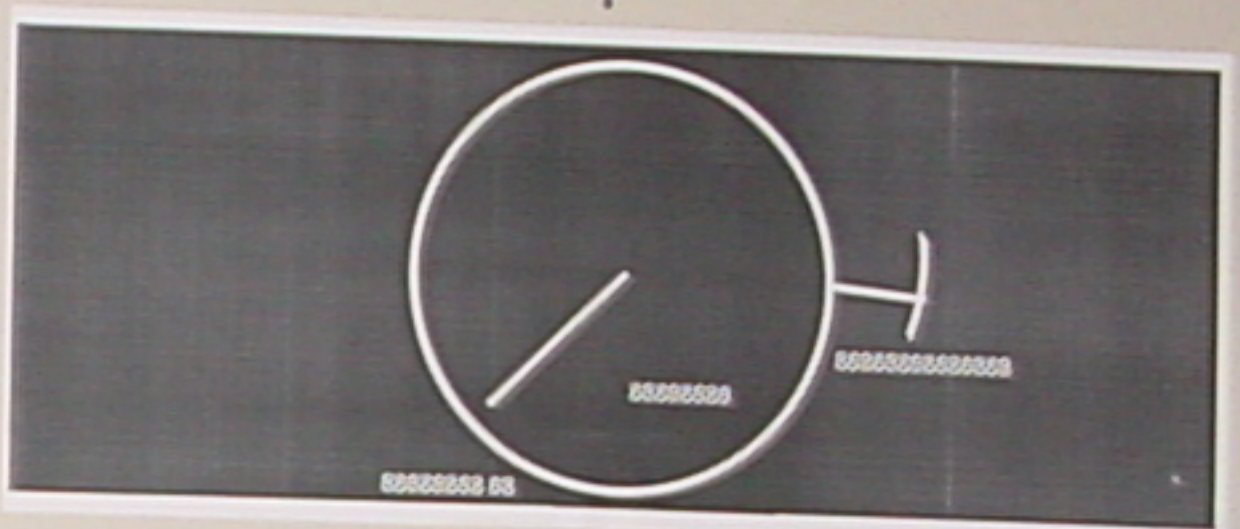
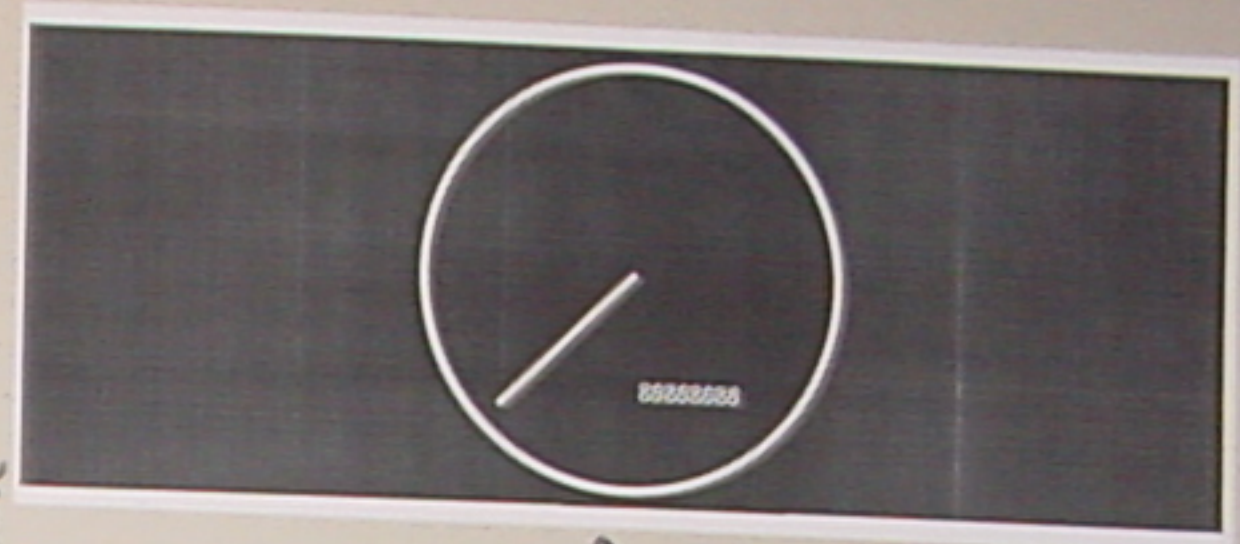
standard



advanced



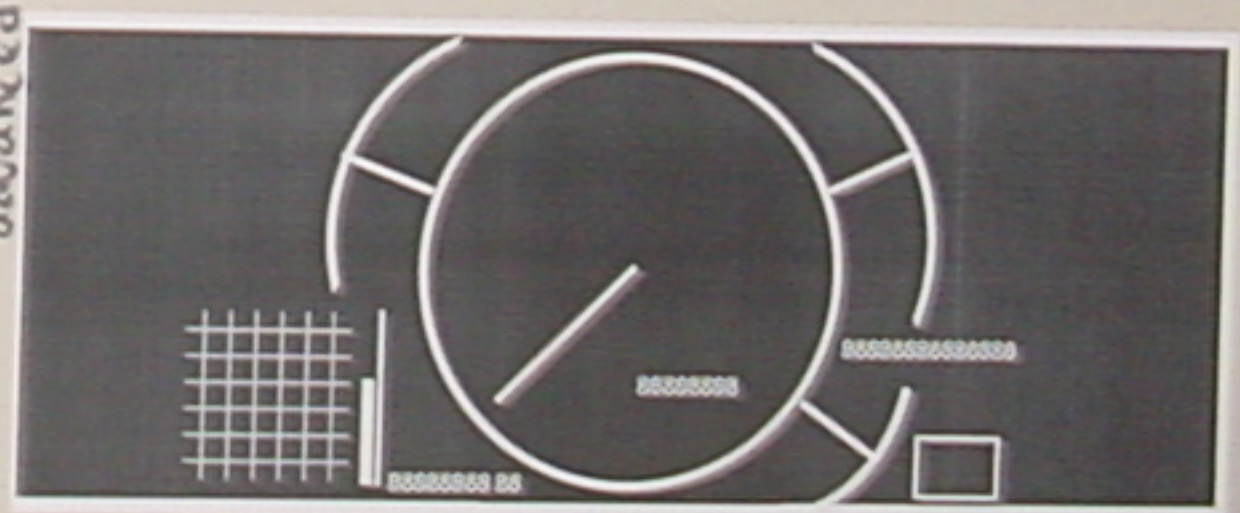
basic



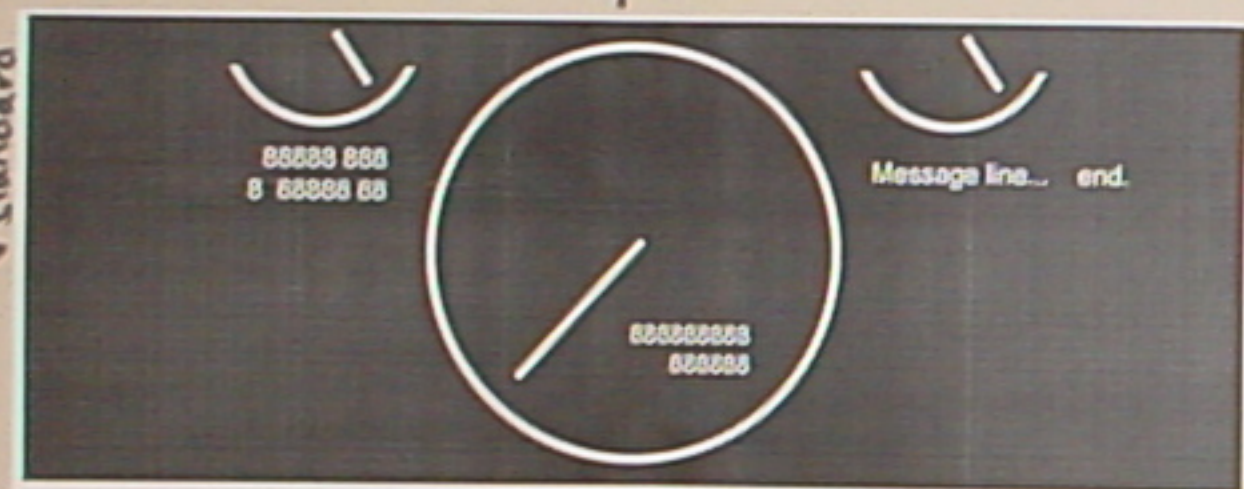
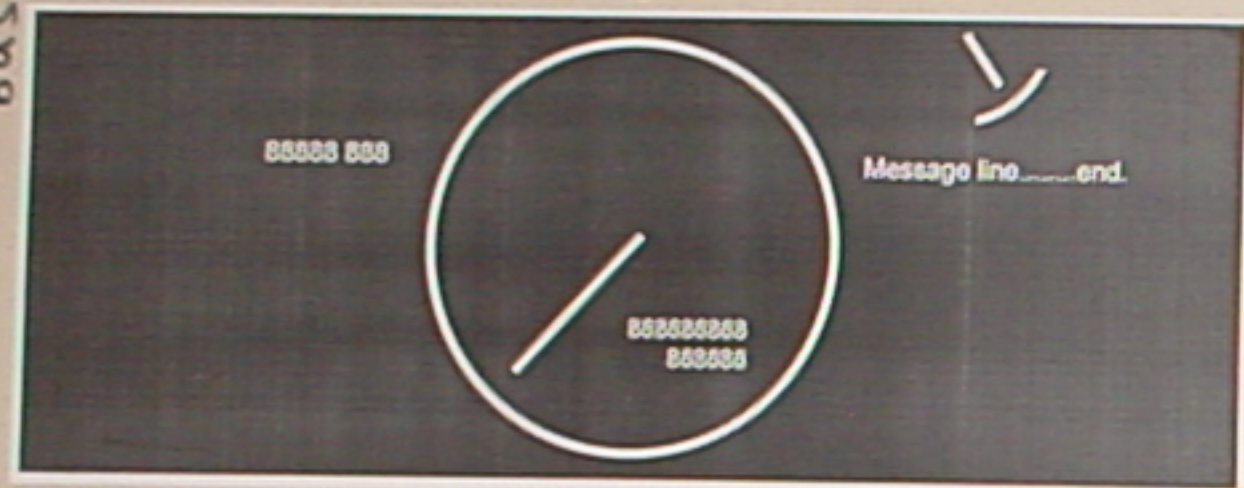
standard



advanced



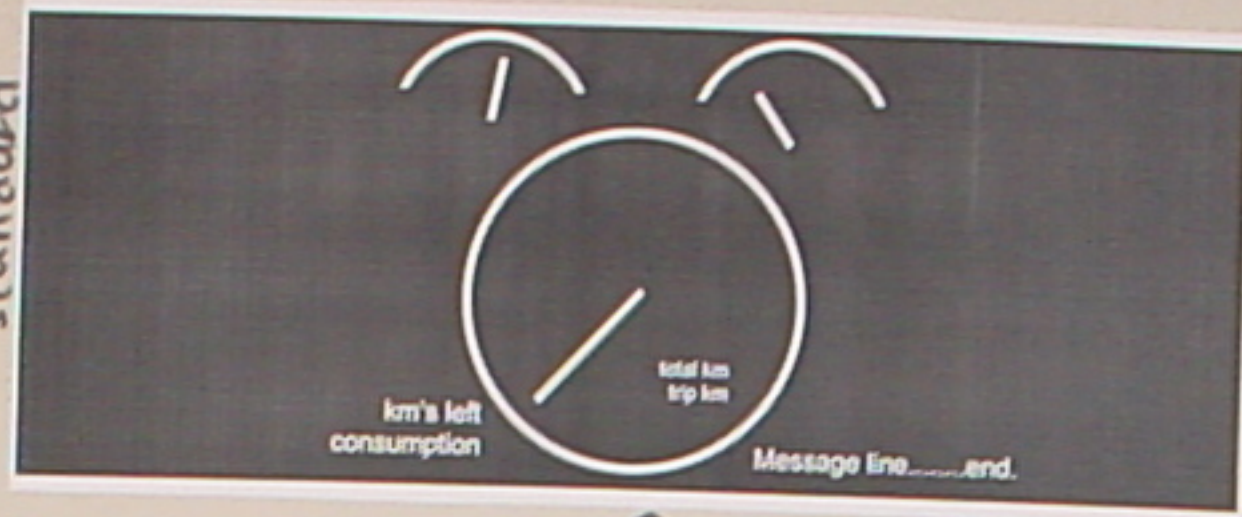
basic



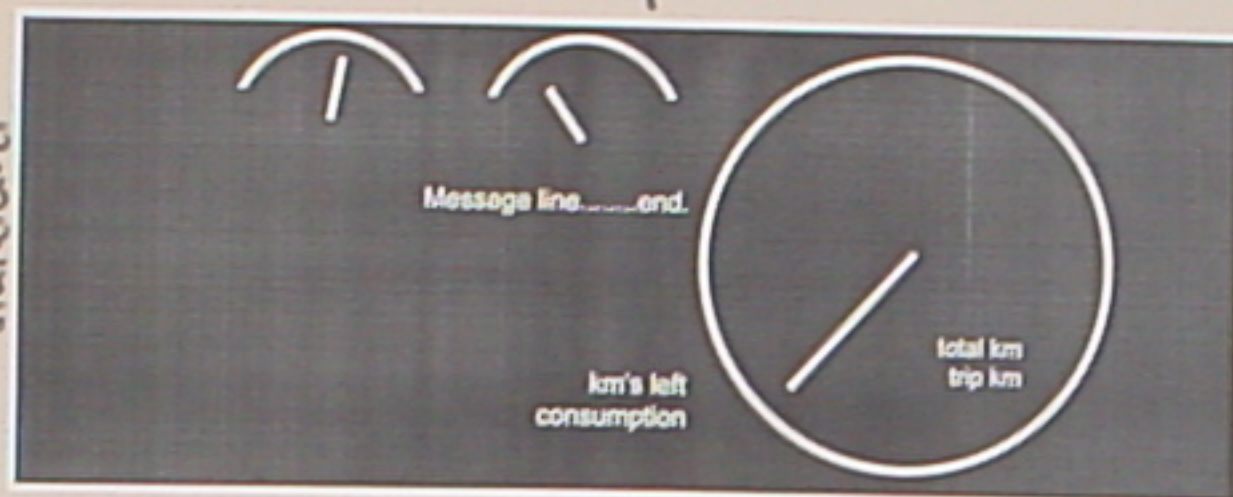
advanced



standard



standard



standard



basic



standard



standard



advanced



Project approach

Car of the future

- design an interface to let the driver understand the working of the car -

Gertjan Endeman
s0043958
University of Twente

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Assignment

The Netherlands Society for Nature and Environment (SNM) and the three Dutch Universities of Technology are working together in a project on developing the 'car of the future'. In this project (NEXUS) each university contributes its part according to a mobility concept for the year 2020. Aim is to present the 'car of the future' at the 2007 AutoRai.

Within this project the following assignment has been formulated. *Design an interface for the car of the future to make the driver understand the working of it.*
This project approach concerns this assignment.

To design such an interface relevant research has to be done. Subjects of investigation could include: literature investigation on powertrain¹ concepts, research on important factors in user acceptance of powertrain concepts, research on the role of an interface in the process of accepting a powertrain concept, research on the workload of the new system (using the new design) and a user evaluation.

In this project approach several aspects on this assignment will be discussed. First an actoranalysis will be made. Then objectives will be determined followed by the research questions. Finally some definitions will be given.

¹ See definitions.

Actoranalysis

Stichting Natuur en Milieu, the Netherlands Society for Nature and Environment (SNM), is an independent organization committed to securing a vigorous and healthy natural environment. The Society is helping to build a sustainable society in which nature, the environment and the landscape are treated with care and respect.

They do this by debating and influencing the policymaking process. Also by conducting research and publishing their findings.

SNM and the three Dutch Universities of Technology (3TU) cooperate in a project named NEXUS. Goal of this project: *Encourage the car industry to speed up the development of sustainable mobility solutions by designing a car for the year 2020².*

In this project NEXUS will combine the strengths of SNM and the three universities of technology to get the best result. The result will be presented to the public and to car manufacturers at the 2007 AutoRai.

Approach

The consumer market is driven by demand. This demand is driven by the needs and wishes of the consumer. Unfortunately the need for environmental friendly properties underlies the needs for performance, design and such.

Here, it is clear that a car has to be designed that is not only sustainable by itself, but sustainable through its broad acceptance. This makes it important to create something that attracts the attention of consumers and the car industry and is desirable³.

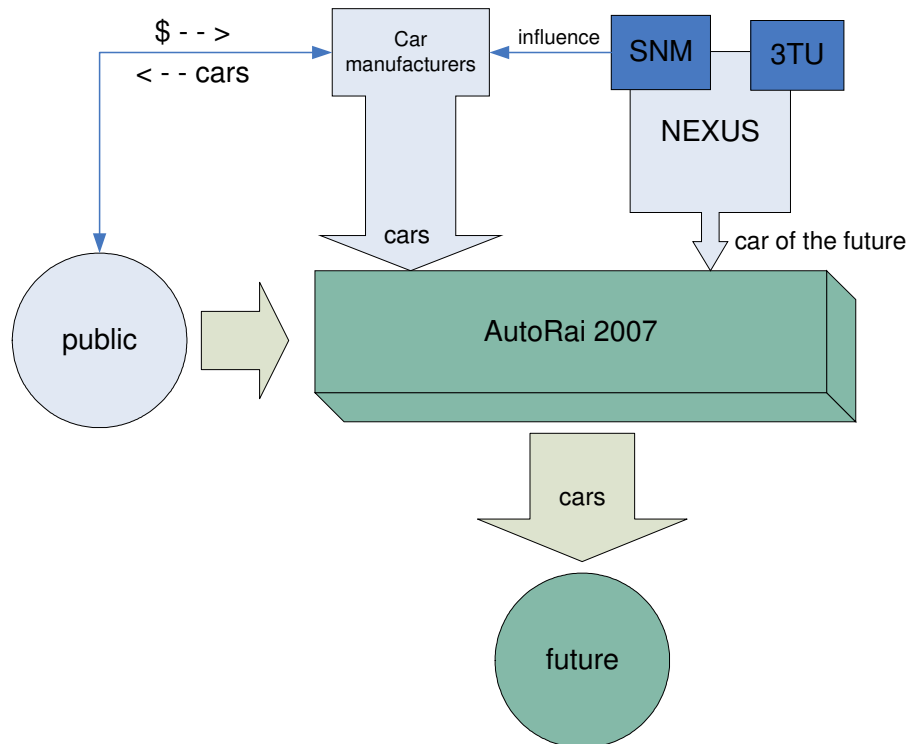


Figure 1 Visualization actor

² SNM, "Cars of the future", see references.

³ NEXUS website, see references.

Projectframe

To successfully introduce a new car it is important that the expectations by the buyers and the characteristics of the car match as good as possible. A part of the car where this accounts for is the powertrain of the car.

It is believed that acceptance of the powertrain should contribute to the success of a new car. Therefore it is interesting what aspects are important in the process of acceptance.

The idea is to investigate the role of an interface in this process and to use this to design an interface to give the driver insight in the working of the powertrain. This interface should contribute to acceptance of the new powertrain concept by the driver.

Objective

This research aims for a practical solution.

The objective for this assignment is to design an interface for the car of the future to make the driver understand the working of the powertrain. This design should be based on research on factors which are important in the process of accepting new powertrain concepts by the driver and on the role of an interface in this process.

The result of this assignment consists of 2 parts. First there will be clear conclusions and guidelines about factors that affect the acceptance of new powertrain concepts in future cars and the role of interfaces in this process. Second, there will be a working interface that displays the working of the powertrain. This interface could be implemented in the car of the future.

Questions

Main questions:

1. What are the basic concepts⁴ of the powertrain of the car of the future?
2. Which factors are important in the process of acceptance of a powertrain concept by the driver
3. How can an interface play a role in the process of accepting a cars' powertrain?
4. How can the interface satisfy the requirements and the stakeholders?
5. What is the effect of the display on the users when it comes to understanding and accepting the working of the powertrain?

Subquestions:

1. What are the basic concepts of the powertrain of the car of the future?
 - 1.1. What are the basic concepts of the powertrain used in current cars?
 - 1.2. What are the possible powertrain technologies for the car of the future?
2. Which factors are important in the process of acceptance of a powertrain concept by the driver?
 - 2.1. When is a new powertrain concept sufficiently accepted?
 - 2.2. What are the relevant factors, concerning the basic concepts of the powertrain, in this process?
3. How can an interface play a role in the process of accepting a cars' powertrain?
 - 3.1. How can an interface display the working of a cars' powertrain to the driver?
 - 3.2. What information does the driver want to know about the powertrain of the car?
 - 3.3. How can the interface fit in the interior of the car?
4. How can the interface satisfy the requirements?
 - 4.1. What are the requirements that follow from the research?
5. What is the effect of the display on the users when it comes to understanding and accepting the working of the powertrain?

⁴ See definitions.

Definitions

Basic concepts:

A set of necessary characteristics to describe and distinguish several technologies.

Powertrain:

An auto's powertrain consists of all the components that generate power and deliver it to the road surface. In conventional cars this includes the engine, transmission, driveshaft differentials, and the final drive (drive wheels). Sometimes "powertrain" is used to refer to simply the engine and transmission, including the other components only if they are integral to the transmission.

Strategy

- 1.1 source: literature, through: study
- 1.2 source: literature (NEXUS material), through: study
source: persons (teammembers), through: interview
- 2.1 source: literature through: study
- 2.2 source: literature, through: study
- 3.1 source: literature, through: study
- 3.2 source: literature, through: study
source: persons, through: interview
- 3.3 source: persons (teammembers), through: interview
- 4.1 source: earlier findings, through: analysis
- 5 user evaluation

First there will be a phase of analysis. Then there will be a phase of design. The phase of analysis can be split in three parts: research on the powertrain concepts, research on relevant factors in the process of acceptance and research on interface design.

All the literature will be studied during a desk research. The literature about powertrain technologies of the future will be obtained from the NEXUS project. Some team members will be interviewed.

The requirements will be obtained from the conclusions of studies of the literature. An interface will be designed according to those requirements. If there is enough time a user evaluation concerning the interface will be carried out.

Time schedule

See attachments

References

Verschuren, Piet & Hans Doorewaard (2005), *Het ontwerpen van een onderzoek*, Utrecht: LEMMA BV.

DHV (2005), *Cars of the Future – A journey past prospective sustainable technological innovations for passenger cars*. On behalf of SNM: <http://www.snm.nl>.

NEXUS: <http://www2.io.tudelft.nl/io1008595>, accessed at 12 may 2006.

Attachments

- Notes first acquaintance
- Time schedule

Notes first acquaintance

Date: March 15th, 2006
Time: 11:00 am
Location: Horst-building, University of Twente

Attendants: Dr ir Frans Tillema, Department of Civil Engineering, University of Twente
Gertjan Endeman, Student Industrial Design, University of Twente

The companion explained the origin of the assignment and the content of it.

In a national context the Society of Nature and Environment challenged the three Dutch Universities of Technology (Enschede, Eindhoven and Delft) to design a car of the future and present this car at the 2007 AutoRai. The Society in fact needs the 3 universities (3TU) to fulfill a promise they made to the car industry in 2005. In this year Toyota introduced the new Prius, an ecologically friendly car. The society honored Toyota in a page-wide advertisement in a national paper and promised to develop a car of the future by herself. This is why the 3TU has to help the society by bringing in their expertise.

So a projectteam has been formed consisting of SNM, 3TU and the consultancy company DHV. This team will design a car of the future. Every university has been assigned a part of the project. Eindhoven takes care about the engineering, Delft about the design and Enschede about the infrastructure and user interaction.

One aspect of the car is the propulsion system. In the future we will most likely use new technologies which are more efficient and better for our environment.

In this context an individual assignment has been formulated: The design of an interface to let the driver of the car of the future know how the propulsion system works. Knowing this should contribute to acceptance of the car of the future by the driver.

To come to a design relevant research has to be done. Some interesting topics could be: research on possible propulsion systems, research on factors which affect acceptance of propulsion systems, research on the possible role of an interface in this process, workload of the interface and user evaluation.

Another aspect that has to be considered is the opportunity to give users control about the amount of information is provided. So grandma can work with the interface, but also an extreme carfreak.

The trainee post will most likely be at the University of Twente or may be at the University of Eindhoven.

Time schedule

week no. (calender)	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
		may				june				july				august						
weeks (bachelor assignment)		1	2	3	4	5	6	7	8	9	10	11	12			x	x			
project approach																				
research/analysis 1.1				x																
research/analysis 1.2				x																
research/analysis 2.1				x																
research/analysis 2.2				x																
research/analysis 3.1																				
research/analysis 3.2																				
research/analysis 3.3																				
design 4.1																				
evaluate 5																				
report																				

X = milestone meeting (SNM Utrecht)

At this meeting the current results will be presented.