Automotive Cockpit Design 2020

Design and Investigation of HMI in Cockpit for Future Concept

Master of Science Thesis

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Design and Investigation of User Interface in Cockpit for Future Concept

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The cover picture shows the final design of this study.

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Abstract

This study is aimed to develop the cockpit for the future personal vehicle by investigating

technology trends and user needs. The study is made in cooperation with Mecel AB, which develops software and vehicle systems. The study outcome is aimed to inspire the Mecel team on the future Human Machine Interface (HMI), enabling them to think ahead and support their customers with state of the art technology. The outcome is also applied as promotional material to attract customers. The study identified current user needs and technical preferences toward HMI of personal vehicles while investigating possible technologies that can be applied to satisfy user needs. The reasonable predictions of user needs and mature technologies in 2020 are conducted based on a literature study and empirical data.

The thesis outcome is two in-car HMIs with focus on displays. The two cockpit conceptual designs are presented to explain the locations and features of the HMIs. The visual materials of the outcome are imported to the company website as promotional material. In the case of attracting Mecel potential customers, the visual material of the study outcome should be aesthetically pleasing to the target market.

Content

1 Introduction

1.1 Background

Mecel is an experienced company developing software and systematic solutions for the automotive industry. Mecel specializes in in-car communication technologies, human machine interface (HMI) development and consumer device interaction.

One of the products that Mecel develops is Mecel Populus suite. The study is cooperated with Mecel Populus team which develops the Mecel Populus suite. The Mecel Populus suite is a product that develops customized user interfaces for distributed embedded systems. As Mecel states (Mecel, 2010):

The Mecel Populus concept has several unique features compared to traditional HMI development. These features, when combined, remove the barriers that traditionally exist between the people working with requirements, system engineering, HMI design and implementation. An HMI is created and verified in Mecel Populus Editor without having to write any software. The HMI is then downloaded to the target environment where Mecel Populus Engine executes it. Mecel Populus has been designed for the automotive industry to deliver high performance user interfaces with short time-to-market and to enable efficient software life cycle management.

Information Technology increasingly develops over years. As software developer, Mecel always need to know how the future scene of IT industry will be. Developing conceptual HMI will inspire Mecel to think ahead and provide their customers state of the art technological solutions. The development of Mecel Populus Suite is ongoing. Mecel needs to know which features should be developed to make populous suite a competitive product. Nevertheless, which features should be developed is contingent on how cars and HMIs will be in the future. This study helps Mecel fulfill the challenge by developing innovative HMI concepts.

1.2 Purpose/Aim

The requirements to this study are to design HMI concept for personal vehicles in 2020, with a focus on the Western European market. Mecel requires more than one concept, corresponding different types of user groups. This study suggests standard user group and expert user group according to previous experience. The standard users represent the people who using personal vehicle for transport purpose while the expert user indicates the drivers who have abundant experiences and enthusiasm on driving. Since these two user groups have different needs upon personal vehicle, it leads two design directions.

The study emphasizes on visualization of the in-car HMIs. Additionally, according to Mecel's requirements, the displays system and the relevant technologies have higher priority than others. The final designs will be presented on Mecel's website as promotional strategy. And therefore, the visualizations of the design should be appealing and communicate with Mecel's customers.

Rather than solve an existing problem, this study explores the possibilities of personal vehicle in 2020. During the project, this study engaged in answering the question:

-How could the HMI of personal vehicle be in the near future?

1.3 Delimitations

The study focuses on the personal vehicle field, so other vehicle types would not be considered. The target market is western European. The physical components of cockpit will be studied in a limit extent. Primary user of personal vehicle is studied while the study of secondary user, co-user and side user is excluded. Among the primary users, driver is the study focus. Front-seat passenger is studied in a limit extent. The study of rear-seat passenger is excluded.

1.4 Terminology

Human Machine Interface (HMI): Where the human and the machine (technology) meet.
User: A person who use a product.
Primary user: A person who use products for primary propose (Buur&Windum, 1995)
Standard User: A primary user who has knowledge of use and average use experience
Expert User: A primary user who has technical knowledge of product/system and abundant use experience
Touch Screens: Displays that able to receive input by touch of fingers

1.5 Overview of the report

The report structure begins with the introduction of the thesis project that what are the purpose of the project and background of the project. Then the theoretical framework describes the theories and principles of the development. The theories and principles are the essential guidelines for conducting user study and HMI design. It followed by Methods. In the MethodsChapter, it theoretically describes the methods used in each development phases.

Development Process Chapter describes the contents and the outcomes of each phase. In the pre-study phase and research phases, the content and outcomes of each method are described. In the design phase session, the design phase is divided into three stages,

which are ideas generation, concept development and visualization. After that, the final design is especially illustrated in the final design chapter. It followed by the general discussions on methods, processes and the results. Then the general discussion leads to the conclusion where demonstrated general thoughts on the entire project.

2 Theoretical Framework

Theoretical Frameworks demonstrated the theories and principles, which conduct the project. The user-centered design is the general design principle for the two HMI. Activity theory is applied during the user study to identify user needs. Ecology interface design is assisted to address the functions and features. The visual design principle is the guideline for visualizing the concept.

2.1 User-centered design and Activity Theory

User-centered design aims to develop products that satisfy the user needs. The focus of user-centered design is to identify the needs of the user and provide solutions to fulfill the needs. In the user-centered design process, identify and describe user needs, in most cases, are the initial point, however, according to Rexfelt(2008)'s research, it is concluded that needs are not easy to study. Nevertheless, by observing and analyzing human activity, needs could be identified when *individual seeks the satisfactions of the needs* (Karlsson, 1996). Frameworks and approaches, applying in the field of human-computer interaction, based on activity theory are developed to help identify human needs.

Furthermore, ISO 13407 (1999, p3) provides the description of human-centered design approach; it states the characteristics of a human-centered approach as:

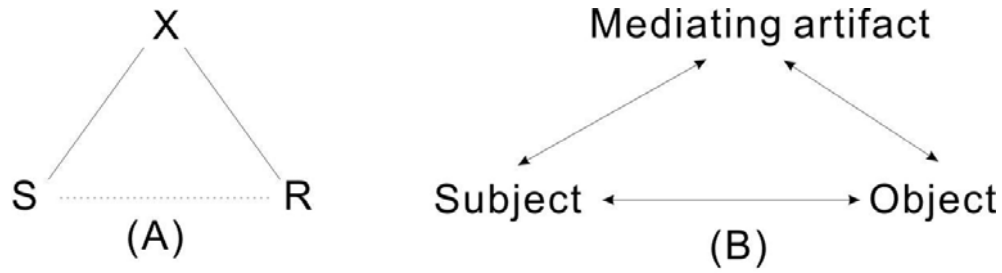
- *The active involvement of user and a clear understanding of user and task requirements*
- *An appropriate allocation of function between users and technology*
- *The iteration of design solutions*
- *Multi-disciplinary design*

According ISO 13407, the three main activities of user-centered design are:

- *Understand and specify the context of use*
- *Specify the use and organization requirements*
- *Evaluate designs against requirements*

Activity theory was developed by the Russian psychologists, Vygotsky, L.S., Luria, A. R. and Leont'ev, A.N. in 1920's. Activity theory is a clarifying framework for studying humans' practices as development processes. It has been applied to numerous science and technology fields. According to Activity theory, human react to the environment through mediation.

Activity is the unit in the activity theory. The basic triangle structure of an activity contains an object, a subject and an artifact (mediation) [figure 1]. A subject is a person or a group engaged in an activity. An object is held by the subject and motivates activity, giving it a special direction. An object is transformed thought the subject reacting and responding to the mediation, which could be tools, artifacts, and signs, etc. It is the factor that distinct one activity from another activity (Kuutti, 1995).



(A)Vygotsky's model of mediated action and (B) its common reformulation

Figure Activity Theory

An activity is a hierarchy that contains an action or a chain of actions. An action contains an operation or a chain of operations. An activity can be described as a network of actions and operations that are guided by an object [Figure 2].

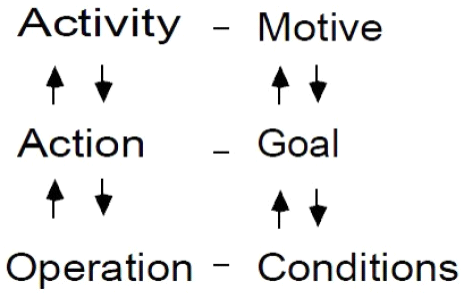


Figure 2 Activity Theory Hierarchy

Activity theory has been applied in human-computer interaction since 1980s.Activity theory allows HCI researchers study the context (Nardi,1995). In the product development process, activity theory could be used to identify human needs and understand the context (Rexfelt, 2008). Bödker(1995) developed practical techniques to analyze video. Bödker gave a definition of "*good artifact that allows us to focus our attention on the real object*". Breakdowns and focus shifts interrupted and/or increase the complexity of the original activity (focus shifts are not necessarily caused by breakdowns).

2.2 Ecological Interface Design (EID)

EID was developed involving different theoretical fields. It roots in a control engineering perspective that has been developed in Denmark since 1960s. Jens Rasmussen, Kim Vicente and other Risö researchers argued that the human operator took an important part of the reliability of the complex system. The interface design of a complex system needs to support three kinds of operators' behavior, skill-based, rule-based, and knowledge-based. Abstraction Hierarchy is a fundamental approach to analyze the environment and the work domain in EID. *Ramussen and Vicente combined the analytical tool of the Abstraction Hierarchy with the insights of the SRK Taxonomy to develop an approach to interface design for complex systems where unanticipated situations were a reality* (Burns & Hajdukiewicz, 2004,P 10). EID has been applied to develop nuclear power

plant, transportation system, process control system, medical system etc.

2.2.1 Work Domain Analysis

Different from user-centered design, WDA begins with analyzing the environment rather than the user. It is crucial to define the system boundary including things the user want to control, must monitor and supervise and that interact with the user's work domain. Abstraction Hierarchy is a framework for understanding work domain constraints in a systematic way. It contains five levels to describe a work domain. The top level is the purpose of the work domain. The following levels are to answer how to realize the level above. The five levels of the abstraction hierarchy are:

Functional Purpose describes what the work domain was designed to do. It is different from the task that contains one or a series of actions that people do. A functional purpose is an attribute of a system or work domain. For instance, the task driving from A to B contains a series of actions that the user must perform. There are numerous of purposes of why a user drives from A to B. But for the car itself, the functional purpose is to transport people from A to B.

Abstract Function demonstrates the causal relationship underlying the work domain. In the actual work, abstract function describes the physical law that cannot be broken and the priorities must be achieved.

Generalized Function describes the processes to accomplish the priorities that described in the Abstract Function. In this level, the description is more concrete and closer to the physical description.

Physical Function means the various components of the work domain. In this level, the questions- what are the components, what are their capabilities and how are they involved in various processes-should be answered.

Physical Form describes the appearances of the work domain. It includes the size, shape, color, location, condition and material of the components.

The application of the work domain analysis and abstraction hierarchy depends on the actual work. It is not necessary to always use the five levels of hierarchy to describe the work domain (Burns & Hajdukiewicz, 2004).

2.3 Design Principles

Since the Users of vehicle UI is persons who have driving permit within Western European countries, the UI is designed for the persons who are visually able to drive. For instance, the driver cannot be color blindness. When design the user interface, the

primary concern is to communicate with the end users by providing understandable message. Color and typography principles are followed to construct the visualization of designs.

2.3.1 Gestalt laws

Gestalt laws, as a common organization principle, used regularly in visual design [Figure 3].

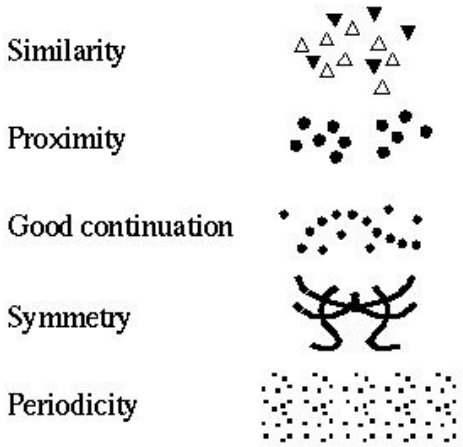


Figure Gestalt Laws

2.3.2Color Principle

From safety perspective, the UI design should be recognizable and understandable under various environments. The color selections should consider western interpretations of color. The perception of colors are usually highly subjective, but when comes to work environment, certain principles could be followed.

2.3.3 Color –coding work environments

The US department of Labor's Occupational Safety & Health Administration (OSHA) has developed guidelines for color-coding work environment (Visocky O'Grady, 2008) [Table 1]

Table *Guidelines for color-coding work environment(Visocky O'Grady, 2008)*

Color		Meaning	Application
Safety Red PMS 1797 C		*Stop,Danger*	Signifies fire protection equipment,"danger" and "stop."
Safety Orange PMS 165 C		*Warning*	Signifies dangerous parts of machinery or electrical components which can crush, cut, or shock.
Safety Yellow PMS 124 C		*Caution*	Signifies physical hazards created by non-moving objects which can be fallen over or into, struck against, or between which one may be caught.
Safety Green PMS 341 C		*Stafety*	Signifies areas and equipment associated with First Aid.
Safety Blue PMS 287 C		*Information*	Signifies safety information; used on informational signs and bulletin boards.
Black+White Process Black		*Boundries*	Signifies housekeeping and traffic areas.
Safety Purple PMS Purple C		*Radiation*	Signifies x-ray, alpha, beta, gamma, neutron and proton radiation.

2.3.4 Color Contrast

The Americans with Disabilities Act (ADA) provide a simple suggestion on color contrast. To make for the most legible message, 70 percent contrast an object and its background is the best (Visocky O'Grady, 2008).

2.3.5 Typography Principle

According to Nini(2006), the human vision declined as age raised. The typography used on HMI should ensure that the information is recognizable and understandable even it becomes blurred or in the dark environment.

The Americans with Disabilities Act (ADA) sets typographic standards for signage. It provides optimal body-width to height and stroke-width to height ratios for the use of appropriate typefaces in signage systems. Compare to serif styles, sans-serif styles works better, due to the thin stroke, which serif styles usually have, would fall away (Visocky O'Grady, 2008)

3 Methods

This chapter theoretically describes the methods applying in the project. The methods consist of system description, use profile, metal model, SAM, personas and scenarios, image board and brainstorming.

3.1 System description

Numerous researchers have proposed the different definitions of system. Sanders and McCormick (1993) summarized that *a system is composed of human, machines, and other things that work together (interact) to accomplish some goals which these same components could not produce independently*. In a human machine system, human operators and users considered as one of elements interacting and communicating with other elements by transforming energy, matter and information. *An element could be physical, social or abstract.* Elements communicated with each other by transforming matter, information, or energy/force (Bligård L., 2011).

System Description is method to visualize the human-machine system by identifying the system elements and their connections. It provides a holistic view for the designers to understand the human-machine system and its context. The outcome of the system description is a graphical system model that illustrates the elements and the connections. To make a graphical system model require four steps (Bligård L., 2011):

- *Identify the element in the system*
- *Describe the properties of the elements*
- *Identify the connections between the elements*
- *Make a graphical system model*

3.2 Use Profile

Use profile investigated the relations between the user and the product. It describes the use experience， influence on and responsibility of use. With the use profile, users can be categorized into types. It is possible to design for specific type of user (Janhager, 2005). The questions associating with the frequency, duration and situations of driving personal vehicle are asked to identify the relations and user type during the interview.

3.3 Mental Model

A mental modal is defined as: knowledge that the user has about how a system works, its component parts, the processes, their interrelations, and how one component influences another (Fein, Olson & Olson, 1993,p 157). The mental model can be useful to understand how the users perform complex tasks. According to Preece(1995), the outcomes from the interview are known as functional models or task-action mapping models which means the models shows users procedural knowledge about how to use the system.

3.4 Emotional Test and Self-Assessment Manikin (SAM)

The Self-Assessment Manikin (SAM) is a non-verbal pictorial assessment technique that directly measures the pleasure; arousal and dominance associate with a person's affective reaction to a wide variety of stimuli (Bradley & Lang, 1994). The SAM is used to understand the users emotional reflections upon each task. After the interviews described the steps of performing specific tasks, the interviewees are required to rate the pleasure, arousal and dominance scales .The ratings given by the interviewees help understand what are the users subjective emotions when performing certain tasks.

3.5 Contextual Observation

The observation aims to study the user context when one operates the system. The video camera is used to record the driving activity that the user involved. The videotape is analyzed, according to the approach described by Bödke (1995). The breakdown and focus shift are paid attention due to their causes are the potential misfits.

When analysis the video, the role of each function unit is identify to understand the how users interact with the system in their actual use situation. The analysis is done by answering the following questions:

- lWho are the users?
- lWhat are the objects?
- lWhich are the activities in which function unit is used?
- lCan the mediation be characterized as tool, medium, or system?

Each focus and focus shifts, the consequences lead to the focus shift are described. In this case, the misfits that arise when user interact with the system could be considered as a potential for improvement.

3.6 Brainstorming

Brainstorming is a method frequently used in ideation. A brainstorming session aims for maximum ideas. The participants are allowed think freely but associating with the scope of topic. A traditionally brainstorming is held in group to solve a specific problem while nowadays an individual thinking and presenting considered as a brainstorming session as well.

3.7 Image Board

An image board *is a form of visual stimulus material*. It usually contains numerous images which present atmosphere, emotions or feelings.

3.8 Persona and Scenario

Persona is a tool frequently applied into user-centered design approaches. Personas are created according to real user or target user information. Each persona represents a user group. It is an effective method for the developer to keep users in mind through the development process. A persona is usually described with life story, goals, behaviors, and professions etc. The description could be varied depending on the purposes and functions of product or service. It allows development team discussing and determining the product/service requirements and its solutions. An effective persona has to be created based on real user information, in order to convince the project team trusts the persona.

Scenarios present how people might interact with and operate the product or service under certain context. It can assist the designers to identify the new features. It also could be used to evaluate the concept by fit the concept into scenario (Janhager, J., 2003).

4 Development Process

The development was carried through four phases: pre-study phase, research phase, design phase and evaluation phase. At pre-study phase, the knowledge regarding in-car HMI design was explored via academic literature study and manufacturer publications. The thesis project was thus defined. The research phase is aimed to identify user needs toward personal vehicle and investigate new technology features that could be applied into automotive HMI design. The design phase is divided into three stages, ideation, concept development and visualization. At the ideation stage, authors generated ideas based on the knowledge gained from pervious phases. Then, the initial concept was delivered to the concept development stage. At concept development stage, the initial concept was fully developed into a detailed functional layout of automotive cockpit. At visualization stage, aesthetic requirements were considered to visualize the HMI with the focuses on dashboard, climate control panel and passenger touch screen. At the evaluation phase, the usability and technical features were checked at Mecel. The final design was delivered after the evaluation phase [Figure 4].

Figure Development Process

5 Pre-study Phase

At pre-study phase, the automotive technology trends were investigated through literate study. The publications from automotive manufacturers as well as scholars were analyzed to predict the mature technologies in 2020. Furthermore, the current marketing with a focus on personal vehicle was studied to define the two types of car.

5.1 Automotive technology trends

In order to foresee the mature automotive technologies in 2020, the technology trends were investigated. It has been identified that sustainable development in the automotive industry has been the curial topic for years. Technologies that assistant and consider sustainable development, are the primary topic nowadays. Technologies, such as electrically driving, clean energy are developed. Safety is still important and will be always important. In the case of constantly maintaining personal and property safe on the road, technologies associating with active safety are trendy. Thirdly, topics on intelligent and interconnected technologies which associated with usability and intuitive design will continued receive attention.

5.1.1 Electronic Driving System and Clean Smart Energy

According to Mitchell, Borroni-Bird and Burns (2010), the three major disadvantages of gasoline make gasoline-powered cars not sustainable. Firstly, the process of powering wheeling by burning gasoline produce local air pollution as well as carbon emissions which become increasing concerned over the world. Secondly, as well known, gasoline is not renewable and the source of that only concentrated in few regions, which lead to the third disadvantage that the petroleum-importing countries are in vulnerable positions.

The three major disadvantages of gasoline power make clean and efficient energy power indispensible. Mitchell, Borroni-Bird, and Burns (2010) also state that integrating electrical vehicles into new energy disturbing system as well as replacing today's mechanical power will solve these problems.

5.1.2 Vision Zero and Active Safety

Vision Zero is a vision of road safety that *eventually no one will be killed or seriously injured within the road transport system* (Ministry of Transport and Communications, 1997). It was passed by a large majority in Sweden parliament in October 1997. To realize the vision, safety has to be high priority when designing the vehicles. Nowadays safety systems are categorized into two major systems, passive safety system and active systems. Passive systems usually refers to the systems and components that protecting injures and lost when accidents happening. Active systems aim to preventing accidents occurring.

5.1.3 Multimodal driving user interface

The basis for a modern human-machine interaction concept is a user-centric design that focuses on the needs of the target user. According Feld, Muller and Schwartz (2010), when design automotive user interface, it is not sufficient to implement a set of fixed interactions for the target user. Since the users and use cases are various, the interface design should consider the actual state of the user and its context. The multimodal stimulus can strengthen and simplify the information while different input methods allow the use preferences. Numerous researches have done on the acquisition of knowledge. The user and context parameters could be detected by different sensors, such as temperature and weight sensory. In addition, the user information could be collect by the users identify themselves; in this case, the basic information from the local database could be obtained.

According to Batliner, Hacker and Nöth(2006), the computer could notice the different human utterances, speck to a computer, speak aside or speak to themselves. So far in the most voice recognition systems, certain inputs, such as press a button, must be delivered by user before user interaction. An elaborate automatic dialogue system can detect on talk speech without any push-to-talk buttons. User interact with computer will be more naturally. Since the spreading of Multi-gesture user interface on handheld devices, gesture based operations become intuitive to individuals.

5.2 Market Analysis

Market analysis was carried out to understand the current car market. To identify some basic points for the concept development, such as the capacity, price level, speed range etc. For each type of car, 8 cars were studied (Appendix A).

5.2.1 Result of Market analysis

From the marketing analysis, gasoline powered vehicles remains dominated nowadays while city car and smart car on their way of being electrical powered or alternative clean and efficient energy. The capacity of long distance vehicles is usually above five persons while the capacity of city car is two persons to four persons. With existing technologies, electrical powered car has a major disadvantage on limited speed range and long hours charging.

6 Research Phase

6.1 Workshop

Workshop was held to gain various ideas. The purpose of the workshop is defined as exploring the possibilities and new features of future personal vehicle.15 participants who have educational backgrounds on automotive engineering and product development were invited to this workshop.

6.1.1 Workshop Procedure

The questions (Appendix B) that lead to discussions of future personal vehicles were listed. When gathered the participants, authors played as hosts to lead the discussion. The discussions were recorded as audio materials. After the workshop, materials were analyzed and compiled.
During the workshop, all the participants were allowed to think creatively and freely. The participants were divided into sub-group. At the initial phase, the discussion was conducted in the sub-group. Then the sub-groups could give comments to each other group.

6.1.2 Results from workshop

The results of workshop provide ideas to the study and inspirations when ideation and concept development. Furthermore, automotive features were consistently discussed during the workshop which provides the study information on automotive technological trend. The original record from the three workshops can be seen in the Appendix (B), but from the vast amount of ideas, there are some thoughts can be summarized.

6.1.3 Thoughts on Standard User Car concept

Interactive displays widely apply in automotive HMI. A lot of the ideas from the workshop are emphasizing the application of multimodal interface. Touch screen, which is widely applied in consuming electronic products, is considered to be applied in personal vehicle HMIs in a larger scale. Other advanced displays, such as Head up Display and Hologram are also considered to be feasible in ten years.
Cars will be developed even more environmental friendly. This is a fact agreed by all of the participants, electric powered and hybrid cars are trendy, as well as the energy recycling system and components, such as Kinetic Energy Recovery System (KERS) and efficient tires.
Automatic functions are even more developed. Cars are driven by themselves is not a fairytale. A lot of participants in the workshop had mentioned different automatic technologies for cars, such as Autopilot and Road Train Technology.

Internet Access will be widely available and vastly improved in the future. New generation mobile telecommunication brings revolutions to the world over time. It is technical possible to watch Blu-ray movie on-line by the in-car infotainment instrument in the near future.
Natural Speaking Command will be available in the future. The voice control could be applied in many kinds of operations to reduce the workload for the driver, and in the future more natural speaking control can be realized.
Smart Navigation System will be popular. It is widely agreed that more information should be provided in navigation, with a more intelligent system, with information on traffic and road condition, even more geographical details and instantly updating route selection.
Infotainment and Communication will be improved. Since the automatic driving functions will be developed, the infotainment experience could be enhanced by adding functions which allows video chatting, watching movies, playing games and so on, diverse communication process could also be done in the car while driving.
Customization is going to be the trend. With memory function developed, the car can remember the driver's settings over different facilities and adjust to fit the driver when recognizing.
Brand New Vehicle Service System. Future vehicle service system may be developed, such as personal vehicle can be combined with public transportation, or the personal vehicle can be leased in some way.
Future Exterior System will be more efficiently structured and intend to have neutral and standard styling. For efficiency purpose, the workshop proposes the car can be smaller, and with larger visual area for driver. Also the exterior can be more aerodynamic efficiency. Also to the user category, the workshop suggested the neutral and standard styling would suit the standard user car.

6.1.4 Thoughts on Expert User Car concept

Interactive displays widely apply in automotive HMI. As mentioned in the standard user category, Touch screen, Head up Display and Hologram is also widely suggested by the participants in the workshop.
New technologies applied in cars for enhancing driving experience. For expert users, the workshop delivered ideas mostly about enhancing driving joy. For example, the gearboxes are remained as manual operation, also more advanced electrical systems like steering by wire.
Internet Access will be widely available and vastly improved in the future. Also the same as standard users, more advanced Internet in vehicle is predicted available in the future.
Natural Speaking Command will be available in the future. More developed, natural speaking recognizing system to be installed in the future vehicle
More car performance features could be set in the expert users cars. The cars for expert users are suggested to have more settings over driving performance, e.g. adjusting the tire pressure or the differentials, since the expert users have more interests and

knowledge on this.
Infotainment and Communication will be improved. Like the standard user car, the Infotainment and Communication system is required to be more reliable and advanced as well, especially when it's focused on such an experienced user group.
Customization is going to be the trend. The expert user car will more adapt to the personal use. On top of the memory function mentioned above, the expert users car can be customized to users' preferences in terms of different vehicle systems and exterior styling.
The expert users car will be much more fuel-efficient. The workshops suggest the cars for expert users are remained with gasoline car since it is only ten years ahead, it is difficult for the electric powered cars to be improved to have equal performance as gasoline cars. But the fuel efficiency will be improved dramatically.
Future Exterior System for expert users car will remain Classic and Premium, yet Sporty, Futuristic, and Aerodynamic. Because of the target user group and the higher price level, compared to the standard user car, these keywords are dragged out by the workshops. The exteriors should also image the performance of the vehicle, as an expert user car, the look itself should provide the same feeling as its performance.

6.2 System Description

The system study aims to understand the current in-car driving system, relations of systematic elements, and the context of that. The automotive cockpit was studied by analyzing three cars, Volvo V70 2.4, SAAB 93 2.0T and Nissan LEAF electric car. The three cars have some differences on driving control system since Nissan Leaf is an electric powered vehicle. When generalized as functional units, these three cockpits have similar layouts and functions. The system description was formulated in a general manner for the current automotive cockpit. Two contextual observations were conducted to identify the relations between elements and understand the context.

The procedure of system description is:

- Identify the elements of in-car driving system.
- Describe the properties of the elements and components of the elements
- Identify the connections between users and other elements. The connections are categorized into transformation of energy and transformation of information.
- Make a graphic system model.

To identify the elements and their properties and components, the three automotive cockpits and user manuals of those were studied. The investigations of relations between users and other elements mainly through observing two use cases; however some elements were not used in those two use cases. The user manuals were studied as supplementary materials to identify the interactions of users and other elements. The system model is a visual result of the system description.

6.2.1 The elements of in-car driving system

The boundary of the driving system is automotive cockpit. The Volvo V70 2.4, SAAB 93 2.0T EW were analyzed to acknowledge the general system description for the conventional sedan and hatchback. Nissan Leaf was analyzed as the electrical car (Appendix C).

Besides the primary users, the other elements were summarized as functional units rather than physical components. The elements were categorized into four types: primary user, driving control system, infotainment system and driving assistance system, and comfort system [Table 2].

Table System description

Driving Control System	Main instruments panel, Pedals, Gear Box, Steering Wheel, Hand Brake, Mirrors, Wipers, Head Lights
Infotainment and driving assistance system	GPS, Radio, In-Car Telephone, CD Player
Comfort System	Climate control, In-Car Lighting, Seat, Windows
Primary Users	Driver, Front seat passenger

6.2.2 Relations of users and other elements

The contextual observations help authors identify the relations between users and other elements. Two participants are both expert users who have driving experiences more than ten years. The contexts are that the users drove in a familiar city without certain destination and time limit. The weather and road conditions are fairly fine for driving. The video tape was analyzed, according to the approach described by Bödke (1995).

In a driving context, the primary users are the driver and the front seat passenger. The objective is actually helping the authors study the driving context. The activity of driving from destination A to destination B could be divided into three actions: start up the car, driving, and parking at a familiar parking lot.

For the action-start up the car-the bellowing elements are used:
seat, handy brake, gear shifter, front mirror, rear mirror, clutch pedal, accelerator pedal, brake pedal, side window, main instrument panel

For the action-driving-the bellowing functional units are used:
Gear shifter, front mirror, rear mirror, clutch pedal, accelerator pedal, brake pedal, radio,

main instrument panel

For the action-parking -the bellowing functional units are used:
Seat, hand brake, gear shifter, front mirror, rear mirror, clutch pedal, accelerator pedal, brake pedal, side window buttons, main instrument panel

Since the observation participants are both expert users and familiar with the driving environment, GPS was not used during the two observations. However, one participant keeps radio on in case of being updated by traffic condition news. The in-car telephone and CD-player were not used during the observations either.

Among these elements, driver had energy / force transformation with all the other elements except main instruments plane which remain as display in the automotive cockpit. Driving assistance system, infotainment and climate control transformed information to the driver while driver operated them during driving.

6.2.3 System Model

System Model is applied to visualize the relationships of the elements within the in-car driving environment [Figure 5].

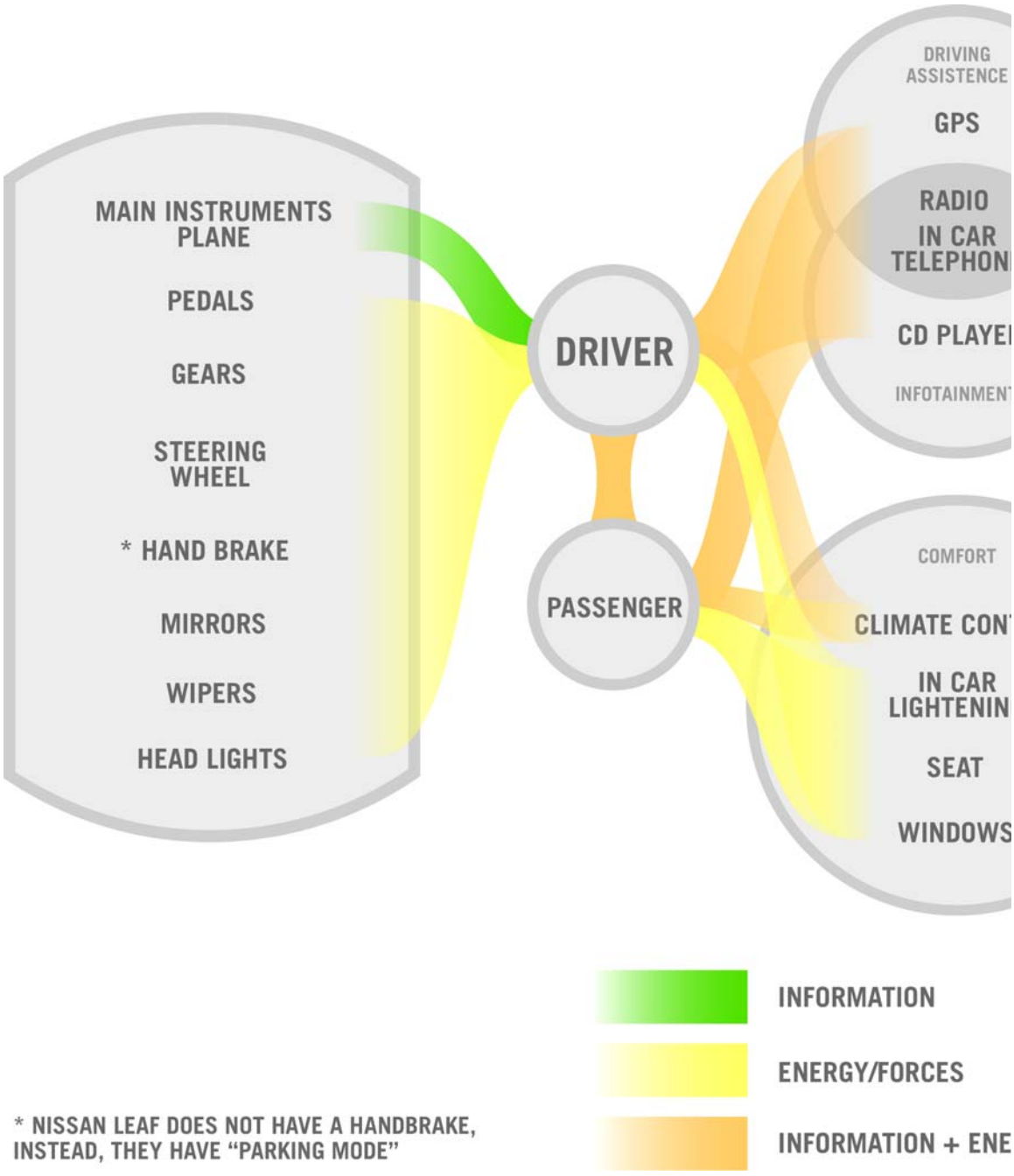


Figure *System model*

6.2.4 Results from system description

Results of system description provide this study understanding of current personal vehicle system and relations of user and system. According to the system model, driver dominantly controls and operates the driving control system. For the current automotive

cockpit, all the driving operations are made by driver. Driver is able to access to all the elements while Passenger is able to access to driving assistance system, infotainment system and comfort system. Besides observing road conditions and outer environment, information is provided via main instrument panel, driving assistance system and infotainment. Besides the main instrument panel, driving assistance system and infotainment systems requires interactive operations. Overall, the elements that interact with the driver are main instrument panel, GPS, radio, in-car telephone, CD player and climate control.

6.3 User Interview

6.3.1 User Interview Content

User Interview was divided into two parts. The first part was mainly questions about driving experiences in general; the second part was a mental model test together with SAM. The original question list is attached in Appendix (C), but according to different profiles from each interviewee, the questions are modified properly.

6.3.2 User Interview Participants

The Target User Interview aims to have users from two categories to be interviewed. The ideal interviewee group would be 10 persons in total, in each category the interviewees are not only matched with each user category's profile, but also among the total 5 from each group, 4 would be the users today and 1 would be the potential user.

The number of final selected interviewees is 9. Among these 9 people, 4 of them are employees in the automotive industry, while 3 are university students with academic background on international marketing, humanity and industrial design engineering. One interviewee is a senior citizen who has driving experience more than thirty-five years. With the definition before the research started, the authors found out that only three users are fully matched the standard users' profile, the other six users all have characters belong to both expert users and standard users as defined: they may have strong knowledge or interests in vehicles, but when considering their choice and usage of their own cars, it turned out to be very much like the standard users. As a result of this, the user interview won't give major input about emphasizing the difference between the two user categories, but the common input to both concepts.

6.3.3 Results from user interview

As stated above, the user interview provided input mainly concerning the common input to both user category concepts, thus the outcomes mainly offered information to the scenarios and the details of the HMI designs in later concepts.

Input To Scenarios

What the user interview introduces to the scenarios is their various situation of using their own car. From the interview, there are several scenarios that happen frequently:

- From home to workplace: this is one of the most frequent scenarios among the users. The differences among this scenario are distance and context: from downtown area to downtown area, from suburbs to downtown area.
- Shopping: frequent as well. Parking and finding parking lot could be this scenario concerns to some extent parking problems.
- Taking child from or to the school.
- Travelling for a short or long distance.

Input To HMI Designs

All of the interviewees have more or less stated some problems they have ever met or their comments on the vehicles and the trend. As a matter of fact, this plays a strong role while developing the concepts, both functional layout and visualization.

- One of the interviewee complained the central control stack of her car is inconvenient to be used during driving due to the display is a touch screen. There are users saying that it would be major inconvenient to use touchscreen while driving since touchscreen always requires visual recognition and the display is not located within nature sight angle.
- There are two interviewees complaining about unpleasant experiences on using navigation system while driving. There are also unpleasant driving experiences from two other interviewees, which concerns the traffic condition. One of the interviewees who has been involved in navigation system development, stated his opinions on what is a good navigation system and what can be improved in the future navigation system:

  What is a good navigation system?

  - The map has to be updated. It is usually two times a year.
  - The navigation system should have clear instruction from its voice and display. Such as the distance instruction should come before the actual action instruction.

  What can be improved in the future navigation system?

  - The parking space updating could be available
  - The traffic information could be more accurate, such as the information of which lane has accident.
  - The navigation system should point out the best parking place for the driver in the future.

- One interviewee who has driving experience upon the car equipped with HUD system, pointed out that the head up display on the windscreen might be annoying while it has blocked the driver's view in some extent.
- One interviewee stated positive opinions upon the active safety system; while two others thought that the too frequent active safety system would be too annoying for the drivers.

6.4 Scenario and Persona

As a result from the analysis of the target user interview and the definition in the very

beginning, personas and scenarios were created (Appendix E). The personas and scenarios reveal the specialties of the standard users and expert users, which was an important input for the concept development later on.

The Summary features of personas and scenarios are listed:

Table Personas and Scenarios

	Persona	Scenarios
Standard User Concept	All ages that can obtain a valid driving license Limited or good financial ability Not that interested in cars and stuff related Male and Female Residents in western European countries	Inner city driving + City to suburb driving Western European cities
Expert User Concept	Car lovers Experienced driver, more than 10 years of driving cars Mid age Mid class	Drive within the city, from outskirt to downtown, trip (long distance) Western European Cities

6.5 Summary

The results of the research phase are vast. By holding workshops, possibilities and thoughts of personal vehicles for the future are explored. These thoughts provide amount of information on technologies which haven't been widely applied in automotive industry while feasible and useful to applied in personal vehicle. These thoughts also inspired authors on constructing the vision of future car, cockpit and HMI.

By conducting system study, authors understand the current automotive cockpit and relations of functional units and users. In the current automotive cockpit, besides observing outer environment and other telecommunicate device, information come from main instrument panel, driving assistance system and infotainment.

User interviews provide many inputs to the constructions of personas and scenarios. The use problems mentioned in the interviews compiled. When design HMI, these problems were discussed to evaluate ideas and concepts in some extent.

Personas and scenarios were constructed based the data from user interviews. The personas and scenarios describe the context of design.

7 Design Phase

As mentioned in the purpose/aim, the design phase has two major tasks: creating the functioning interior layout with a focus on the display, and visualization of these parts. After the design phase, two HMI designs, one for each category, were delivered. The two HMI designs should involve the incoming technologies and new thinking, which should feed the users' needs in both physical and mental dimensions. The visualization should correspond to each user category, and be aesthetic to the users.

The design phase was divided into three stages, ideation, concept development and visualization. It was carried based on the conclusions from previous phases, discussions with Mecel, and experiences and knowledge upon HMI design. At the concept development stage, concept proposals were generated by individual brainstorming and discussion. Then the concept proposals were discussed with the Mecel Populus team. During the concept development stage, the features, function area and functional hierarchy were defined. Eventually, the graphic user interfaces were designed and visualized at the visualization stage.

7.1 Ideation

At the idea generation stage, it mainly contains individual brainstorming, creative discussions and sketching the ideas. The purpose is to generate new ideas upon the entire automotive cockpit with the results and thoughts from previous study. At first, the authors sketched the ideas and designs individual. Since at this stage it aims for as many ideas as possible, the individual sketch and brainstorming are to explore new ideas without being affected by each other. Then the discussion was carried on with the principle of developing the ideas not judging. At the discussion sections, details were naturally developed for each idea. Six concept proposals were generated during ideation. They are different in functional layout. Four concept proposals are for Standard User Car whiles two for Expert User car.

When generating ideas, there are two prerequisites. First, the keywords of standard user car are city car, small, purely electrical powered while those of expert user car are safe, fuel-efficiency and fun to drive. Secondly, when brainstorming, the five functional areas (windscreen, dashboard, steering wheel, and passenger infotainment instrument and climate control panel) are the focuses.

7.1.1 Concept proposal and Analysis

Standard User Car –concept proposal 1

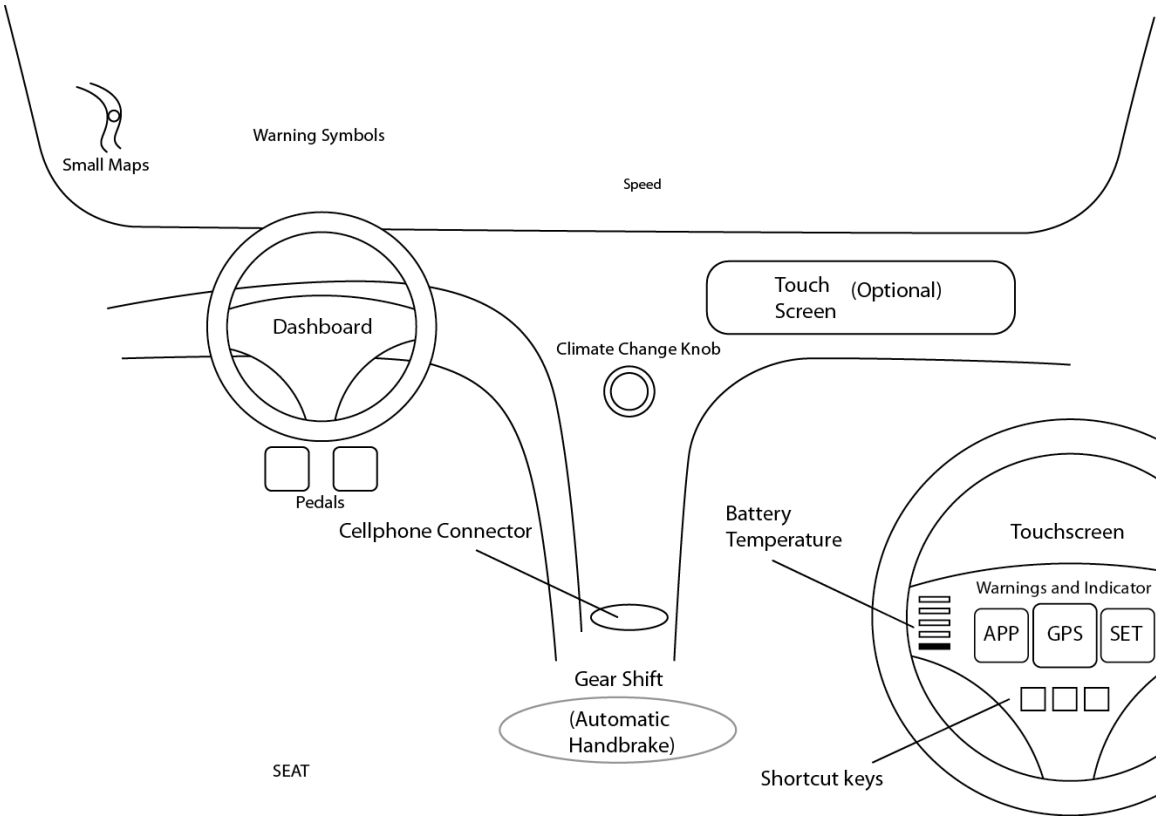


Figure Standard user concept1

The standard user concept 1 has the dashboard and functional shortcut keys on the steering wheel. The dashboard is a touch screen, and therefore driver could intuitively operate the car on the steering wheel. The windscreen is a head up display which demonstrates speedometer, turn by turn navigation map and warning symbols. On the front passenger side optionally installs a passenger infotainment instrument.

Standard User Car-concept proposal 2

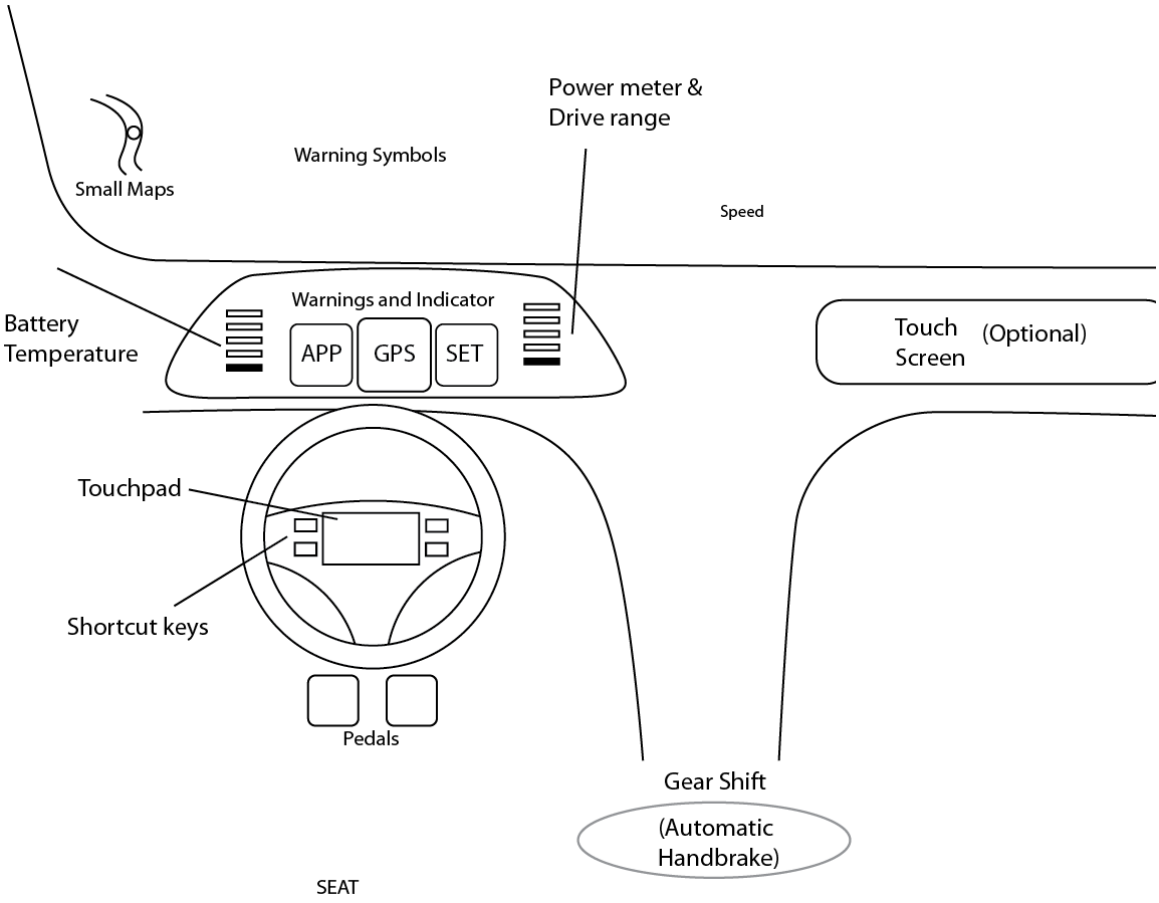


Figure Standard user concept2

The standard user car remains the main functional areas of the current conventional car. On the steering wheel installs a touch pad that allows user operating the car. The operation approaches are gesture based. Similar to the concept 1, the priority information illustrates on the head-up display.

Standard User Car –concept proposal 3

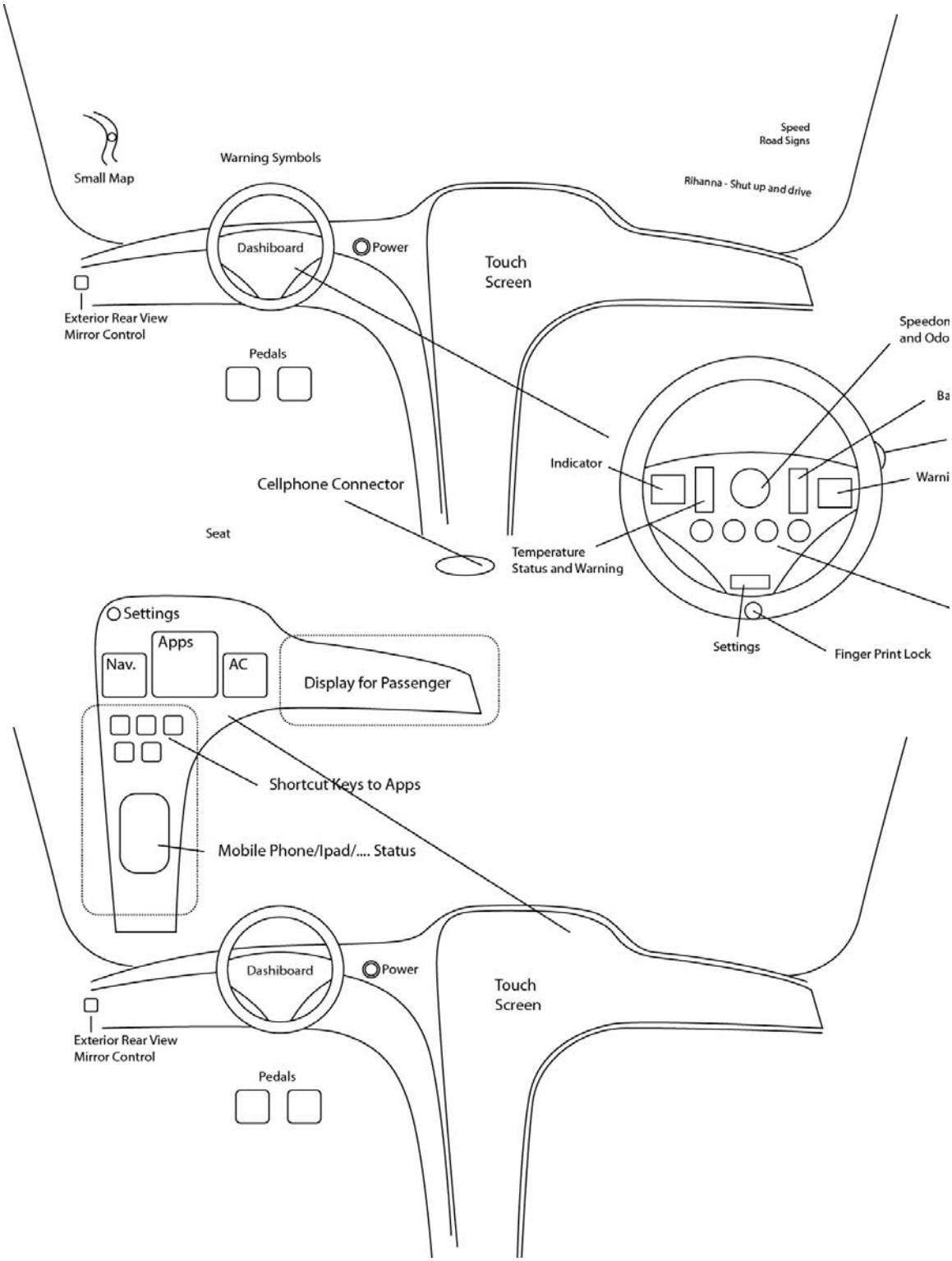
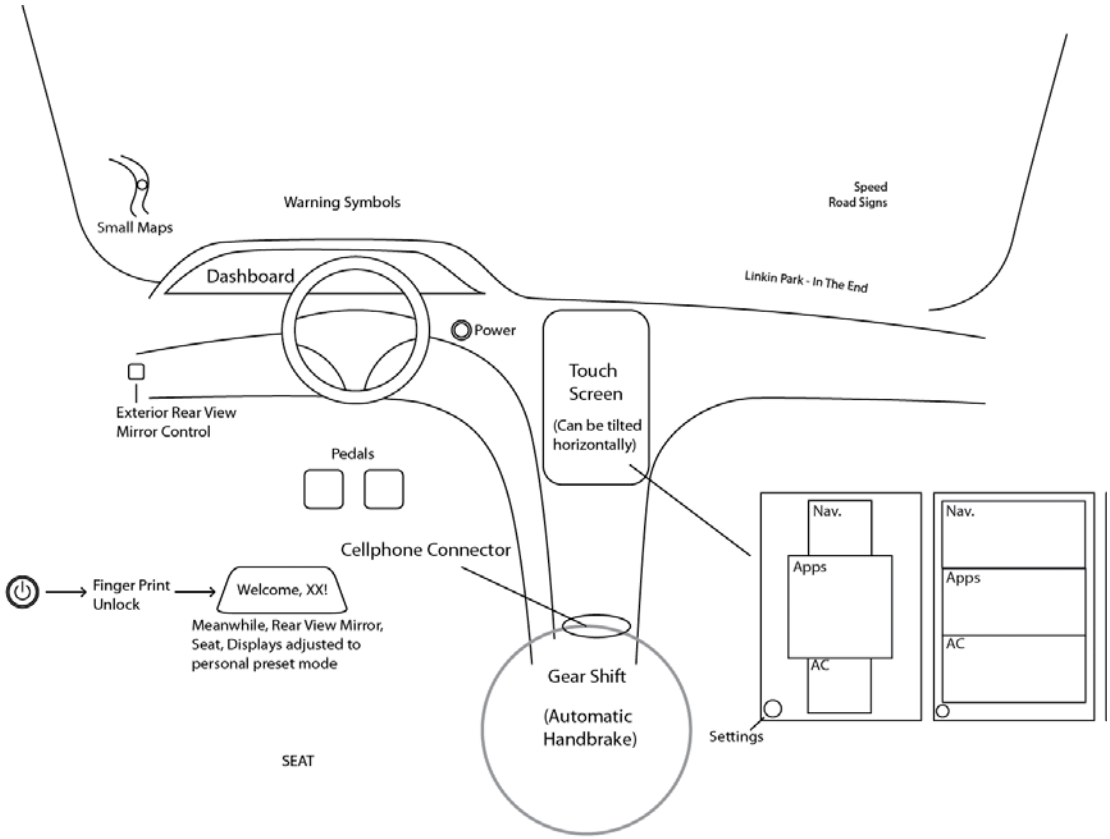


Figure Standard user concept3

The concept 3, as the concept 1, moves the dashboard on the steering wheel, while the operations are through a button, knob panel on the side of steering wheel. The main

information presents on the steering wheel. Navigation map, speed, and a taskbar (shown processing) demonstrate on the head up display. The main instrument panel is positioned on the center.

Standard User Car-concept proposal 4


Small Maps
Warning Symbols
Speed
Road Signs
Dashboard
Linkin Park - In The End
Power
Touch
Screen
(Can be tilted
horizontally)
Exterior Rear View
Mirror Control
Pedals
Nav.
Apps
AC
Nav.
Apps
AC
Cellphone Connector
Finger Print
Unlock
Welcome, XX!
Meanwhile, Rear View Mirror,
Seat, Displays adjusted to
personal preset mode
Gear Shift
(Automatic
Handbrake)
Settings
SEAT

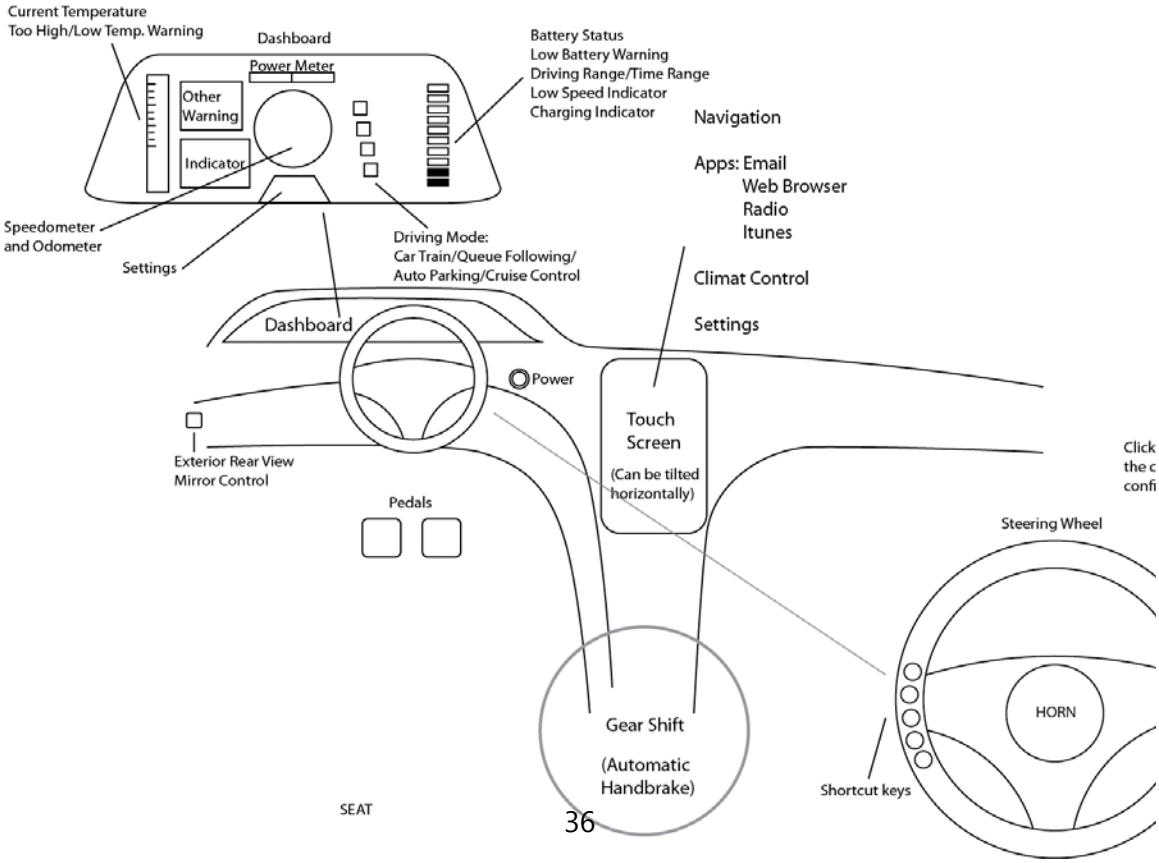

Current Temperature
Too High/Low Temp. Warning
Dashboard
Power Meter
Other
Warning
Indicator
Battery Status
Low Battery Warning
Driving Range/Time Range
Low Speed Indicator
Charging Indicator
Navigation
Apps: Email
Web Browser
Radio
Itunes
Speedometer
and Odometer
Settings
Driving Mode:
Car Train/Queue Following/
Auto Parking/Cruise Control
Climat Control
Settings
Dashboard
Power
Touch
Screen
(Can be tilted
horizontally)
Exterior Rear View
Mirror Control
Pedals
Steering Wheel
HORN
Gear Shift
(Automatic
Handbrake)
Shortcut keys
SEAT

Figure Standard user concept4

The concept 4 is similar to concept 2, except the touch pad is replaced by shortcut keys on the steering wheel and click wheel on the side of steering wheel.

Expert User Car-concept proposal 1

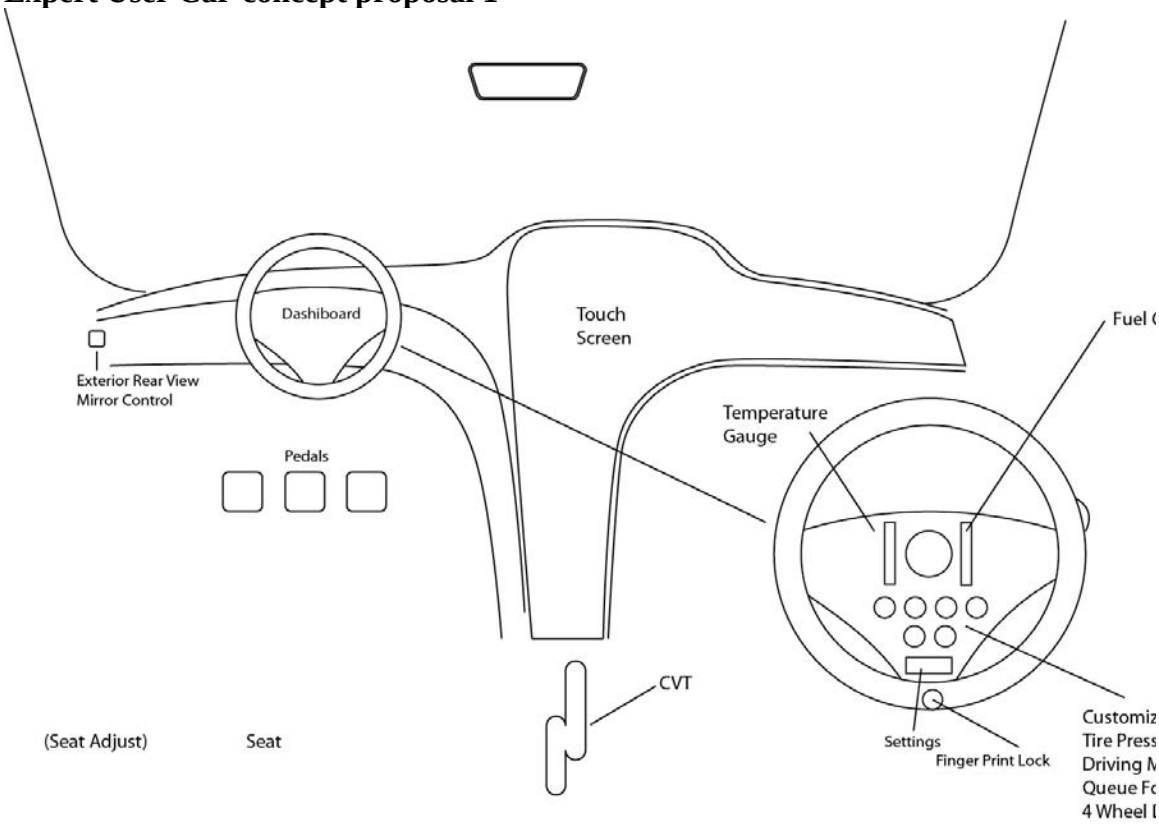


Figure Expert user concept1

The expert user concept 1 also has dashboard on the steering wheel with the operation panel on the steering wheel. The information associating with controlling system is demonstrated on the steering wheel while driving assisting and infotainment information are shown on the touch screen.

Expert User Car-concept proposal 2

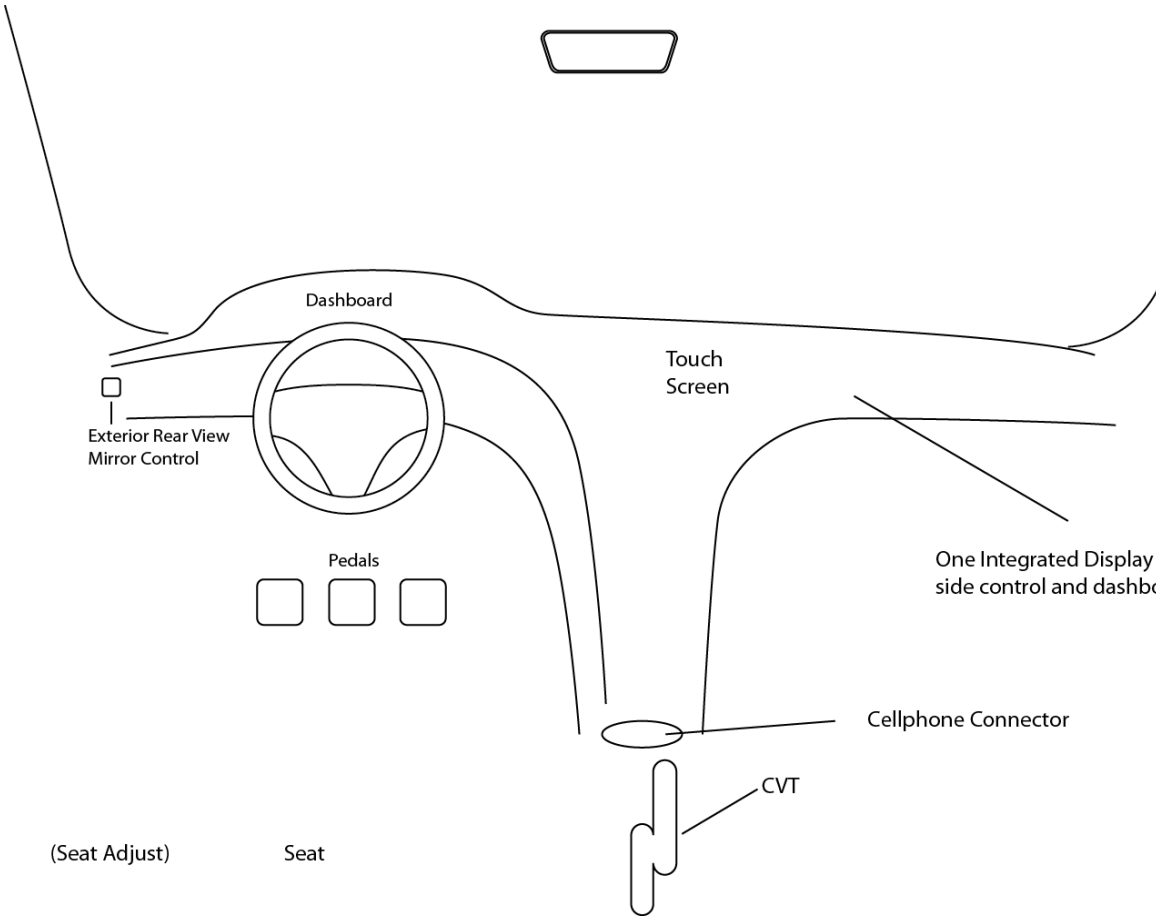


Figure Expert user concept2

In the expert user concept 2, the passenger infotainment instrument, climate control panel and dashboard formed a gigantic display while climate control panel and front passenger infotainment is one unique touch screen. The driver operates the car by controlling panel on the steering wheel.

7.1.2 Result of ideation

After discussion with Mecel, the concept proposal 2 is selected for developing both standard user cockpit and expert user cockpit. There are two reasons for the selection of concept proposal 2.For one thing, Mecel questioned on physical ergonomics of the idea to place main instrument panel on the steering wheel. The authors agreed with the opinions that in a conventional car the location of steering wheel is not an optimal choice for the dashboard from the physical ergonomic aspect. This solution may solve the problem of intuitively interacting with dashboard but bring the problem of placing the steering wheel with physical ergonomic consideration. To solve the problem of that required designing the physical components of the car, which is out of the scope of this study. And therefore, standard user proposals 1,3 and expert user proposal 1 are

excluded. The other reason of the selection is that compared with knobs and buttons, placing touchpad on the steering wheel is an innovative solution to the problem of interacting with complicated HMI from the perspective of Mecel. Gesture based interactive manners are commonly applied on laptop but seldom used in the automotive cockpit from knowledge of Mecel and authors. Since the outcome of the study required to be perceived as futuristic, innovative solution is preferable.

At the beginning of the ideation, the proposals are produced into two categories which corresponding the two types of personal vehicles. But only the proposal 2 is selected for the further development of both types of cars. To dig into the reasons, the proposals for the standard user car and expert user car are not distinctive. They have similarities. The differences are only reflected on the gear shifter and the content of the main instrument panel. The proposal 2 can be produced for standard user car but it also could be applied into expert user car by modifying the content of dashboard and changing gearshift. To sum up, Mecel and authors select the proposal 2 to continue the development of standard user car and expert user car.

7.2 Concept Development

The primary task of concept development is creating the functioning interior layout with a focus on main instrument panel, windscreen, steering wheel, climate control panel and front passenger touch screen. The initial concept of automotive cockpit is fully developed through designing how user should interact with the car and the locations of cockpit features. Then, the focus shifts to design the functional content of main instrument panel, climate control panel and passenger touch screen for each category.

7.2.1 Functional Layout

The functional layout was developed. The cockpit is divided into five functional areas, as mentioned. At this section, the task is to locate the features into functional areas. The method for locating the functions is scenarios, personas and use cases.

The persona and scenarios were set at the research phase. Then, authors brainstorm the possible use cases. The use cases are the activities happened in the car.

For instance, scenario A is “persona A drives to the work place from home, persona A lives and works at inner city”. The primary goal is “drive from home to work place”. The context is driving within inner city. Use cases are possible to be produced by brainstorming. The first level of use case is to fulfill the primary goal, which is “drive from home to work place”. With the system describing in the initial concept, the possible second level of use cases is:

Table the second level Use cases for scenario A

The Second level Use cases category	The second level Use cases

Communicating	Making a phone call Answering a phone call Texting Emailing Messaging (MSN/Skype etc.) Video Chatting (MSN/Skype etc.)
Entertaining	Listening to Media Playing games Internet Surfing
Assisting Driving	Searching a certain place Searching Nearby Looking up map

After brainstorming the use cases, the actions and operations for accomplished the tasks are considered. The actions and operations are based on the selected concept proposal. The principles for designing the actions and operations are:
1. The first level of use case should not be disturbing by the second level of use cases.
2. Usability consideration

According to the principles, functions are located into functional area to fulfill tasks.

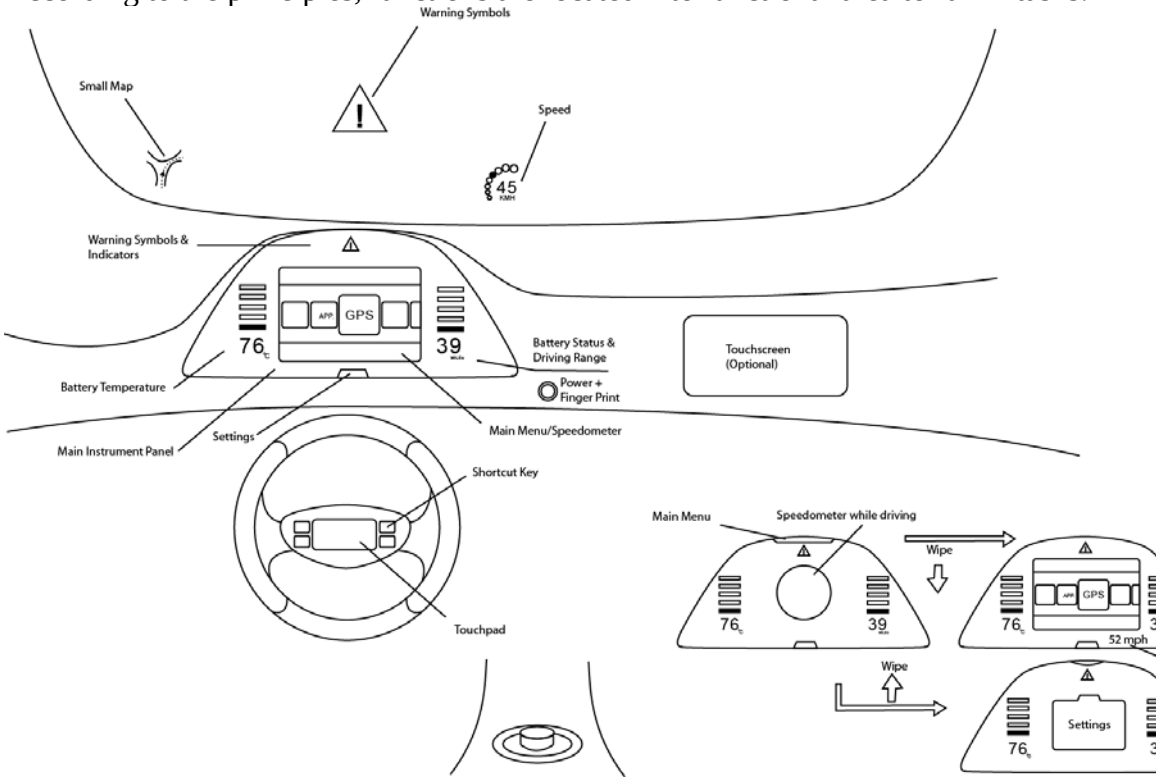


Figure 12 Functional Layout Of Standard User Car And Expert User Car

7.2.2 Functional Hierarchy

After the functions location, the functional hierarchy of HMI is designed (Appendix F). Functional hierarchy is a result that combines user action, operation and HMI feedback. It is used to visualize the operation and feedback map [Figure 13, 14].

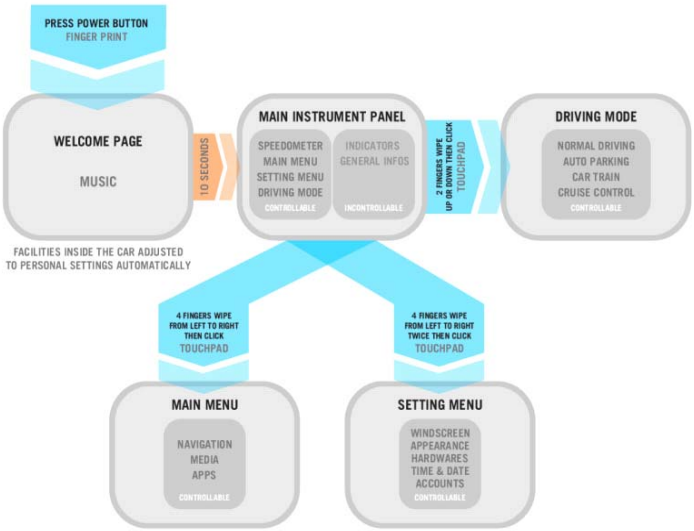


Figure Part of Standard User Car Functional Hierarchy

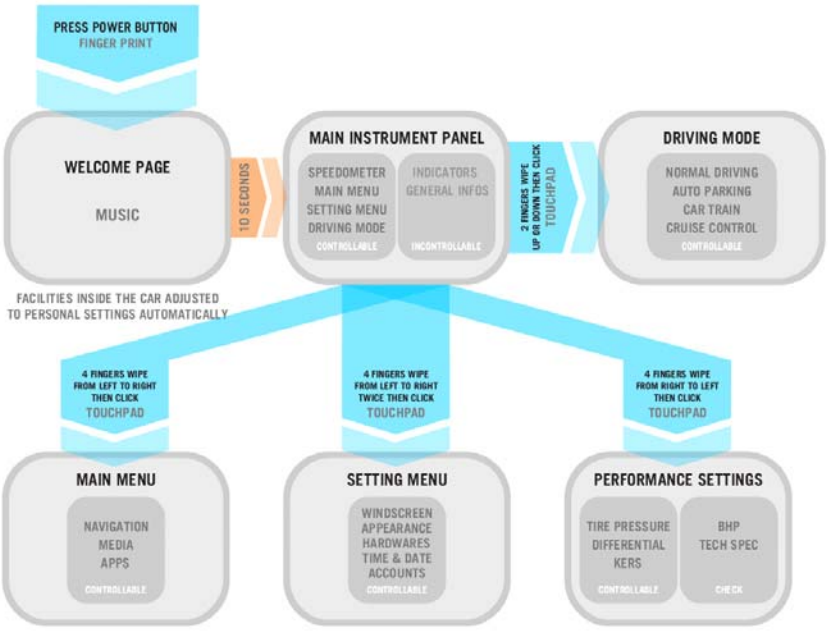


Figure Part of Expert User Car Functional Hierarchy

7.3 Visualization

The visualization process contains three stages. The first stage is mainly developing a visual structure, creating mood board and delivering a wide range of sketches, while in the next style development stage, the general look is created based on the first stage and the function hierarchy structure. In the last visualization stage the whole design is refined by looking into details.

7.3.1 Inspiration Gathering and Sketch

For the inspiration gathering, creating the mood board is an efficient method. Based on the results from the user research, more keywords have been concluded. Besides the mood board, a bunch of designs that appeared to have similar topic have been found for inspiration as well. After this session, Sketches will be delivered by brainstorming, and among these to decide which to develop further more.

7.3.1.1 Mood Board

Keywords for the standard user: Simple, Organic, Futuristic, Neat, Intuitive, Light, and Cohesive
Keywords for the expert user: Speed, Aerodynamic, Premium, Retro, Scientific, and Futuristic (Appendix G).

7.3.1.2 Sketches

Standard User
The first brainstorming sketch session is about to have different ideas on styling of several instruments. The second one is to match the results from the first brainstorming and get a whole look to decide which way to go. After these two sessions the results are selected and put together. By comparing these concepts, and consulting from the company, there are some generated thoughts, sketches and opinions coming out as listed below:

Figure The Selected Speedometer Sketch

The speedometer has been selected as such. Because of the electric power system, the ammeter should be shown in the cluster as well, and in this case it has been integrated into the speedometer. The style is neater, which matches with the standard user style

keywords. And the flashing blocks which indicates the current speed, looks like part of the Mecel AB logo. It is valuable for the brand identity embedded.

Figure A rough layout to show the place of different instruments on the dashboard for standard user

From Figure 4.8 There is a general image about the position for each instrument on the dashboard, for the standard users. For driving an electric power car, besides the speed information, the battery temperature and the battery status are equally important to know, according to the system study. Because of this, the battery temperature and the battery status gauges are located to the sides of the speedometer, two obvious positions.

Expert User

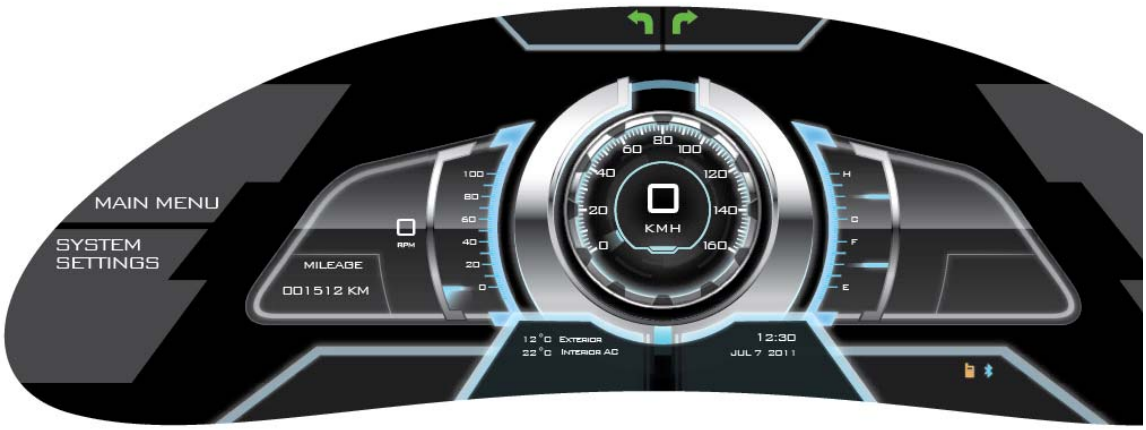


Figure The selected sketch of expert user concept

With experience from the standard user concept development, the expert user concept is much easier getting into the details. The traditional speedometer is set in the center of the dashboard, with other driving information located around. The main menu and system settings are at the left while the performance setting on the right side. What has been added here is the performance menu. The research results suggest that the expert user car has more settings over the driving dynamics, and to separate this from other general applications and settings, the performance menu is at the left side of the dashboard, equally as the main menu and system settings.

7.2.2 Style Development

In the style development stage, the sketches are further examined. The user interfaces of main instrument panel for each concept will be completely organized in this phase; the instruments and secondary menu will be designed.

The style development is mainly based on the brainstorming, sketches and discussions, discussions and consulting from Mecel

The Standard User Concept Development

From the previous sketches, the general structure and the idea about how the speedometer looks like are kept to this stage. Basic required information, such as the warnings and indications, time and date information, is put into the proper position as well. Every item in the main instrument panel is more detailed compared to them from the sketches.

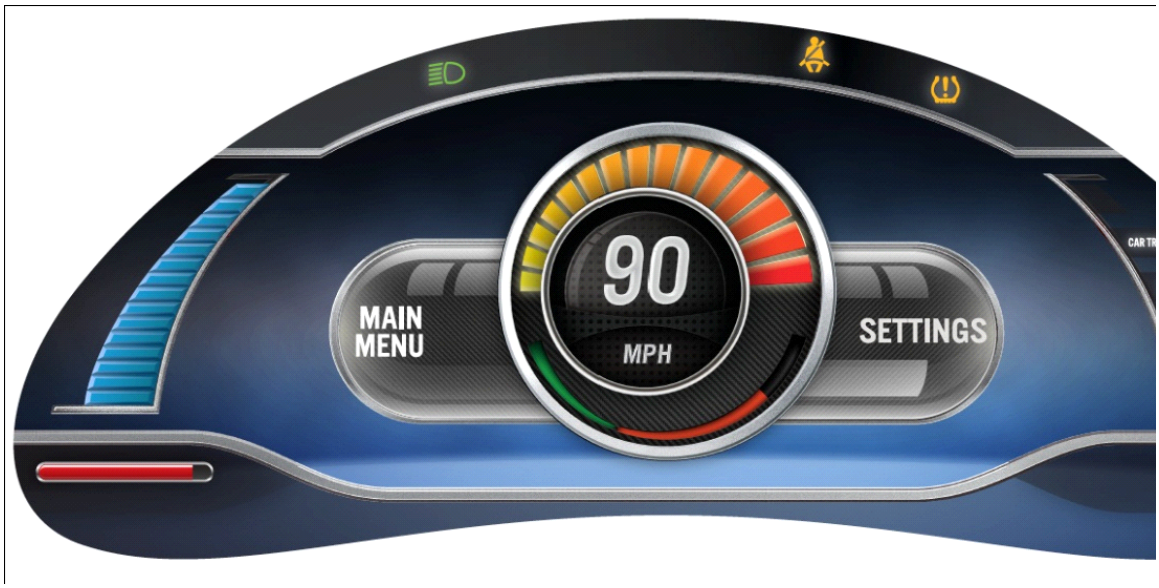


Figure Developed Main Instrument Panel Concept For Standard User

The general position and look are completed: warnings and indications are on the top, with the battery status staying at the left side. The apps, media player and navigation system are integrated into the main menu, while other settings are organized into the settings menu. The lower bar involves less important information: the battery temperature at the left side and the time at the right side.

The Expert User Concept Development

Figure Developed Main Instrument Panel concept for expert user

The instruments and information are set into positions as well as the standard users. Based on the experience and the structure from the standard user development, the development process becomes much smoother.

7.2.3 Detail Design

The detail design phase focused on the missing gadgets and buttons required by each layer of the user interfaces, typefaces and distance in between. The climate control and passenger touch also will be finished after this stage.

Standard User Concept Detail Design And Finalization

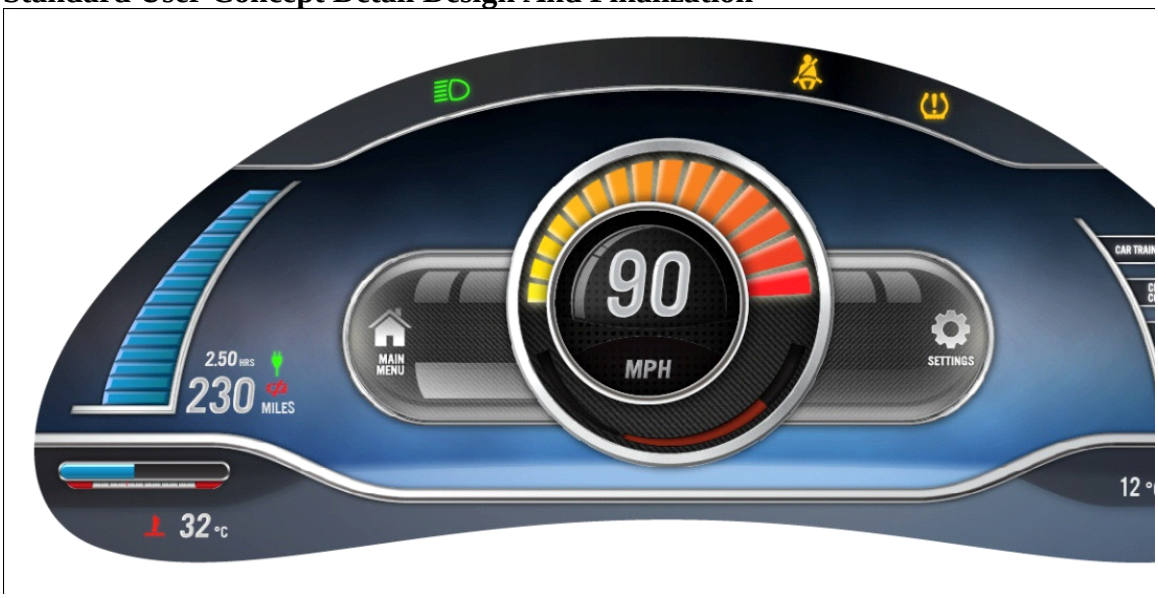


Figure 20 Standard User Concept After Detail Design And Finalization

The instruments in the dashboard are more designed with details after this stage. What has been modified from style development, first is the color correction, warnings and indicators color are changed with higher purity since that makes higher contrast with the background, which means they are more visible to the drivers. Second the main menu and settings titles are changed from text to graphical icons, which allows both remain the same and smaller size.

Expert User Concept Detail Design And Finalization

Figure 21 Expert User Concept After Detail Design And Finalization

Compared to the expert user concept after style development, the color correction to warnings and indicators are also been done. Besides this, the typefaces are modified into trade gothic font, because it makes better recognition. Furthermore, Mecel uses this typeface for a long time, so it cooperates with Mecel brand identity.

8 Evaluation Phase

The process of evaluation phase is shortened compared to the one set in the beginning. The evaluation mainly involves usability examination and technique possibility check, thus the final design could be more reliable.

8.1 Usability Evaluation

Because of the purpose of this study, the usability is not possible to be profoundly tested. Thus, the usability evaluation is set to base on several roughly mocked up scene, e.g. displaying the instruments to a 1:1 scale and checking for problems. Also gaining opinions and suggestions by showing the concept to the automotive and software experts in Mecel.

By doing a rough usability evaluation, the graphics has gained some modifications. The outer glow effect has been deleted for some of the text displaying; the font size and space in between has modified larger due to the unclearness of several words; Instruments placement has been reordered as well, such as the warnings and indications in expert user concept are moved to the top of the main instrument panel because of the logic and habit.

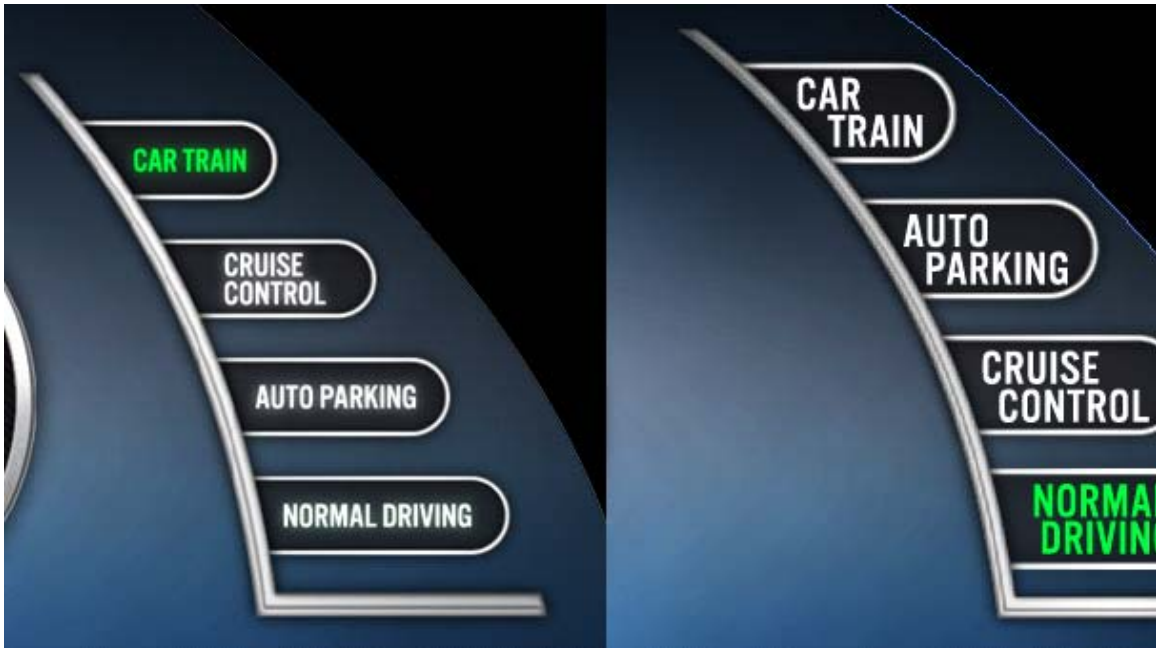


Figure Font size and space between modifications for the driving mode section, the right one is the modified version

Figure Before(bottom) Evaluation and Modified(top) Expert User concepts

Before(bottom) the indications and warnings are at the bottom section, while the modified version(top) has them in the top and bottom section for driving mode. The contrast of the text and the background has been raised in the performance settings as well.

8.2 Technique Check

In this evaluation, the technique check is carried out to make sure that the features applied in concepts are technically possible. By consulting with experts within Mecel, the touchpad will be modified to a lower place on the steering wheel because the central part

has the airbag and it will destroy the touchpad while it is activated.

9 Final Design

9.1 Standard User Final Concept

Driving Systems and General Features
Fuel type and fuel capacity: Electricity powered, 230 miles distance to go when fully charged
Highest speed: 90 mph
Transmission: Automatic gearboxes

9.1.1 Standard User Car-Cockpit

Figure Interior layout of standard user final concept

As shown in figure 5.1, the standard user final concept consists main information sections of main instrument panel, center stack and wind screen instruments. As an electric

powered vehicle, the gearshift is altered with the gasoline vehicle. The power button is located on the gearshift; the steering wheel contains a touchpad to control, accompanied with four shortcut keys. The display system covers the main instrument panels and the passenger touch screen, while the windscreen also contains information to show.

9.1.2 Main Instrument Panel And Touch Pad

The main instrument panel in front of the steering wheel shows all the main driving information and the infotainment for the driver. Push the power button to start the car, the fingerprint system that located on the power button, will automatically recognize who is the driver, and set every facility inside the car to the specific driver's mode. The main instrument panel lights up with a welcome page [figure 25].

The touch pad is the main control unit to the dashboard, by using different finger gestures, different command can be sent by the driver. There are four short cut keys under the touch pad as well, which are direct link to media, navigation, driving mode selection and natural speaking function on/off.

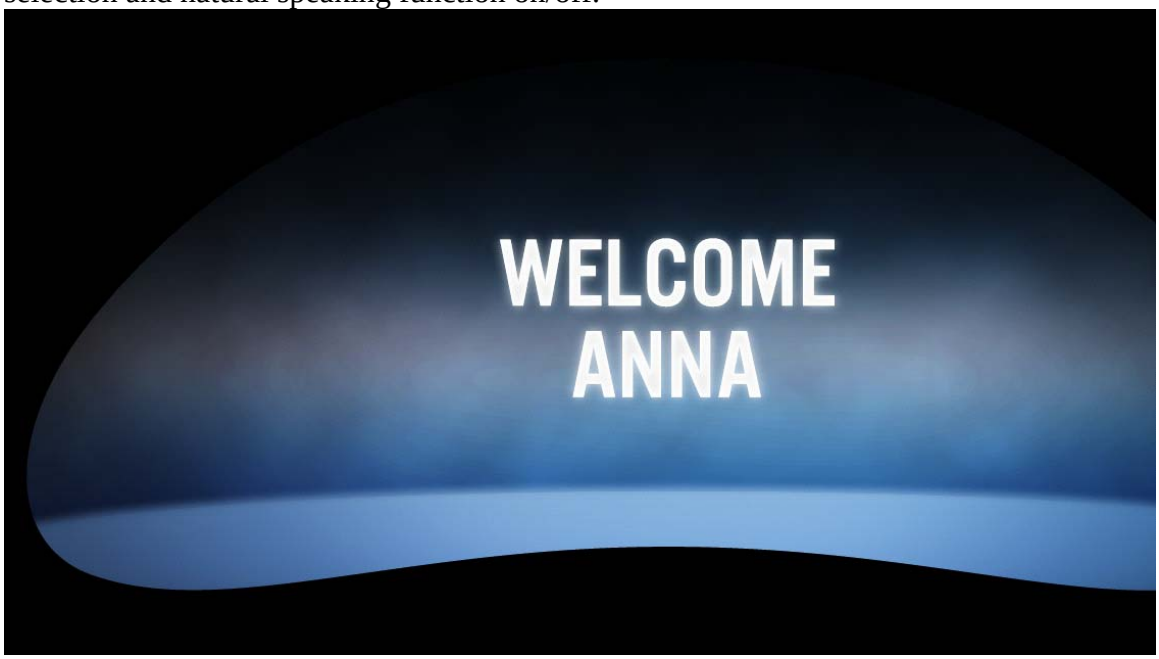


Figure Welcome Page Of Opening For Standard User

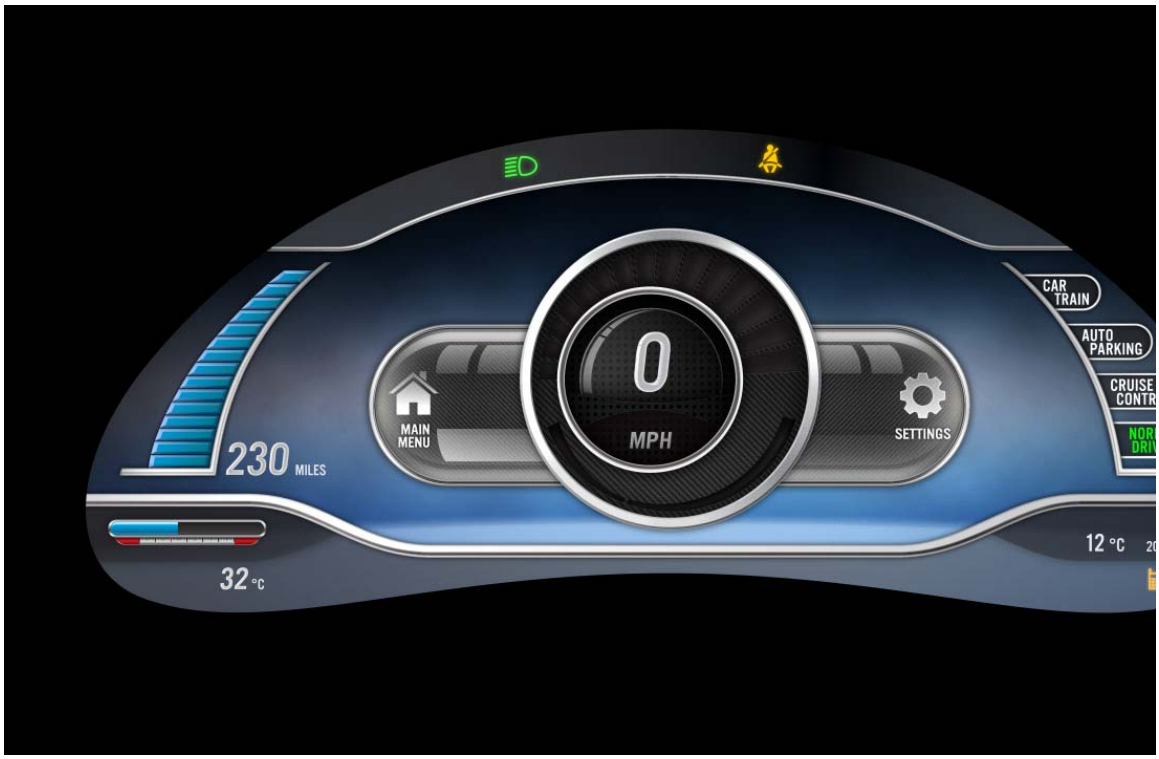


Figure The Main Instrument Panel Of The Standard User With No Speed On

After the welcome page, all the main instruments come afterwards [figure 26]. The speedometer locates in the center of the dashboard, with showing the current speed and the power meter. The two instruments locate both sides are main menu and settings, to switch to them, use four fingers wipe to left/right. To change the driving mode, press short cut key “driving mode”, and use two fingers wiping up and down to select, click to confirm.

Besides the controllable instruments, to the left side is the battery status, showing the current power ability and the distance left to travel. To the left side of the bottom bar there is the thermometer showing the battery temperature, and the right side is basic information including time, date, Bluetooth status and connection status to third party facilities. The top bar shows all the indication and the warnings when it is needed.

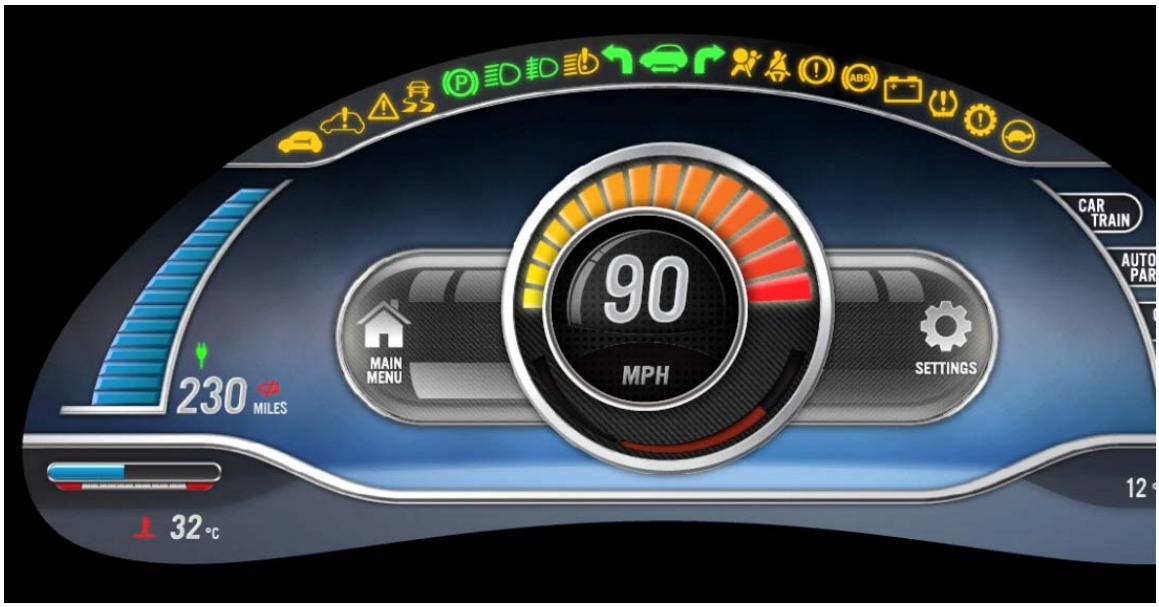


Figure The Main Instrument Panel Of The Standard User With All Indications And Warnings On

Figure Low battery status and abnormal battery temperature

In the Figure 28, when the car is in the low battery status, the blocks will turn to red color, with a low battery sign aside to warn the driver, meanwhile, the car will automatically slow down the speed, with a warning sign on the right top. When the temperature goes abnormally the thermometer will also turn red as a warning sign to the

driver.

Figure Driving mode status section and right side of lower information bar

The driving mode section is located at the right side of the dashboard. Besides normal driving and cruise control functions, there is car train, which allows the driver following another car and completely relaxed from driving, and auto parking, which can automatically park the car into right position, being added. The apps except telephone are only available to use when the car is under control of car train and auto parking.

The right side of lower information bar shows some basic information, e.g. the current time and outside temperature, the date of today, and the connection status to the mobile phone and the on/off status of the Bluetooth.

9.1.2.1 Main Menu

Figure The Main Menu User Interface

The main menu is divided into three sections: The navigation, the media and the apps. The navigation and the media are the most widely frequently used applications so they are separated from all the other apps. By choosing the different section, using two fingers wipe up or down on the touch pad.

Figure The navigation page user interface

The figure 31 shows the main look for the navigation page. The functions within the navigation section are pretty simple, there are destinations, in which the driver can search the targeted place where to go; in search nearby, various facilities around the current position can be found; the settings menu allows the user for customization.

Figure The destination input page

The navigation system are accompanied with naturel speaking function, which means the

system becomes smarter to recognize the place or the addresses that the user said and give out the answer more correctly. To set a destination, the user need to make sure the naturel-speaking button is on, and speak the destination's name to the car. The car will process one or more possibilities, then the user can select the answer by wiping two fingers up or down on the touch pad and confirm the answer by clicking or say positive word to the car. If the right destination is not among the list, the user can let the navigation system search again or directly type in with the keyboard embedded.

Figure Processed route by the navigation system

After confirming the right destination, the navigation system will process a route, and showing the distance ahead and time left to reach the destination. If there are inconvenient traffic situation on the route, e.g. traffic jam, traffic restriction controlling etc. The navigation system will be automatically updated and tell the driver [Figure 33]. The driver can decide if he or she would like to change the route, the navigation system will reprocess the route after the decision [Figure 34[.

Figure The traffic information updated from the navigation system

Figure Reprocessed route after the driver's decision from traffic information updated

In search nearby, the driver can search different facilities, e.g. the restaurants, the parking places, etc. like the above, and naturel-speaking input can recognize different target places smartly [Figure 36]. The navigation will show these places in the map around the car's current position [Figure 37]. The system will also show different information for these places, e.g. the rates for the restaurants or the available parking positions situation in a parking place.

Figure Search restaurants nearby by naturel speaking input

Figure Searching results shown in the navigation map

In setting menu, there are switch for voice guide, map style (2D or 3D), map update and traffic information, for customization [Figure 38].

Figure Navigation settings menu

Media

Figure Media page user interface

The media section combines all the music and radio players and apps together. The user can create playlists not only from the local sources but also the Internet sources and third-party applications. It is also possible to go to these third-party applications' pages by clicking the icons at the left bottom side. The driver can also access to the radio channel and listen to the radio [Figure 40].

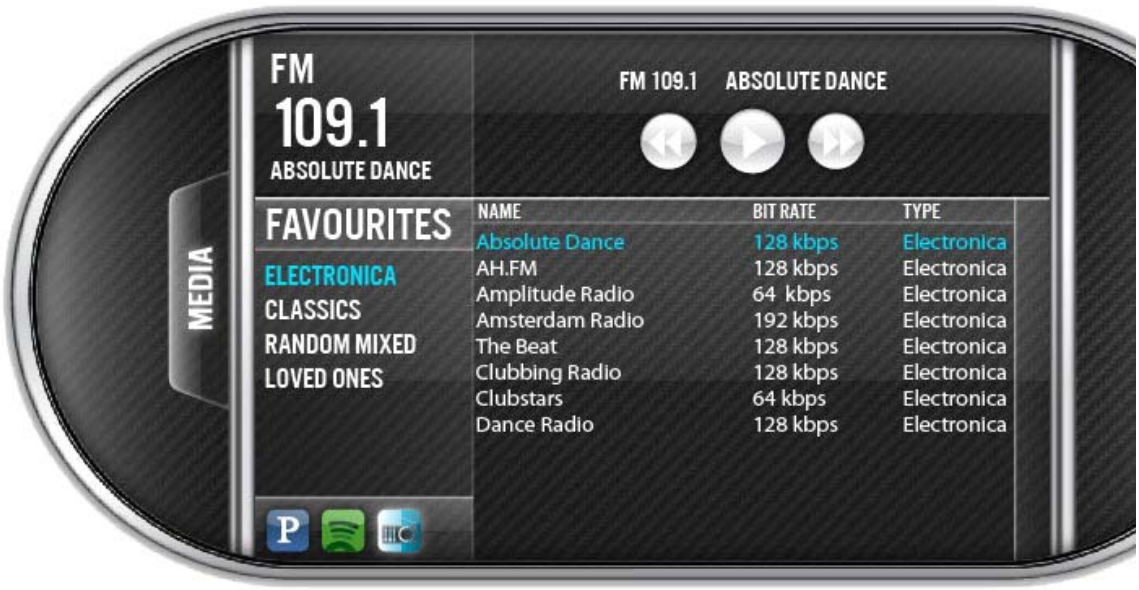


Figure Radio channel in media section

Apps

Figure Apps page user interface

Apps section includes the four basic apps: Telephone, email, Internet and calendar, embedded in the system initially [Figure 41]and other downloadable third-party apps from apps store. Only the telephone function can be activated in all the driving modes. The other apps are only available in car train and auto parking driving modes; otherwise they will turn grey [Figure 42].

Figure Apps page during cruise control or normal driving mode


APPS
INBOX
DRAFT
SENT
DELETED
NEW
REPLY
REPLY ALL
FORWARD
DELETED
FROM
TITLE
TIME
NADINE YAMAMOTO
Re: Re: Hello! Here is the final ve...
Thu 5/26
Jesper Larsson
Nu på måndag!
Thu 5/26
Biblioteket
Mon 5/30
Booking.com
Your booking at Hôtel Sylvabelle
Tue 5/31
www.ticnet.se
Bokningsbekräftelse - EJ BILJETT
Wed 6/1
Designboom
Designboom News
AM 08:32
FROM: noreply@hub-1.ticnet.se
BOOKING CONFIRMATION FROM TICNET
Thank you for booking your tickets with us. Please note that it's not possible to reply to this email. For questions about your booking, please see contact information further down in this mail.
Booking number : GOT-GVX562
Event : The Teenagers
Venue : Parken
Date and time : Thursday July 19, 2011, at 09.30 PM

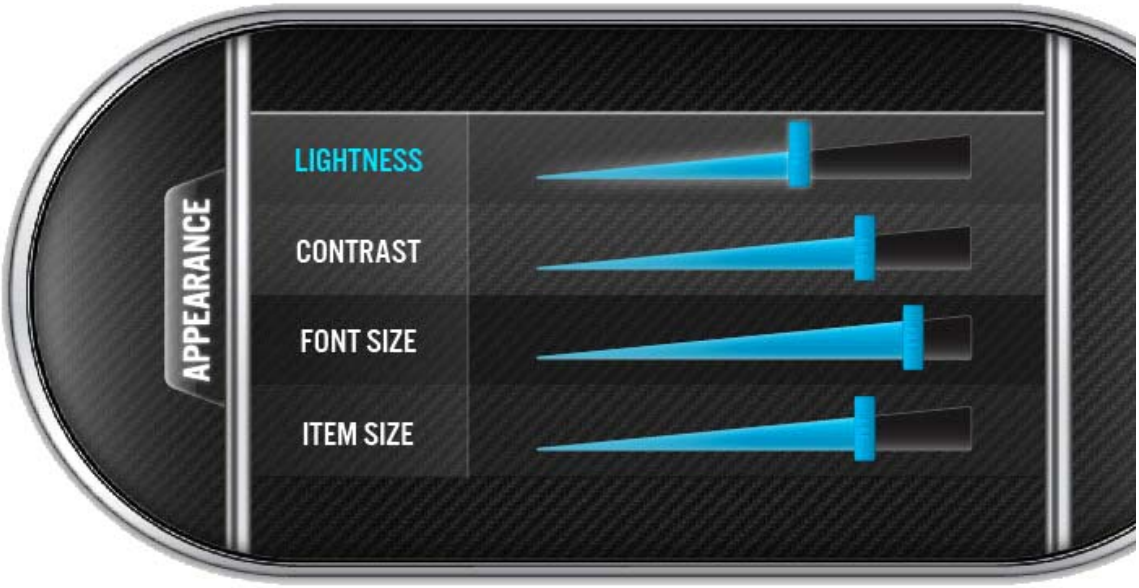

APPS
EDIT
WEEK 24
12 SUN JUNE
13 MON JUNE
14 TUE JUNE
15 WED JUNE
16 THU JUNE
17 FRI JUNE
18 SAT JUNE
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
YEARLY LE...
BONUS
KICK OFF RADISSON..
STORE STATUS UPDATE
NEW STORE REVIEWS
PLANNING
CAPITAL PLANNING
FALL PROMOTION
IDA BIRTH...

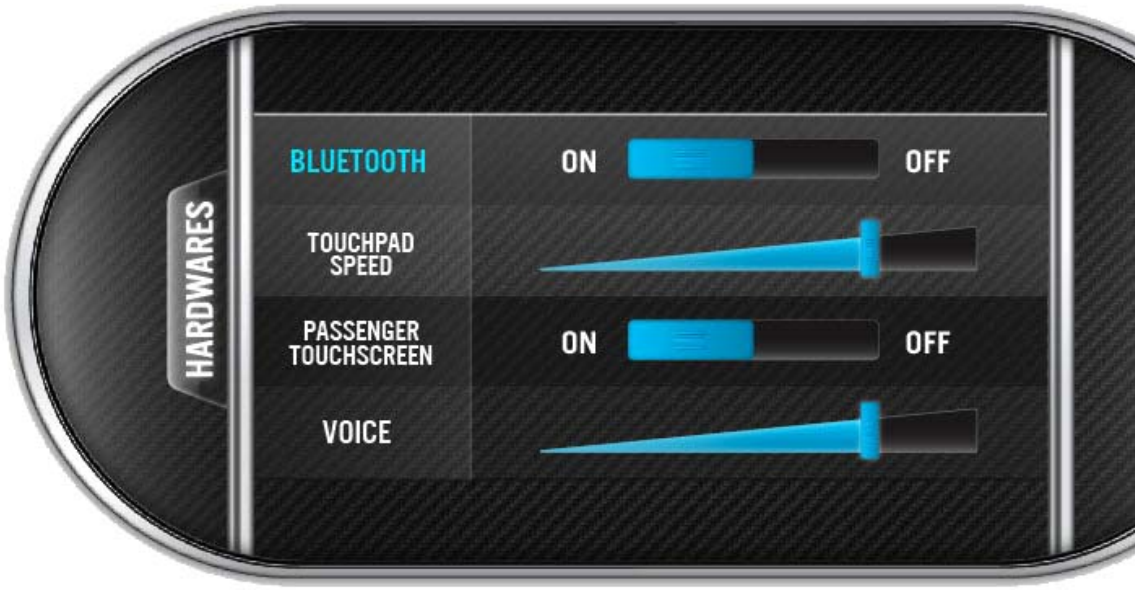
Figure Four basic apps user interface

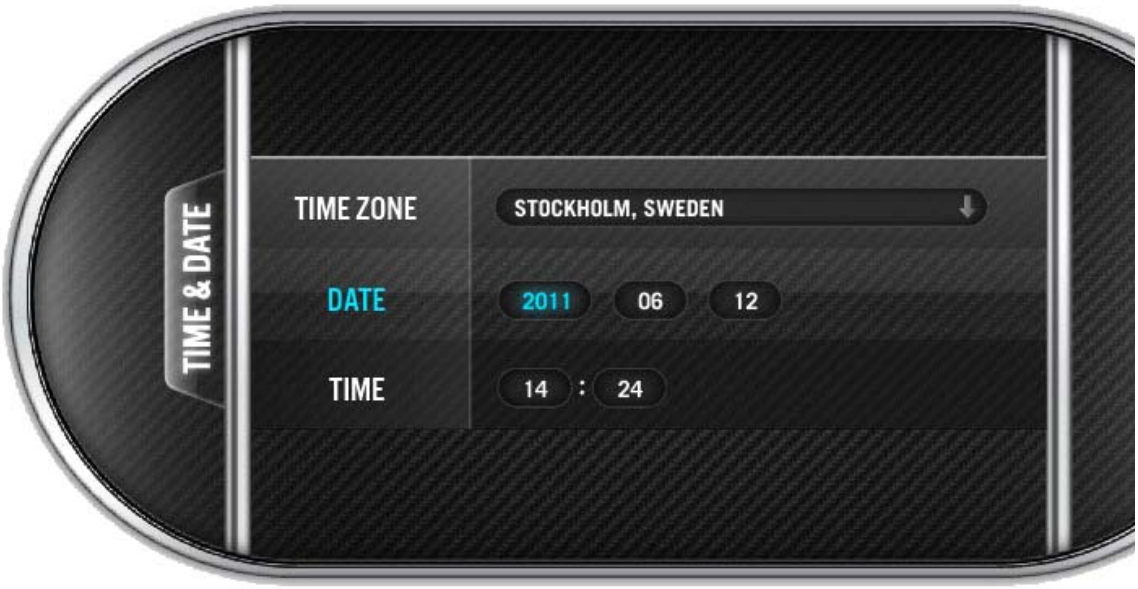
9.1.2.2 Settings menu

Figure Settings menu user interface


WIND SCREEN
LIGHTNESS
ITEM SIZE
NAVIGATION
ON
OFF
SPEED
ON
OFF
WARNINGS
ON
OFF
NOW PLAYING
ON
OFF


APPEARANCE
LIGHTNESS
CONTRAST
FONT SIZE
ITEM SIZE


HARDWARES
BLUETOOTH
ON
OFF
TOUCHPAD SPEED
PASSENGER TOUCHSCREEN
ON
OFF
VOICE


TIME & DATE
TIME ZONE
STOCKHOLM, SWEDEN
DATE
2011
06
12
TIME
14
:
24

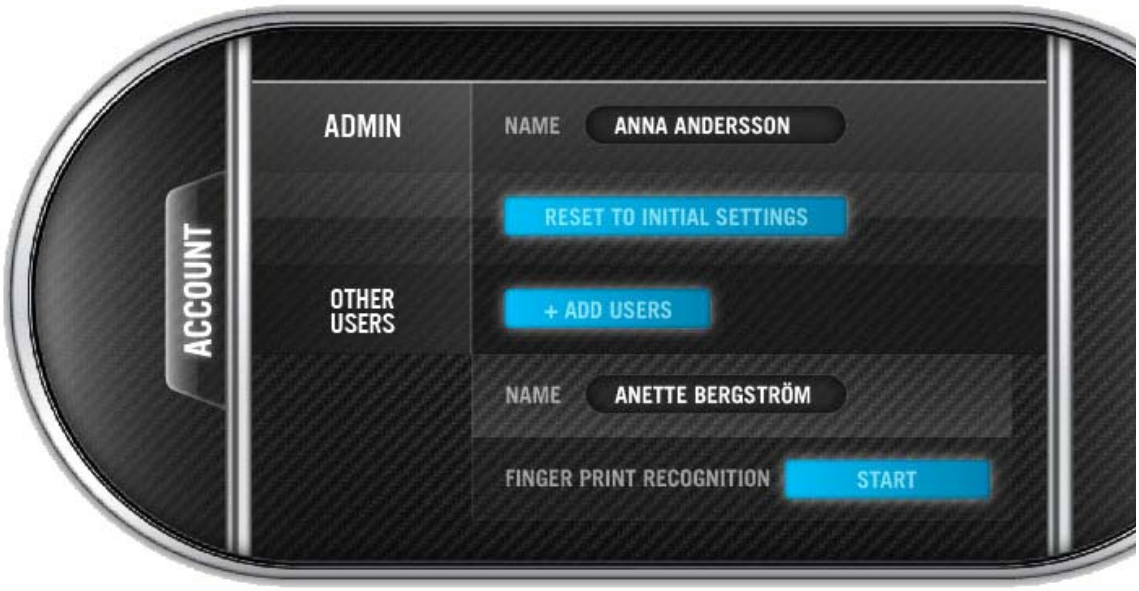


Figure User interface of windscreen, appearance, hardware, time & date and account settings

The settings menu is divided into five sections: windscreen, appearance, hardware, time & date and account. Each of them has several things to be adjusted as shown in the figure 45 when get into the settings menu, use two fingers wiping up and down to select. While getting into the specific menu, the same wipe two fingers and click to select, and use one finger wiping to adjust. While in the account setting, naturel-speaking will recognize the talk and put in the names.

9.1.3. Climate Control And Passenger Touchscreen

Figure General look of the climate control and passenger touchscreen

The climate control and passenger touchscreen are located at the center stack and the passenger front panel. There is part of the passenger touch screen situated in the center stack, together with the climate control. The running apps are shown there, so that both the driver and the passenger can click them and activate them in their window. The driver should click and drag left and the passenger should click and drag right.

Figure Climate control system user interface

The climate control is right in the middle of the center stack, so that both the driver and the passenger can control it. There are three physical knobs: temperature adjusting knob, wind speed adjusting knob and the mode select & on/off switch. Since climate control is one of the operations that driver will frequently use, easy to reach and operating without watching it turn out to be the main issues. Thus, the three physical knobs are remained. Also on the mode select knob, there is a bulge to indicate which mode is selected, so that the driver can just by touch it to know that.

Figure Passenger touchscreen user interface

The passenger touchscreen have a lower bar [Figure 48], which has all the applications that dashboard main menu has. This allows the passenger to use all the apps as well.

9.2 Expert User Final Concept

Driving Systems and General Features
Fuel Type and Capacity: Gasoline, 80L
Max Speed: 160 mph

Interior Layout

Figure Interior layout of expert user car

Compared to the standard user concept, the interior of expert user is modified on the gearshift because of its gasoline power.

9.2.1 Main Instrument Panel and Touch Pad

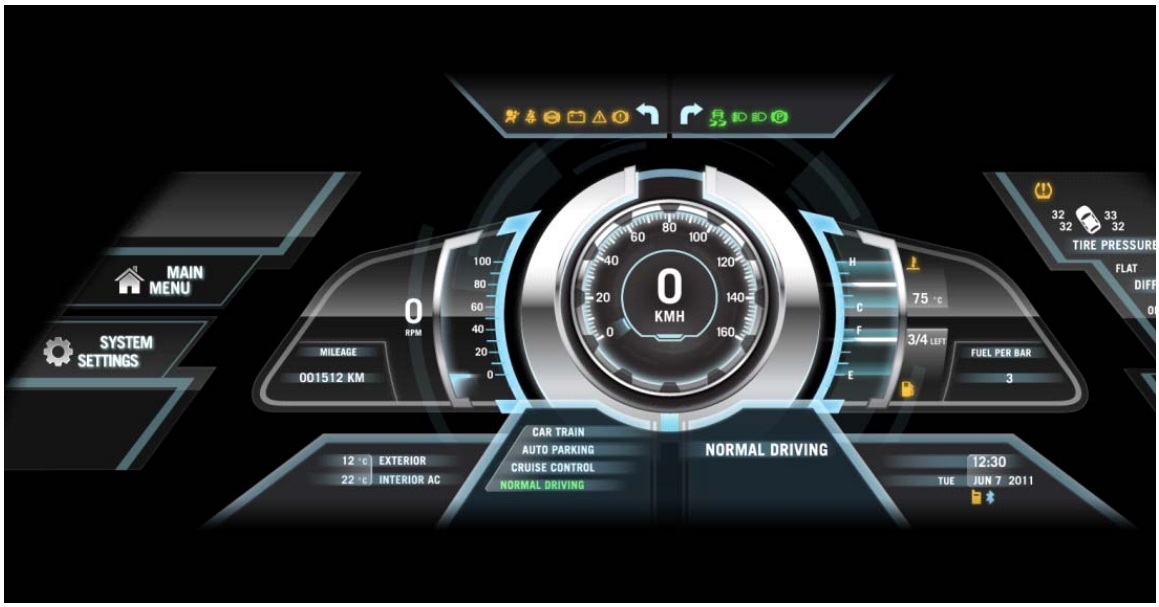


Figure Expert user car dashboard user interface

Unlike the electric powered vehicle, the expert user car still remains the instruments belonged to the gasoline vehicles. Main menus and system settings are at the right side to the dashboard while the performance settings is at the left side. General information and driving mode menu are at the bottom side with the warnings and indications located at the top.

Figure Speedometer, tachometer, thermometer and other driving info instruments

For the expert user using, the driving and performance information are more on the screen, Besides the speedometer, the dashboard has information about the mileage, engine RPM, engine temperature, fuel amount and fuel per bar, located aside the speedometer [Figure 51].

Same with the standard user car, the expert user one also has the touch pad to control the

dashboard instruments. Four fingers wipe to right once for main menu, wipe to right twice for system setting menu. Wipe to left for performance settings menu. Wipe to top for the driving mode selection.

Figure 52 and figure 53 show all the user interfaces in main menu and system settings, which is mostly the same with the standard users in content.

Figure User interface of applications in main menu

Figure User interface of system settings menu items

9.2.2 Climate Control And Passenger Touchscreen

The figures below show how the climate control and passenger touchscreen look. The function layout is the same with the standard user one, while the style goes together with the expert user dashboard design.

Figure Climate control and passenger touchscreen of expert user car

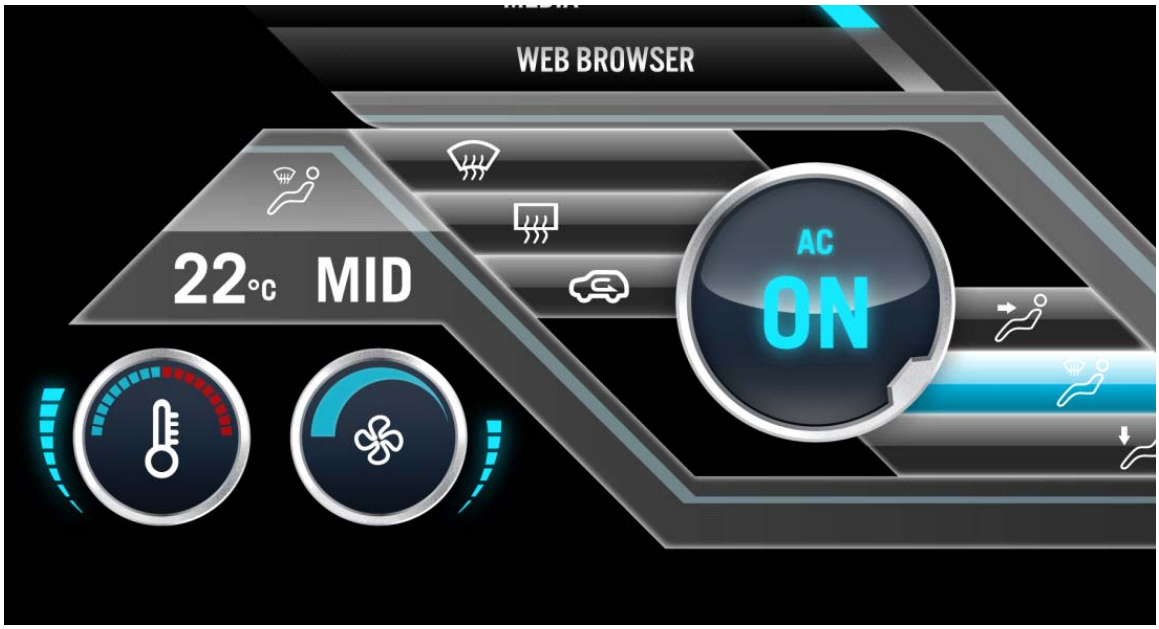


Figure Expert user climate control user interface

Figure Expert user touchscreen user interface

10 Discussion

10.1 Method Discussion

10.1.1 The HMI Development

The development process is roughly set at the beginning of the project. It is based on developer's knowledge upon product development process. The actual process remains the same but the evaluation phase is shortened. The evaluation phase supposed to include a usability test. Due to the technological and time constraint, the mock-up of HMI and cockpit are not feasible. By discussing with the supervisor at Mecel, the HMI designs are modified to fit the aesthetic requirements. To make reliable and user-centered HMIs, the evaluation upon usability should be held.

Since the thesis topic is futuristic, the development focuses on explore the new features of personal vehicle and decides which features are more likely being applied on personal vehicle in 2020. And therefore, workshops and discussions with experts took up large proportion of entire process. Besides, Mecel specially emphasizes on visually attraction to their customers. The visualization also took up fairly large part of development process. At the beginning of the thesis, the scope and requirement are loosely set, the pre study phase is specially set to define the project and narrow down the scope.

10.1.2 Workshop

Workshop is designed to explore the possibilities of personal vehicle from different perspectives. When design the HMIs, it turned out that workshop is one of the most useful methods. The outcomes of workshops provide numerous feasible features and ideas from technologies and user-centered perspectives. There are several reasons of why workshops contribute most to the project. Firstly, the participants are at their ages of 23 to 29. They are the potential users of personal vehicle in the future. Their opinions upon personal vehicles largely represent the young generation who will be the target user group in 2020. Secondly, the participants mainly divided into two categorized. One group has automotive engineering background while the other has industrial design engineering background. The former provides mostly new technical features and trends which developers are likely familiar at the beginning of the project. The latter is considered having rich knowledge regarding user-centered design. Their discussions provide a lot of ideas and thoughts from user's perspectives. Thirdly, most of participants are active and talkative. They consistently present their opinions, explain the ideas and discuss in a nature approach. For each workshop, the presentations and discussions are all recorded. Their notes are also kept. When design the HMI, these materials inspire the developers frequently.

10.1.3 System Description

System description is applied to understand the entire automotive system. This is important to the developers, since none of developers has rich driving experience. To investigate the system elements, three cars are studied. The study directly contributes to the design of functional layout, because the project topic is futuristic and conceptual but not inventing a car. Furthermore, to map the relationship of users and the functional units, the developers acknowledge the priority of functional units. It allows developers to locate the functional units into appropriate functional areas.

10.1.4 User interview

The user interviews contribute largely to the personas and scenarios. Through the interviews, the developer acknowledges the actual use context and users. The outcomes from mental models demonstrate how the user interacts with the car. Also, the use cases when driving are provided.

However, besides the inputs to scenarios, user's interviews supposed to contribute to identify user needs. This part is not filled due to the users considering mostly upon the existing driving environments and physical components.

10.1.5 Observation

Observation is designed to understand the actual context of driving. The ideal process should be following a user to record an actual use case. However, when arranging the observations, the time for the two volunteers is unlikely use the car. The activities are actually helping authors. The observation remains on actions level.

10.1.6 Persona, Scenarios and use cases

Personas and scenarios are important outcomes from the research phase. They illustrate the summaries of user study. For this thesis projects, persona and scenarios make designs possible through narrowing down the scope. After persona and scenario set, the use cases are able to be brainstormed.

10.2 General Discussion

As generated in the beginning, the initial purpose of the two HMI designs is clarified: exploring the possibilities of personal vehicles in 2020, with an emphasis on both the function layout and the visualization. Together with the delimitations, it has directed the

whole master thesis process. The entire work went successfully in general, according to the purposes and the delimitations.

The Reliability
The purpose of this master thesis is to explore possibilities, which means to give out a suggestion about what is likely to happen in the year of 2020. And this suggestion is mostly based on two facts, the cognitive needs of the user and the technical possibilities in 2020. According to this, the final design is not a concrete answer to the question. It is still a guess, but with exploring and demonstrations. This cannot be guaranteed to happen for sure, since the future is a very uncertain fact: the technology development cannot be predicted exactly; the society and culture progressing is constant, all of these make the future needs are not concretely answered, even though it can be concluded and predicted somehow by the fact of today. In general, several things result an uncertainty to the final results of this study.

The Feasibility
The feasibility of the function layout and the visualized HMI still needs to be examined. The purpose requires the function layout contains features that future needs and technically possible, and the HMI layout to be visually attractive. Thus, the usability issue is considered mostly based on the experiences from the master thesis worker, limitedly from the research. To make the HMIs fully worked, it needs quantity of deepened researches, experiments and evaluations to be finished.

The Supportive Components
The main work of the design phase is the function layout and the visualization of HMI. Objectively, the final design cannot stand solely on these two contents, e.g. the function layout refers to several physical assemblies. So the final design consists several parts are not included in the design purpose, such as physical models of the cockpit layout, the touchpad and shortcut keys on the steering wheel. They are in a supportive way to explain the functions and the HMIs, but not as part of the design in the results.

The Development Process
As planned in the beginning of the study, the process is planned to have the pre study phase first, about searching future technologies and theoretical studies, as well as setting up a clear purpose of the master thesis and the delimitations. Second for the research phase, with the applications on several methods mentioned before. Then is the design phase, including the function layout design and the visualization. The development process structure is proved to be good in general; it allows the information and results efficiently processed from one stage to the next, while there are still some actual problems existing. In the pre study phase, the setting up of the purpose and delimitations is done too curtly and subjectively. For example, the two user groups are decided due to the very different profiles they have, which may ease to distinguish the two user groups and the results. But the fact is, the expert user group as expected is a rare colony in the society, which makes it is much more difficult to find the ideal expert users to do the research as to support the final design.

Some of the research methods are mainly about the usability issues, while in this case it stands for a second position. The user interviews and the contextual study contributed very limited effort to the design development.

In general, the topic of this thesis is a vast one and did not set up a concrete scope at the beginning for a master thesis project. If the time for the entire development process is prolonged, it will be major effective for the final design.

The Master Thesis Topic

The master thesis topic has not been clearly identified in the beginning, for example the targeted users, the scope for the designing objects within this large topic. While it is also time consuming to narrow down the thesis topic, the work that is going to be finished should balance with the time issues as well. As a matter of fact, the master thesis topic could be limited in some way to direct the whole study clearly, e.g. focusing on one user category or a single part of the HMI, which could lead to a more concrete HMI design on every aspect of the purposes.

11 Conclusion

The final design can be considered that has fulfilled the purpose of this master thesis: exploring the likely future function possibilities and visually attractive HMI, and answering the question of how could the personal vehicle HMI be in 2020. The result of this study receives positive feedback from Mecel AB. At the meantime, there are still reliability issues, which lay in the function hierarchy, the steering wheel layout and the cockpit layout. To perfect them, more usability tests are required.

The development process is generally good, but with some issues. Since the initial topic is uncertain and has a very large scope, to minimize the research and design scope becomes very important in this issue. Thus, extending the pre study phase is quite necessary. Besides this, the consideration of methods using is not very accurate, which can be improved when there is more time doing the theoretical study in pre study phase. Also to make the final results more concrete, a detailed and convincing evaluation should be carried out. In general, the study procedure can be maintained with more time put into the pre study and evaluation, this is highly recommended to these kinds of projects.

The whole project is constantly inspiring for both authors, with knowledge study on vehicle technologies and research theories. It is also a highly self-motivated project, with many decisions on processing the thesis development. Unlike usual industrial design project, this study concerns a lot of expanding knowledge. Also the design objects and contents are various and vast, which lets the authors to narrow down the thesis topic by themselves.

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Appendices

Appendix A Market Analysis
Appendix B Workshop Materials
Appendix C System Descriptions
Appendix D Target User Interview
Appendix E Scenarios And Personas
Appendix F Functional Hierarchy
Appendix G Visualization Inspiration Board