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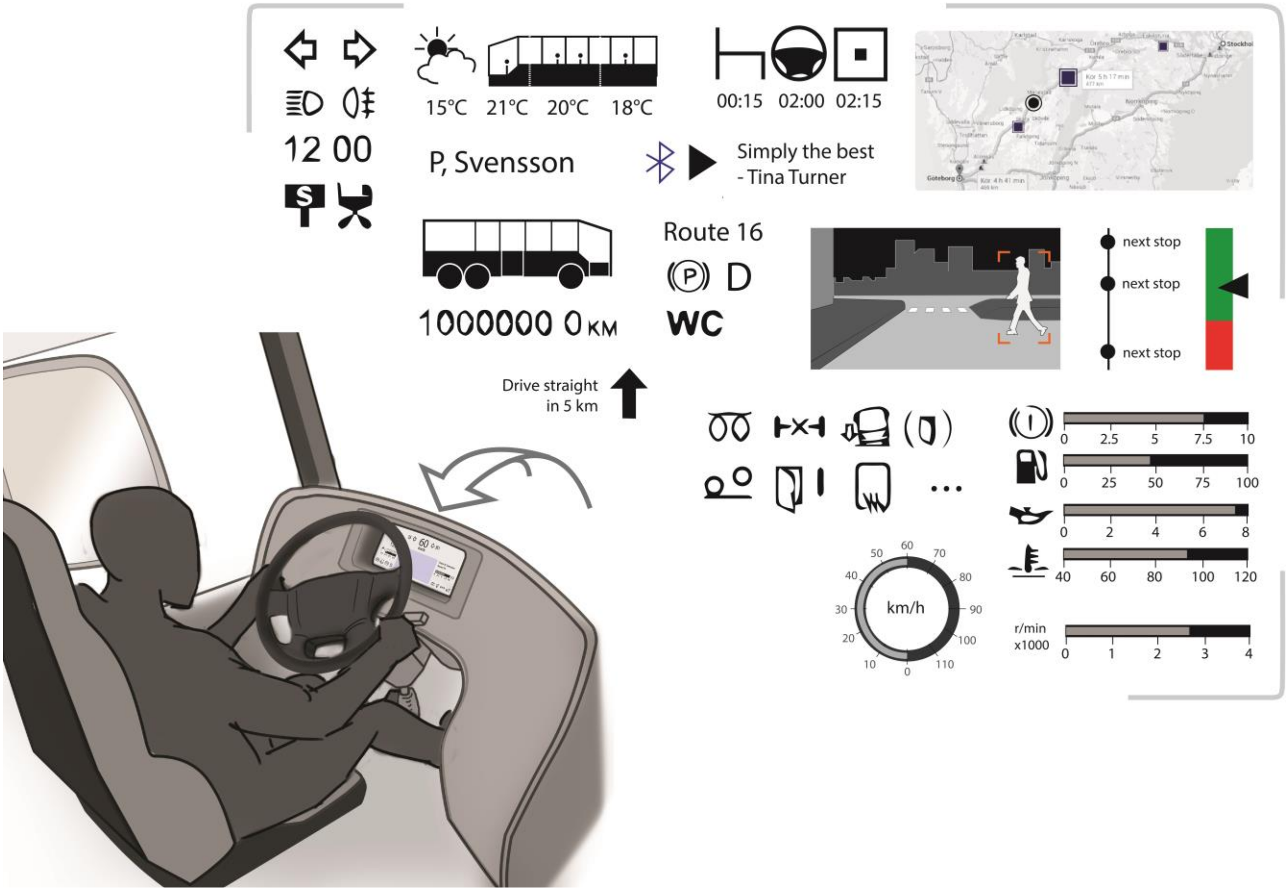

Redesign of Instrument Cluster

User-Centered Product Development at Volvo Bus Corporation

Master's thesis in Industrial Design Engineering and Product Development

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Cover:
an illustration of information needed when driving a bus,
with the driver position in the center and the new instrument
cluster design on the dashboard in front. For further knowledge
of the redesigned instrument clusters see p. 95
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ABSTRACT

The report describes a Master Thesis project at Chalmers University of Technology conducted with Volvo Bus Corporation. The project concerns information handling and perception through the instrument cluster from the bus drivers' perspective. Bus drivers are increasingly exposed to more complex traffic environments with more technically advanced busses. The project purpose is to understand the factors affecting the drivers and conclude how the instrument cluster can provide information in a good way to support easy perception. The scope is to map different user needs and present the holistic layout and design, as a base for more detailed design of the instrument cluster.

The current instrument cluster is placed on the dashboard, has analogue pins and lamps visualising warnings and is controlled by a stalk placed by the steering wheel. Depending on type of action and situation, the driver perceives and processes the information in different ways, which contributes to varied amounts of workload. Too little workload as well as too much workload can affect the performance of the person negatively when performing a task. To elicit user needs, data collection through user studies was performed. The data was analysed and represented with help of several different methods, concluding the needs of the drivers. The bus drivers have different work environments and needs, depending on what type of route they drive. Some aspects are common, while others are more specific for the three identified groups: city, intercity and tourist drivers. The information presented was therefore concluded to be task oriented, rather than user oriented. Use cases with defined tasks were therefore used as a base for the generated concepts. The new system was decided to focus on solving the issues with problem handling and perception of information in the instrument cluster. The new system will be connected to support functions such as traffic management and workshop to maximise the convenience at work for the drivers. Information about errors and problems will be sent directly to the concerned function to decrease risk of corrupting information. The concepts generated shows different ways of conveying information to the three types of drivers, since it was determined that their needs of information perception differed due to the different situations they were exposed to. The concepts have a standard screen with relevant information that is always displayed and has adaptable areas where information is shown, depending on situation and individual preferences are shown. Through evaluating the generated concepts together with bus drivers some aspects that needed to change and improve with the concepts were found. In general, the drivers wanted less information on the instrument cluster, enabling faster overview and additional functions to be preferably placed on secondary information displays. The final, overall features of the concepts were created and then changed according to the evaluation sessions in the second design phase. The final concept describes the redesigned bus system in its totality and presents graphical variations of the instrument clusters for the three different types of drivers and the situations they are exposed of. The scope and implementation of the project produced new and interesting findings that answered the questions stated. The findings and concepts can be of use for further development of instrument clusters at Volvo Bus Corporation.

Keywords: bus driver interface, instrument cluster, product development, user-centred design, usability, cognitive ergonomics.

SAMMANFATTNING

Denna rapport beskriver ett masterprojekt och examensarbete på Chalmers Tekniska Högskola, utfört i samarbete med Volvo Bussar. Projektet behandlar informationshantering och perception genom instrumentklustret, från bussförarens perspektiv. Bussförare är alltmer exponerade för komplexa trafikmiljöer med mer tekniskt avancerade bussar. Projektets syfte är att förstå de faktorer som påverkar förare och dra slutsatser kring hur instrumentklustret kan ge information på ett bra sätt som stöder enkel perception. Fokus i projektet är att kartlägga de olika användarnas behov och presentera en holistisk utformning och design, som en grundläggande plattform för mer detaljerad design av instrumentklustret.

Det nuvarande instrumentklustret är placerat på instrumentbrädan och har analoga visare och lampor som visar varningar och kontrolleras av en spak placerad vid ratten. Beroende på typ av uppgift och situation så uppfattar och behandlar föraren information på olika sätt, vilket bidrar till varierande mängd arbetsbelastning. För lite arbetsbelastning kan såväl som för mycket arbetsbelastning påverka personens utförande av en arbetsuppgift negativt. För att få fram användarnas behov utfördes datainsamling genom brukarstudier. Data analyserades och representerades med hjälp av flera olika metoder som sammanfattade användarnas behov. Bussförare har olika arbetsmiljöer och behov beroende på vad för typ av rutter de kör. Några av aspekterna är gemensamma, medan andra är mer specifika för de tre identifierade grupperna: city-, intercity- och turistförare. Informationen bestämdes därför vara uppgiftsorienterad snarare än användarorienterad. Användningsfall med definierade uppgifter var därför valda som bas för de genererade koncepten. Det nya systemet fokuserar på att lösa de frågor inom problemhantering och perception av information i instrumentklustret som identifierats. Det nya systemet kommer att vara uppkopplat mot stödfunktioner som trafikplanering och verkstad för att maximera bekvämlighet i arbetet för förarna. Information om fel och problem sänds direkt till den berörda enheten för att minimera risk för förvanskning av information. Koncepten som genererades visar olika sätt att förmedla information till de tre typerna av förare, eftersom det var fastställt att deras behov vid perception av information skilde sig beroende för situation de befann sig i. Koncepten har en standard skärm med relevant information som visas konstant och har anpassningsbart område där informationen varierar beroende på situation och personliga preferenser. Genom att utvärdera de genererade koncepten med förare framgick vissa aspekter som behövde förändras och förbättras. Generellt, så ville förarna ha mindre information på instrumentklustret, vilket medger snabbare överblick där de ytterligare funktionaliteterna hellre skulle vara placerade på sekundära informationsskärmar. De slutgiltiga, övergripande egenskaperna hos koncepten skapades och förändrades enligt de utvärderingsmöten som utfördes i den andra design fasen. Det slutgiltiga konceptet beskriver det omformade bus systemet i dess helhet och presenterar de grafiska variationerna på instrumentklustret för de tre olika typerna av förare och de situationer de är utsatta för. Omfånget och genomförandet av projektet ledde till nya intressanta upptäckter som svarade på de frågor som ställts. Kunskaperna och koncepten kan vara till nytta för fortsatt utveckling av instrumentklustret på Volvo Bussar.

Nyckelord: bussförargränssnitt, instrumentkluster, produktutveckling, användarcentrerad design, användarvänlighet, kognitiv ergonomi.

FOREWORD

This report describes a Master thesis project in the course Masterexamensarbete vid Produkt- och Produktionsutveckling (PPUX05), 30 ECTS at Chalmers University of Technology. The project is conducted in collaboration with Volvo Bus Corporation and the work is focused on providing material for the product development for the department of Ergonomics and Driver Interface. This work could not have been done without support and help from the Ergonomics and Driver Interface department at Volvo Bus Corporation, the company supervisor Sara Alpsten and the academic supervisor Lars-Ola Bligård, Ph.D. Researcher from the department of Design & Human Factors, Institution of Product and Production Development at Chalmers University of Technology.

Special thanks also goes to the bus drivers and bus companies expressing their opinions and providing important information during the user study and evaluation. The information was essential to understand how the instrument cluster could be designed in a user friendly way.

Special thanks to:

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- Keolis Sverige AB
- Nobina Sverige AB
- Sandarna Transporter AB
- Volvo Bus Corporation

CONTENTS

1. INTRODUCTION

This report constitute of a project within the bus industry which focuses on supporting the driver by introducing better information handling through the instrument cluster on the dashboard. In order to have a better understanding of the project scope and purpose, the background and the foundation of the work will be introduced here.

1.1 BACKGROUND

Traffic environments are complex and bus drivers would benefit from retrieving the information needed in an easy and understandable way to enable a safe and efficient drive. One part of the interface giving information to the bus driver is the instrument cluster containing a display with speed indicator, tachometer, warning signals and some additional information.

This project is focused on developing a new digital instrument cluster that enables proper information perception for bus drivers. Technology breakthroughs and new possibilities of digitally displaying information create a need for investigating a new design. New technology enables more functions for the user, but can make the systems more complicated to use, hence an investigation about this is needed. The user demands need to be investigated and the instrument cluster needs to be adapted to changes in user behaviour and expectations.

The project is conducted in collaboration with Volvo Bus Corporation. The process is divided in several phases, a first part which will mainly involve user studies and elicitations of user requirements and a later part, describing the concept development based on knowledge compiled in the previous phases. Focus will be on improving the human machine system in order for the solution to enable a safe driving situation and suit the user needs emerged during studies of the user segments. The current product portfolio of the company is used as benchmark for the concept development in the project.

1.2 PURPOSE

The purpose of the project is to conclude how information should be handled and presented to drivers in Volvo's buses through the instrument cluster. The product development is based on a digital instrument cluster which is not restricted to the technology used in the current system, i.e. scales with analogue connected pins.

The project seeks to conclude what information is necessary for the driver, in what context it is needed and how it should be provided to the driver. This in order to maximise awareness of the vehicle and its surroundings as well as minimise distractions.

To fulfil the purpose of the project, knowledge from the education will be utilised and integrated with knowledge brought forth in the project, both from Volvo Bus Corporation and from data collection methods, in order to develop a solution for handling information digitally in the area of safe driving and map the discovered customer needs of bus drivers.

1.3 OBJECTIVE

The main objective is to produce design recommendations for a digital instrument cluster. Additionally, design concepts will be developed and evaluated to give examples of how the user needs can be fulfilled.

1.4 QUESTIONS

- What information should be presented to the driver?
- When should the information be presented?
- How should information be presented to the driver in a good way?
- Where should the information be presented?
- How does the need of information vary for different drivers, bus models and context?
- What information does the bus driver need and what could be delegated to other parts of the organisation? How should that collaboration work?

1.5 SCOPE

The project will include mapping of user needs and the factors influencing bus drivers in different types of buses and traffic. The project will end in a solution focusing on an overall design system. This includes the handling of the needed information in the instrument cluster. Development of individual symbols and detailed design will be excluded.

1.5.1 EXPECTATIONS FROM CLIENTS

Volvo Bus Corporation wants to map the differences between the human machine systems in their product range. There are mainly two big categories of buses, city buses and coach buses. There are also many variants between these buses and data will be collected from buses and bus drivers in different parts of the spectre. Aspects differentiating in the spectrum should be identified and presented in a way that is easy to grasp. Volvo Bus Corporation wants to know what characteristics are common for driving the different types of buses and what is different and might need adaption. Therefore, generalisations of how requirements and user environment changes in their product range will be concluded and based on the conclusions, a new concept for the instrument cluster will be developed. The concept will not be developed in detail (such as development of symbols), but rather explain how information should be grouped and presented in the bigger picture.

The concept development is not restricted to technology available today. Instead, the concept will focus on presenting information in an ideal way. At the same time, it should be plausible to actually use the concept or parts of it in future bus development. There are already technologies on the market that are not implemented in today's instrument cluster that will be taken into consideration in this project.

The results of the project should be represented as 2D visualisations of placement and design.

1.5.2 PRIORITIES

The project mainly focuses on cognitive ergonomics and how information is presented to the driver. Another important aspect taken into consideration is sustainability and how the driver is encouraged to drive as eco-friendly as possible. Since the connection between sustainability and fuel consumption and costs of driving is very strong, these aspects are also associated with economic factors. Laws and regulations are taken in consideration as there are constant changes with aspect to safety and environment. Technology, materials and detailed construction will be less prioritized.

Theory and literature studies will be an important tool in creating and verifying concepts. The end user will also be able to give feedback in the concept development iterations in interviews or in bus environments. There will not be any verification tests in actual driving or simulations. Evaluation is instead based on feedback sessions where visual presentations and scenarios are used as mediating objects.

1.5.3 Sustainable development

Sustainable development is not in itself the main goal of the project. Safety and user friendliness will be prioritised even more. Although sustainability is one aspect that continuously will be taken into consideration in the project, both when exploring the current situation, creating new concepts and evaluating the concepts. Current solutions for coaching bus drivers to drive in a fuel efficient and safe way will be analysed and if possible improved.

1.5.4 Process and iterations

The process follows the first steps of the generalised development process by Bligård (2011), that is need identification, function and task formation and overall design. The fourth phase of detailed design will not be covered thoroughly, since the goal of the project is to do an overall way of handling information to the driver, rather than a detailed design of how it would look. Since the project is at an conceptual level, and not bound by current technology available, the last phases of construction and deployment will not be included either. The project process will therefore end with a final solution at an conceptual level. The process will be further explained in Implementation, chapter 5, and methods used in the project are presented in Methods, chapter 4.

1.6 Project outline

The layout of the report is divided into main chapters consistent with the project process. First an introduction to the project subject will be given and some knowledge background needed to understand the work done. Relevant theory has been added in a separate chapter which will be used throughout the project as a support for the results and conclusions. Methods used during the project will be described as well as how they were implemented into the project process. The findings will be presented under each process step; need identification, function and task formation, concept design 1 and concept design 2. The final concept chapter will as a summary explain what the final solution constitute of and how it will work. The project, and report, is outlined as follows.

1. Introduction
2. Knowledge background
3. Theory
4. Methods
5. Implementation
6. Need identification
7. Function & task formation
8. Concept design 1
9. Concept design 2
10. Final concept
11. Discussion
12. Recommendations
13. Conclusion
14. References
15. Appendices

2. KNOWLEDGE BACKGROUND

In order to understand the basics of the project area, some knowledge of the current system is presented in this chapter.

2.1 BUS TYPES AND DRIVER RESPONSIBILITY

Volvo Bus Corporation provides different types of busses depending on the client's use. Volvo defines them as city, intercity and coaches (AB Volvo, 2011). Three examples of buses in these categories are shown in figure 1. The differences lie in the client's use and the busses are designed for the different needs. The buses provided for city and intercity is lower than the coaches and is constructed to fit more passengers with less luggage and focus on the effectivity in passenger on and off load, whereas the coaches are designed for comfort and longer trips with larger room for brought luggage.

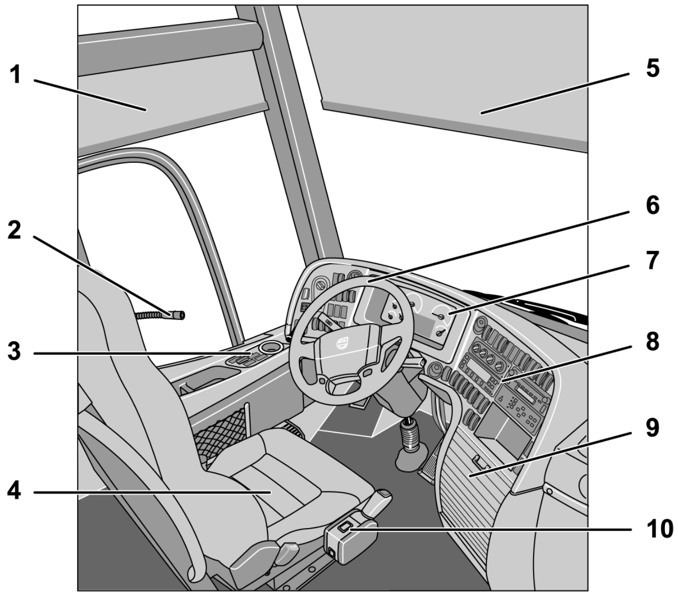
Figure 1: Examples of the bus types city, intercity and coach accordingly (AB Volvo, 2011).

To drive a bus requires a certain driver's licence. It is the drivers' responsibility to keep the passengers safe and comfortable when driving a bus (AB Volvo, 2014). The drivers are therefore supposed to have read and know the driver manual. The driver is responsible of safety equipment, capacity of the bus and to know how technical functions important for driving works. The bus driver needs to prevent hazards and pay attention to possible failures in the bus.

2.2 BUS DRIVER AREA

The driver is seated in front of the bus, which looks a bit different depending on type of bus. Figure 2-3 show an example of a driver place in a Volvo coach bus, for further information see Driver Handbook 900, Volvo Bus Corporation.

The driver keeps track of the traffic and environments outside through the windows in front and on the sides. Information about the vehicle and its instruments appear on the dashboard with the instrument cluster and in some cases additional information is presented, as for example lamps and controls is placed around the dashboard. The driver controls the functions and system in the bus through the controllers on the dashboard and side panel. Gear is selected by the lever by the seat (nr 10 in figure 2) and the menu in the instrument cluster can be controlled and reached by the stalk behind the steering wheel (no. 10 in figure 3).



Driver Area Specifics:

1 Side sun visor

2 Driver's microphone

3 Side panel

4 Driver's seat

5 Front sun visor

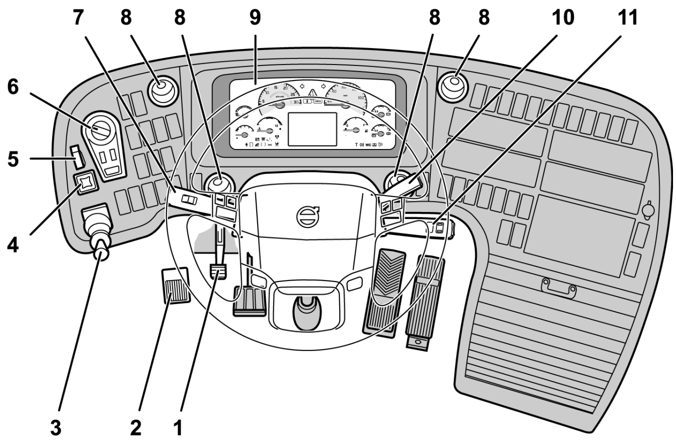
6 Steering wheel

7 Dashboard, instrument cluster

8 Controllers (AC, audio-visual system)

9 Locker, audio equipment

10 Gear selector



Overview of Instruments and controls:

1 Steering wheel adjustment pedal

2 Microphone switch

3 Parking brake

4 Adjustment of rear view mirrors

5 Emergency stop

6 Light switch

7 Control stalk for indicators and cruise control

8 Air inlet

9 Instrumentation

10 Steering wheel settings, retard

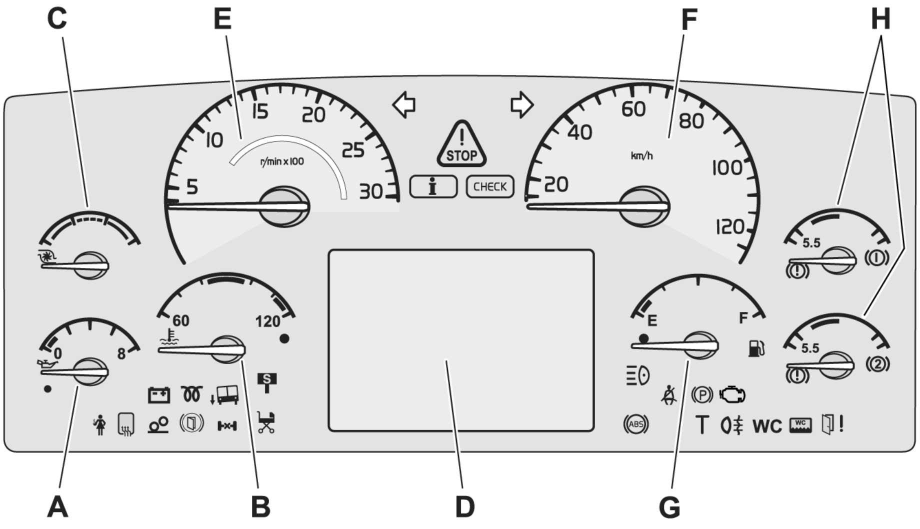
11 Control stalk for wipers, washers and display

Figure 2-3: The bus driver's work area and the tools and instruments needed to maneuver the bus. (AB Volvo, 2014)

2.3 INSTRUMENT CLUSTER

The instrument cluster differ slightly due to the difference in included functions in the buses, but almost has the same standard look in different busses. It has analogue pins showing the level state of some instrument of importance and warnings lamps behind cut out symbols representing other instruments in the bus, see figure 4.

The current system has three different types of messages conveying information to the driver. The most severe is the stop message, and then there is warning messages and information messages. When a warning comes up, both the warning symbol is indicated as well as the lamp displaying what group it belongs to.



Types of instruments:
A Engine oil pressure gauge
B Coolant temperature gauge
C Turbo pressure gauge
D Display
E Tachometer
F Speedometer
G Fuel gauge
H Air pressure gauge for brakes

Figure 4: The instrument cluster and the information it display.

The instrument symbols displayed in the instrument cluster has a certain meaning that the driver needs to know by heart in order to manoeuvre the vehicle safely. The symbolised meanings of the instruments are further explained in Appendix 1.

2.4 ADDITIONAL ADD-ON POSSIBILITIES

Equipment often used in buses, but not designed by Volvo Bus Corporation or other bus manufacturers are defined as additional systems, or add-ons, and are further described in this section.

2.4.1 PUBLIC TRANSPORT ORGANISATION'S TIMETABLE

Bus drivers driving specifically in city traffic for public transport organisations often use the organisations' own timetable software which is visualised on an add-on screen on the right hand side of the driver seat. This screen shows the bus stops on the current route and the time table the driver needs to follow. Additionally, the acutual time and place compared to the scheduled time is displayed through colour codes. A similar version to the timetable software used in Gothenburg through Västtrafik is shown in figure 5 as an example.

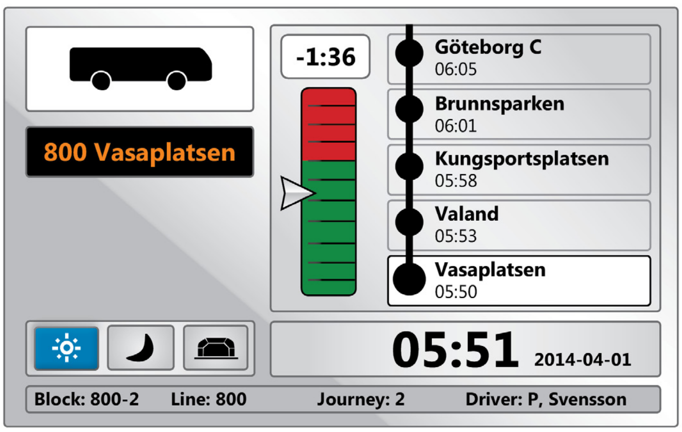


Figure 5. A similar version of the timetable software called "I Tid" used by Västtrafik, Gothenburg.

2.4.2 CAMERAS

Cameras showing the sides, back and front of the bus are available in some buses. The camera input is visualised on additional add-on screens around the bus driver space, often placed shortly under the roof of the bus in front of the driver.

2.4.3 PAYMENT SYSTEMS

The bus companies use different payment systems for their passengers depending on the type of the bus organisation. Either the bus company the driver is driving for is hired by another organisation as for example a public transport organisation, or the bus organisation themselves get paid by the passengers. Depending on if the bus conpany use a middleman, e.g. public transport organisation, or if they get paid directly by the passengers, the driver has different responsibilities towards passenger payment systems and the environment in the bus looks different.

But either way, all bus companies have some way of payment system installed in the buses that may or may not need additional interactive screens to manoeuvre by the driver. For the bus drivers that take care of the payment manually that means they need several more screens to keep track of than the drivers who drive in companies not responsible for the passenger payment. This needs to be considered when evaluating information needed visualising in the instrument cluster.

3. THEORY

In the theory chapter relevant theories from literature is presented to give a frame of thinking about problems and evaluations discussed later in the report. First some basic models over human behaviour and thinking are presented, followed by problems related to the area of human-maschine interaction as well as usability. Finally, theories about design guidelines and heuristics useful for the design of the instrument cluster are stated.

3.1 HUMAN THINKING AND BEHAVIOUR

When designing the interface of a product it is useful to have human processing and the human way of thinking in mind. Models of the human information processing can therefore be a base for thinking about how to present information to the driver. Interaction between human and machines is about exchange of information (Salvendy, 2006). The human in the interaction is also called operator and performs actions that provide the machine with information. The machine will then provide information back to the operator about its state and feedback on the operator action. The operator process and make decisions from the information given. The information is taken in by the senses (sight, hearing, haptics, etc.), in the stage called perception. There are limitations of the human perception, and an interface of a machine therefore needs to be designed with this in mind. After perceiving information, processing is needed.

There are models describing how the processing and decision making of humans is divided. Depending on what type of task the operator performs, different ways of thinking is activated. The behaviours of humans can be divided in skill-, rule- and knowledge based behaviours (Rasmusens, 1983). The skill based behaviours describes sensory-motor performance that occurs when the person intend to do something but perform the action without conscious control. The actions are then highly integrated patterns of behaviour with automated character. On the next level, the behaviour is instead rule-based. Rule based behaviours are used in familiar situations where the person consciously uses a sequence of subroutines to achieve a goal. The rules are formed by experience, communication with other people or as results of other conscious problem solving and planning. In unfamiliar situations where a person lacks rules and know-how applicable, the control of performance is goal-controlled and knowledge-based. Instead of using rules and automatic behaviour the person needs to set a clear goal, develop and evaluate a plan for execution. This high level of knowledge-based behaviour can be supported by good mental models of the system. The mental model is a representation of the internal structure of the system in the users mind (Rasmussen, 1983). To have many different mental representations of a system helps the user when formulating new rules and solving problems in real time.

When a human is interacting with a machine system the process can be divided in seven steps (Norman, 1986). The first step is about the human creating a goal, next step is that the person wants to act in order to achieve the goal. After that the person plans the actions to reach the goal and then perform the actions. Then the person perceives what has happened and the state of the world. The impressions are interpreted by the person's expectations and finally the interpretation is evaluated to what was anticipated to happen.

3.1.1 MENTAL WORKLOAD

The instrument cluster developed in this project can preferably be developed with a goal to have a balanced amount of mental workload for bus drivers. According to Andersson[1], mental workload can be divided into mental effort, stress and time pressure. Some of the factors influencing mental effort are the complexity of tasks, simultaneous tasks, prior understanding and the levels of skill-, rule- and knowledge based behaviour.

Accidents can occur when tasks are physically or mentally difficult (Kletz, 2001). If people get too much information they can become overloaded and switch off. There is also a problem if people are under loaded, then they are not staying alert and might miss important events. If too much of the work is left to automation, there is a risk for this effect. A way of helping to solve this problem is to give the user other tasks which are valuable, but not critical to continue if the main tasks need more attention. Mental workload is only too high in special situations and often automation is relieving the user from mental demands that were on a good level without automation (Young & Stanton, 2002). This can cause mental underload which significantly can lower performance.

If the mental workload is too low that could be a risk (Kletz, 2001). If the mental workload is too high that also causes fatigue and risks when driving. The instrument cluster should therefore strive to keep drivers alert and not mentally overloaded in order to create a safe drive. Risk due to mental underload occurs when the driver is non alert, especially when driving to and from garage without passengers, see user study conclusions. In order to keep mental workload down, the instrument cluster should help the driver in problem situations when knowledge based behaviour is required.

An increase in RTO (Road Transport Informatics) and applications connected to this information could decrease road safety (Ward, 1996). This can happen if the drivers' capabilities are too low compared to the task demands. Then errors can become critical for safety, especially if the layout of instrument panels is not designed with a human factors concern.

3.1.2 PERFORMANCE SHAPE FACTORS

There are internal, external and stress factors influencing the performance of the user (Bohgard et al, 2008). Internal factors are individual and contributed from the user. The internal factors can be both physical and mental. Physical factors can be age, physics, hearing, sight and health. Mental factors can be personality, attitude, motivation, stress endurance, behaviour and emotional state. Other abilities such as knowledge, experience, skill and problem solving abilities also affect the system. External factors are divided in latent and operational factors. The latent factors exist in the surroundings, for example environment, work hours and structure of the organisation. The operational factors are dependent on the work task and process, for example instructions, equipment, machine interface, risks and work procedures. These internal and external factors can in combination affect the user in the form of stress factors. There are psychological stress factors, for example high workload, distractions, threats, and mental bluntness. There are also physiological stress factors such as pain, tiredness, hunger, vibrations, high sound levels, lacking ventilation and stress during long time intervals. These factors can affect the interaction in the human-machine system directly or indirectly and influence acting and decision making. Vibrations can for example make it harder to steer a system and read on displays.

1: Andersson, J. Lecture in the course MPP036 Cognitive Ergonomics: Mental workload, automation, performing shaping factors, 12 november 2013.

3.2 Miscommunication between user and machine

The machine interface needs to communicate information to the user in a way that decreases the risk of accidents because of errors in usage (Bohgard et al, 2008). There are two types of gulfs of knowledge between the user and the machine when miscommunication can occur (Norman, 1986). The first one is the gulf of execution where the user finds it hard to do the actions in order to reach the goal. The other gulf is where the user finds it hard to evaluate the information from the machine and therefore cannot know if the goal has been reached. In this study focus lies on the second gulf of evaluation. The object which the user interacts with in order to execute tasks are mostly outside the scope of the instrument cluster. The instrument cluster is an interface where the user perceives signals and information and the main aspect is therefore to make sure the user evaluates information in the correct way.

3.3 Usability

Usability is an important aspect in designing the machine interface (Bligård, 2011). Usability is a measure on the quality of interaction and how well the machine supports the user in performing the intended task. Both physical and cognitive ergonomics is important factors that affect the usability. In addition to usability, aesthetics and functionality needs to be taken in consideration when designing an interface. For a successful interaction all three aspects needs to have high quality. The aspects should not be sub optimized, while they affect each other. Instead the focus in development should be to find ways so the aspects support each other and create synergy.

Usability is achieved differently depending on the type of user and situation. The user drives the bus on an everyday basis and has education before getting the license and also further regular education at least every five years (Trafikverket, 2014). Therefore focus should be mostly on providing good learnability, which is the ability to make the user perform the right action at the second try (Jordan, 1998). Guessability, which is the ability of the machine to make the user perform the right action at the first try, and intuitive understanding, is not as important when it comes to function and signals the user interacts with on an everyday basis. Although less frequent information occurring in unusual situations might have a bigger need for intuitive perception and processing through good memorability. Another aspect is novice-ability, which is the ability of the machine to make a novice achieve high effectivity and efficiency.

Problems with usability can lead to that the user is unable to reach the goal, that the use is inefficient or ineffective or that the user feels unsatisfied with the use (Bligård, 2011). Negative effects can be summarised in four problems:

1. The user spends too much time to interact with the machine, which gives less time over for other tasks.
2. The user handles the machine in an incorrect way, which can cause damage on humans, material and the environment.
3. The user gets stressed and insecure, which decreases the ability to solve other tasks.
4. The user cannot take full advantage of the possible technologies.

3.4 Heuristics & design guidelines

When designing interfaces it is important to provide the user with relevant information that makes the mental processing easier and enables the user to take decisions on further actions (Bohgard et al, 2008). The physical and mental capacity of the user needs to be taken in consideration when designing the interface. Overall, four important guidelines to think about is that the device has to be reachable, able to discover, able to identify and understandable (Bligård, 2011).

- Grouping

On a screen, things that are related should be placed close to each other (Bohgard et al, 2008). While objects placed near to each other tend to be grouped, according to the gestalt principle of proximity (Robinson-Riegler & Robinson-Riegler, 2008).

Things with the same or similar function should look similar. (Bohgard et al, 2008). While the principle of similarity describes the tendency to group things that are similar to each other (Robinson-Riegler & Robinson-Riegler, 2008).

Elements that are belonging to the same area or region tend to be grouped when perceived (Robinson-Riegler & Robinson-Riegler, 2008).

Elements tend to be integrated to a whole which is also perceived differently from the sum of its parts (Robinson-Riegler & Robinson-Riegler, 2008). Apprehension of wholes is a natural tendency which needs consideration when designing.

- Colours

Generally, no more than four different colours should be used at the same time in an interface. (Bohgard et al, 2008)

Red and green colours should only carefully be used in combination because 8% of men have colour blindness. (Bohgard et al, 2008). These persons are unable to see the difference between the hues (Wickens et al, 2004). The sensation for the colour blind person is identical for when the colours are of the same luminance intensity.

Colours carry messages which can be different in different cultures. (Bohgard et al, 2008)

The stereotypical meaning of red is stop, danger, hot, fire. (Bohgard et al, 2008)

The stereotypical meaning of yellow us warning, slow, testing. (Bohgard et al, 2008)

The stereotypical meaning of green is OK, drive, continue, on. (Bohgard et al, 2008)

The stereotypical meaning of blue is cold, water, calm. (Bohgard et al, 2008)

- Readability

For easier reading of text, the font used should have typical letter shapes, because of greater familiarity than for non-standardised shapes. (Wickens et al, 2003)

When using single and isolated words, readability is good with uppercase letters. For example when using ON or STOP to describe something. (Wickens et al, 2003)

For text with multiple words lowercase or mixed-case text is preferably used since uppercase text is more difficult to read. (Wickens et al, 2003)

Example recommended height of text at a distance of 71 cm is 1 / (200*reading distance) (Sanders & McCormick, 1993).

- Multimodality

Vision tends to dominate audition (Robinson-Riegler & Robinson-Riegler, 2008).

Time-sharing between different modalities is better than intermodal time-sharing (Wickens et al, 2004).

Two competitive visual channels might cause confusion and masking if placed too close to each other and cause visual scanning and additional demand if placed far apart.

Clear and salient physical or sensory signals or reminders are more likely to make the person switch to another task than less obvious triggers or merely memorial representations (Wickens & et al, 2004).

3.4.1 DESIGN VARIABLES

There are different types of design variables that can be alternated when designing an information device (Bohgard et al, 2008), see table 1.

Table 1: The different information types are here described further by the design variables that each is constituted of.

Information Type	Design Variable
Visual	Size, form, contrast, colour, luminance and movement
Auditive	Volume, frequency, rhythm, pitch, melody and language
Haptic	Size, form, surface structure, weight/force, vibration and temperature.

3.4.2 HEURISTIC CHECKLIST

A list often used for evaluation of usability in technical systems is presented and summarised below (Nielsen & Mack, 1994).

1. Show system status and give feedback at the right time to keep user informed.
2. Create similarity between system and reality and use words and phrases familiar to the users'.
3. Give the user control and freedom, to exit from functions accessed by mistake.
4. Conform to standards and do not use different words that mean the same thing.
5. Hinder errors from occurring.
6. The user should not have to remember information, it should be visible and easy to find when needed.
7. Be flexible and effective so that experienced users can adapt the system for commonly used functions, without disturbing novice users.
8. Have aesthetic and minimalistic design, irrelevant information should not be displayed. Every unit of information are competing for attention and irrelevant information hinders perception of relevant information.
9. Help the user to recognise, diagnose and recover from errors through conveying the message in a simple language, clearly indicate the error and constructively suggest a solution. The information should not be displayed with codes.
10. The system should enable use without documentation but if such information is necessary it should be easy to find and search from. It should be focused on the user task and list concrete actions that needs to be performed in an effective way.

3.4.3 DESIGN PRINCIPLES FOR SITUATIONAL AWARENESS

When driving situational awareness is very important and principles of designing for situational awareness (SA) can be of great help (Endsley et al, 2003).

- Principle 1: Organize information around goals and not from the technology (Endsley et al, 2003). For the current instrument cluster some scales show values directly from the sensors and let the driver evaluate the information themselves. But the goal of the bus driver is to identify the state of the machine and understand which action to take if there is something wrong. The interface should therefore directly give information of what action that is needed. Meanwhile, sometimes the way of showing information directly connected to the sensors might be a good thing. It could help the user to get a good understanding of the machine.

- Principle 2: Present Level 2 information directly and help comprehension.

Attention and working memory is under heavy load when driving a bus, especially when driving in cities, see results from user study summary. The driver should not have to calculate and estimate the deviation from current state to desired state (Endsley et al, 2003). This should instead be displayed in a clear way.

- Principle 3: Provide assistance for Level 3 SA projections.

The user should preferably be able to predict future states of the system (Endsley et al, 2003). One way of enabling this is to use trend displays, which are graphic presentations of changes in a parameter over time. The driver can sometimes avoid errors or occurrences through anticipating them in advance.

- Principle 4: Support global SA.

There can be problems if information is too narrowed and the user focus too much on subset of information (Endsley et al, 2003). The user can therefore be provided with displays that show the big picture of the system and give a good high level overview.

- Principle 5: Support trade-offs between goal-driven and data-driven processing.

There needs to be a balance of goal-driven and data-driven processing (Endsley et al, 2003). Cues that capture attention, for example flashing lights, loud sounds and bright colours, should only be used as critical cues that requires action from the user. Those kinds of cues should be avoided if not critical.

- Principle 6: Make critical cues for schema activation salient

Critical cues for overviewing the system needs to be clearly displayed in the interface (Endsley et al, 2003). In order to facilitate good decision making, the important attributes needs to be salient for the perception of the driver. One example of an important attribute is fuel level, which also can benefit from marking breakpoints to help the user take decisions.

- Principle 7: Take advantage of parallel processing capabilities.

The user has abilities to share attention between different tasks and information, which should be used in the design to support parallel processing (Endsley et al, 2003). It can be beneficial to provide some information visually and at the same time provide auditory information in order to enable processing of more information at the same time. The different modalities use different cognitive resources. To use multiple modalities to convey information is useful when there is an information overload.

- Principle 8: Use information filtering carefully.

Information filtering and reduction of data can in many cases provide a better situational awareness than having too much information shown and solve problems with information overload (Endsley et al, 2003). Although, the filtering needs to be done carefully to not reduce data that supports the global awareness of the situation. If only information needed at the moment is displayed, planning and prediction by the user might be aggravated. This happens because situational awareness is often created over time through identifying trends and changes in the system. Different users might benefit from different type of data to create understanding of the system. Therefore it is important only to filter out information that is not useful.

4. METHODS

In the methods chapter different procedures that support the product development process in the project is presented. The methods are grouped with aspect to the type of method it belongs to.

4.1 DATA COLLECTION

Interviews in combination with observations are ways of collecting data about the users. These methods were used in the need identification phase, to bring in user knowledge.

4.1.1 INTERVIEWS

Interviews are a way of gathering raw data from customers through meetings going on about one to two hours (Ulrich & Eppinger, 2012). The purpose with the interviews in an explorative study is to get qualitative and rich information to get ideas of how the system could be designed in a better way. Interviews can be structured, semi-structured or unstructured (Lantz, 2007). Unstructured interviews give qualitative data and are beneficial for explorative studies. Unstructured studies are preferable conducted on a small number of persons. Already after 6 interviews the main picture of the problem and area could be clear. Interviews of this type demand high resources and the result is hard to summarise and compare. On the other hand, the type of interview can be good for deeper understanding and when it is unclear which areas are of importance for understanding the problem. An alternative is to use semi-structured interviews, where a structure for the areas of interests covered in the interview is used. The person performing the interview then needs to have a clear picture of what is important. With a semi structured interview there is room for follow up questions and probing. The type of interview can give qualitative as well as quantitative data.

4.1.2 OBSERVATIONS & CONTEXTUAL INQUIRY

Field observations are a method where the researcher watches the actual situation, user and task in the real environment (Kylén, 2004). The purpose with the observation is to understand the use without affecting the behaviour of the user. Observations catches what the users actually do and not what they say they do. Observations can be unsystematic, which means that everything of interest is noted. This method is often used in early stages where it is unclear which areas are important. Observations can reveal important details about customer needs (Ulrich & Eppinger, 2012).

4.2 DATA ANALYSIS

With the analysis methods, the data found could be handled in a structured way that enables easier presentation.

4.2.1 KJ ANALYSIS

KJ Analysis, similar to Affinity diagram (Foster, 2013), is a method for summarising and overviewing large amounts of data (Kaulio et al, 1999). In the method, the data is divided on small notes and then sorted in groups where notes related to each other are grouped. The process is made from the bottom up, so that the details are studied and then builds up the holistic view. The groups of information are formed during the analysis process.

4.2.2 HTA

Hierarchical Task Analysis (HTA) is a method that describes the steps a user needs to take in order to achieve a set goal (Stanton, 2006). A main goal is identified and then the sub goals needed to reach the main goal are described. The sub goals are then further divided and eventually, the end tasks will be found at the bottom of the hierarchy. HTA is used in order to structure and understand the actions of the user.

4.2.3 System description

In order to deal with complex things in a holistic way system thinking can be a useful framework (Flood & Carson, 1993). A system representation show the organised whole, the parts it contains and the communications and relationships between them. The communication or relationships can be different forms of information, material and energy flows between the elements. In the system description, boundaries around subsystems and the chosen system are visualised. The system description is often presented in graphic format to make the contents easier to understand. The system description can be done on different levels of detail. Systems thinking can improve effectiveness on how to manage problems in real-world applications.

4.2.4 User profile

User profile is a method to represent the abilities and limitations of the users (Janhager, 2005). It can describe relevant data of the users for the studied system with for example aspect to mental, physiological and demographic status. The use profile can also capture characteristics as experience and other work related abilities. The method captures the variation within the user population.

4.2.5 Persona

A persona can be created as a complement to a user profile (Bohgard et al, 2008). Persona is a method where an imaginary typical user is described. Its purpose is to make the user feel more personal and real in order to make it easier to understand the needs and preferences of the user.

4.2.6 Use case

Use Case is a method to get a generalised description of a use situation (Bligård, 2011). It describes the goal of the actor and the actions and interactions with the machine needed to reach the goal. The Use Case describes the actors, where the action is set, under what preconditions the action take place, how the actions take place, alternatives to reach the goal and actions that could hinder the actor to reach the goal.

4.2.7 PESTEL

PESTEL analysis is a framework that can help organisations assess the environment in their business, by focusing on some important aspects (Yeates & Cadle, 2010). The categories in the analysis is political (P), economic, (E), sociocultural (S), technological (T), legal (L) and environmental (E). The framework can be seen as a checklist that helps identify the factors that can be of importance for the organisation that is to be analysed.

4.2.8 SWOT

SWOT analysis is a method to summarise results from analysis of external and internal environments (Yeates & Cadle, 2010). The key strengths (S), weaknesses (W), opportunities (O) and threats (T) are summarised and often visualised as a 2X2 matrix. SWOT analysis is a help for performing overall audits of a business and its surroundings.

4.2.9 Redesigned system description

A system description of the redesigned system can be performed in the same way as in the system description performed in the need identification phase. The same method is used, but describes a new system instead of an existing one.

4.2.10 Requirements specifications

After identifying the customer needs, the development team can set target specifications (Ulrich & Eppinger, 2012). These specifications reflect the ambitions and hopes on the solutions, but are set before technology restrictions have been identified. As the development work proceeds these specifications needs to be updated and will become final specifications. Requirements specification summarises the requirements on different levels in the product development process. A requirement can be described by its ID, the requirement statement, reason, source and fulfilment. The requirement specification can be controlled with verifications.

4.3 Concept generation, selection & evaluation

The concept design phases were performed according to methods presented here.

4.3.1 Brainstorming

Brainstorming is a method to quantitatively elicit ideas of solutions to a given problem (Bohgard et al, 2008). In the method, the participants thinks freely about the problem and encourage each other to find new solutions by association and continuing on developing the thoughts brought forth by other participants. In brainstorming, no critique is given and all ideas are collected to be evaluated in a later stage. This is done in order to not hinder creativity. To have a creative and positive environment support creation of ideas. Brainstorming is internal and captures knowledge already existing in the team members (Ulrich & Eppinger, 2012). Brainstorming can be performed by individuals working by themselves or with a group of people working together.

4.3.2 Concept combination table

In order to analyse different combinations of sub solutions in a systematic and structured way, a concept combination table can be used (Ulrich & Eppinger, 2012). The columns in the matrix are arranged after the different sub problems identified in an earlier stage of the product development process. Under each sub problems the sub solutions solving the related problem are presented. When finding overall solutions and concepts these sub solutions are combined and lines drawn combining sub solutions from different columns with each other. This method aims at creating concepts to compare, combine and evaluate. It is a part of the iterative concept generation and concept selection phases in the product development process.

4.3.3 Pugh concept selection

Concept screening matrixes, also called Pugh Concept Selection is a method for narrowing concepts down quickly and evaluate which concepts can be combined (Ulrich & Eppinger, 2012). The Pugh matrix contribute to decide which one of the concepts that fulfils the requirement specification in the best way, assumed that all solutions fulfil the demands. In the method the different concepts developed are compared to a reference concept. The concepts are compared on the basis of several selection criteria. The selection criteria are based on the customer needs found earlier in the product development process. The concepts are rated as better than (+), same as (0) or worse than (-). These rates are summarised and combined in a way that can remove bad features in good concepts. Issues that require further investigation can be identified in the process and the results and processes are reflected on and discussed to make sure they are reflective and valid.

4.3.4 CONCEPT EVALUATION

Interviews can be conducted with mediating objects that triggers discussion and thoughts by the user. When presenting early concepts to the user in a visual way, the user can evaluate and give feedback for coming design iterations. Positive and negative aspects with different types of concepts can be elicited through asking the user directly. This is performed in order to understand if the concepts actually fulfil the user demands and needs.

4.3.5 HEURISTIC EVALUATION TO THEORY

Heuristic evaluation uses lists with principles and guidelines for evaluation (Nielsen & Mack, 1994). The method is analytical and performed through evaluation by persons with knowledge in cognitive ergonomics and interface design, and not the actual users. The criteria in the evaluation are called heuristics. The first step is to develop design principles relevant for the system. A list of heuristics can be developed from theory in a specific area. The heuristics can be based both on principles for cognitive and physical ergonomics. During the evaluation, deviations from the guidelines are documented and the severity of the problems caused by this estimated.

5. IMPLEMENTATION

The implementation describes the processes performed during the project timeframe. The project steps are presented in figure 6. The outcomes from each step are described on the right side in the funnel and more detailed explanations of the work are presented under the different headings in this chapter.

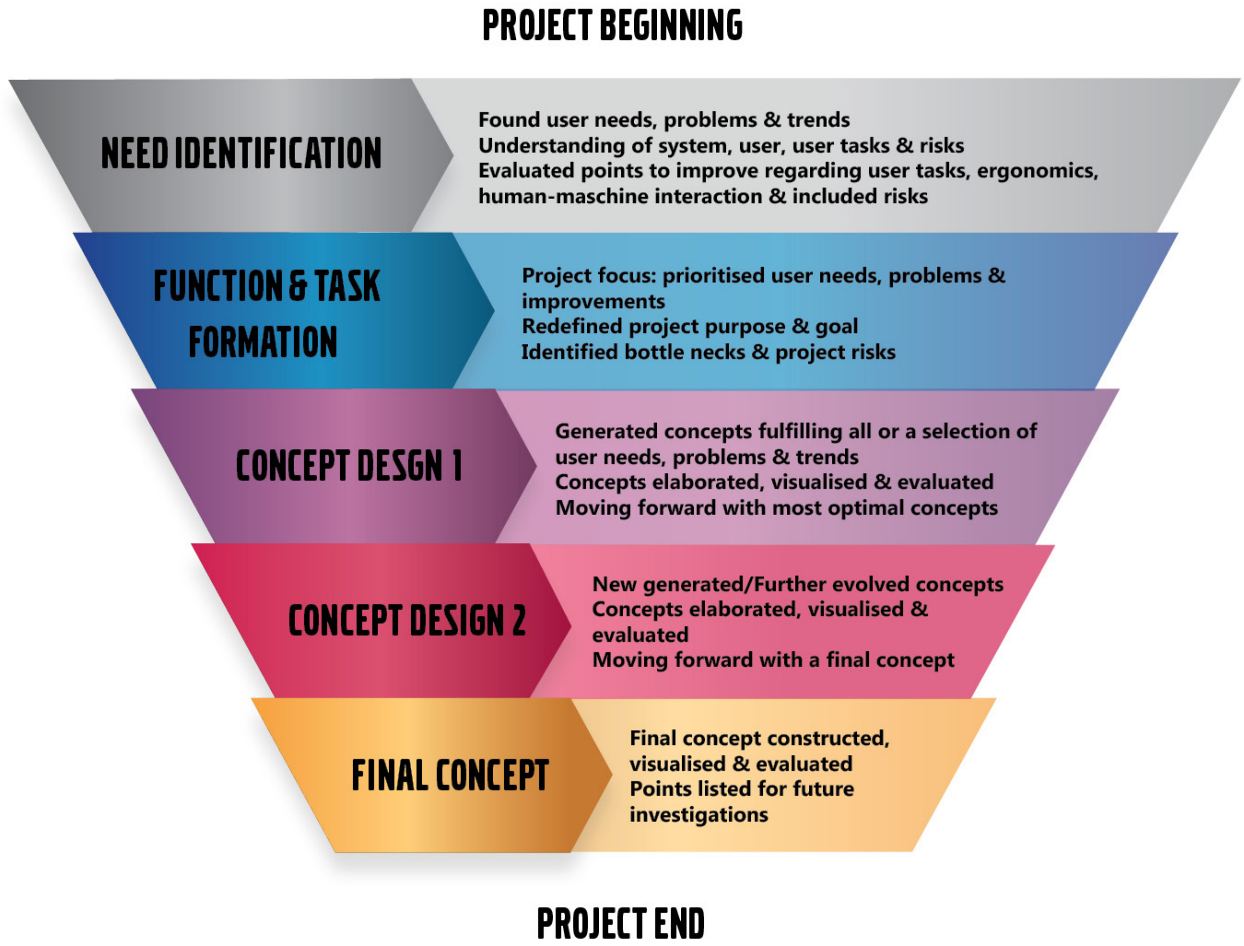


Figure 6: The project process described through the project steps and the outcome each conclude.

The main frame for the process was inspired from the generalised development process (Bligård, 2011). The generalised development process is divided in different phases where the needs are first identified and from that the product is developed in iterations where the product gets more and more ready for the market, the longer into the process it comes. The first two phases of the generalised development process were performed with a lot of conformity to the described process. Since the new concepts where not narrowly specified, these frameworks suited the project well to start off with and find the right way to proceed. After understanding the bigger picture, the generalised development process was changed a bit to accommodate the specific needs in the project. The project is not conducted throughout all phases in the generalised development process, and will not cover the phases where the product comes close to market introduction. Therefore, the earlier phase, with overall design was performed in two iterations with evaluations instead. This procedure could increase the credibility and usefulness of the findings in the earlier development phases. These findings and results could be the base for further work, to get the ideas and concepts implemented in actual products introduced on the market.

5.1 Need Identification

The need identification was performed in order to understand the users and the system of today. It focused mainly on collecting information through user studies. Then additional literature studies were conducted to get information about the problems and use areas found.

5.1.1 User Study

A user study was conducted by contacting local bus companies that employ drivers. The bus companies contacted are both in public or commercial businesses and have their drivers driving in city traffic, in between cities (inter-city driving) and/or tourist driving situations. Several organisations employing bus drivers were contacted and asked to join the study. Access to bus drivers and secondary users were given at seven different companies and times for interviews and observations were booked and performed.

The companies contacted provided relevant user subjects to interview and observe, all summed up in table 2. In order to provide as much input as possible from the interviews, the methods used to conduct them varied. A few interviews were conducted with two or more interviewees, which enabled an easy fluid conversation, while other interviews and observations were conducted with individual interviewees where the planned questions ruled the interview. The interviews lasted for 30 minutes to 2 hours and observations lasted for about 1½ hours each. The interviews were in between structured and semi structured, with several predefined open ended questions in different areas and time enough to deviate from plan if a new interesting area was discussed. The data gathered mainly contained information about users, tasks, the surrounding environment and used technology.

Table 2: The interviewees grouped by factions in order to understand the width of gained knowledge.

	User involved	Nr of Persons interviewed
Bus drivers	City bus drivers	8
	Intercity bus drivers	6
	Tourist bus drivers	2
	Total Bus Drivers Interviewed:	**16**
	Total Bus Driver Observations:	**5**
Experts	Technical manager (central organisation large bus company)	1
	Union Chairman large bus company	1
	Experienced ergonomics/HMI engineer Volvo	1
	Total Expert Interviews:	**3**
Study Visit	Traffic managers city traffic	2
	Technical Service city traffic	2
	Interviews Study Visit City:	**4**

Additionally, the busses at the companies were visited, used as mediating tools and the work environment discussed together with the bus drivers. This informal complement to the study brought forth a lot of important information that were captured with photos, voice recordings and notes.

The user study did not aim to go into detailed level of the instrument cluster, but rather kept an overview of the driver experience as a whole and the driver place and situation in its totality. The overview was kept in order to see the bigger picture of the system, enabling deeper understanding of the driver situation and to get a better solution to stated problems.

The user study was guided by planned interview questions, but the interviews were kept at a semi-structured level, where the started discussion was prioritised over planned questions. The interviews concerned the driver profession, the driver tasks included in work, experienced problems and future available possibilities for integration and use in the bus. Inspiration and structure for questions were taken from the ACTA method (Klein, 1997). The questions involved asking about the tasks performed during a workday and other questions for overview. Then the questions finally got more closely related to the instrument cluster. The questions asked and the structure of the interviews are presented in Appendix 2. The interviews put forth a lot of information and were recorded and transcribed to remember all important findings and descriptions. By using these transcriptions of real conversations a lot of detailed information could be used and analysed.

The data collected was summarised and then analysed and grouped through the KJ Analysis. The conclusions drawn are stated in Appendix 10. However, only some groups of conclusions will be of importance in this project and is further described as results in the need identification.

5.1.2 Market Analysis for Trends

By analysing the data collected from the user study as well as reading relevant literature and performing internet searches, trends in the market and available future improvements for the industry were identified. The data concluding the trends and future improvements were collected from all types of vehicle industries, not only the bus industry, in order to conclude where the vehicle industry is heading in general and what sorts of future improvements can be integrated and used in a bus. For an easy overview of the market trends found, the trends were divided according to the method PESTEL: political, economic, social, technological, environmental and legal trends.

5.1.3 Concluding Visualisations and Descriptions

To capture the overall picture and information about the system and users, visualisations were created through discussing and studying the summarised data in the KJ Analysis. These visualisations were made from a holistic approach and created from the qualitative descriptions of the users. Results from this process are the system description, user description and use cases presented in the need identification (Chapter 6). Values and dimensions of parameters are estimated and are not based on facts. Although, when creating the pictures, effort was made to make the reader understand the main features and aspects found.

5.1.4 Concluding Driver Needs

Conclusions and prioritization of problems were based on the data collected. Through discussion and iterations with graphic material a representative picture of the needs and demands on the instrument cluster could be identified. Through colour coding the HTA the severity of different problems could be identified.

5.2 Function and Task Formation

During the Function and Task Formation phase the specification of the system was developed. Through discussions and studying of the data collected in the need identification (Chapter 6), the new system slowly evolved. Some aspects could be described directly from the users' ideas and other had to be developed through redesigning the use cases and visualising new system descriptions. The process of defining the system was iterative and a lot of sketches and ideas were evolved in several steps, which become the results in the function and task formation (Chapter 7) The aim in the function and task formation phase was to state the changes in the total system that should be made in order to optimise information perception and technical problem handling. Concepts developed in the next phase were to be based upon these system changes.

5.3 CONCEPT DESIGN 1

The first concept design phased aimed at identifying different ways in which the instrument cluster and the system around could be designed to suit the needs identified and system formation described earlier. In the first design phase, the different functions and parts of the system was grouped according to how the new system works in the results from Function and Task Formation. In addition to the grouping of functions, sub concepts were generated and organised to answer the questions stated in the introduction (Chapter 1). The concept generation and selection process was an iterative process visualised in the process funnel, see figure 7.

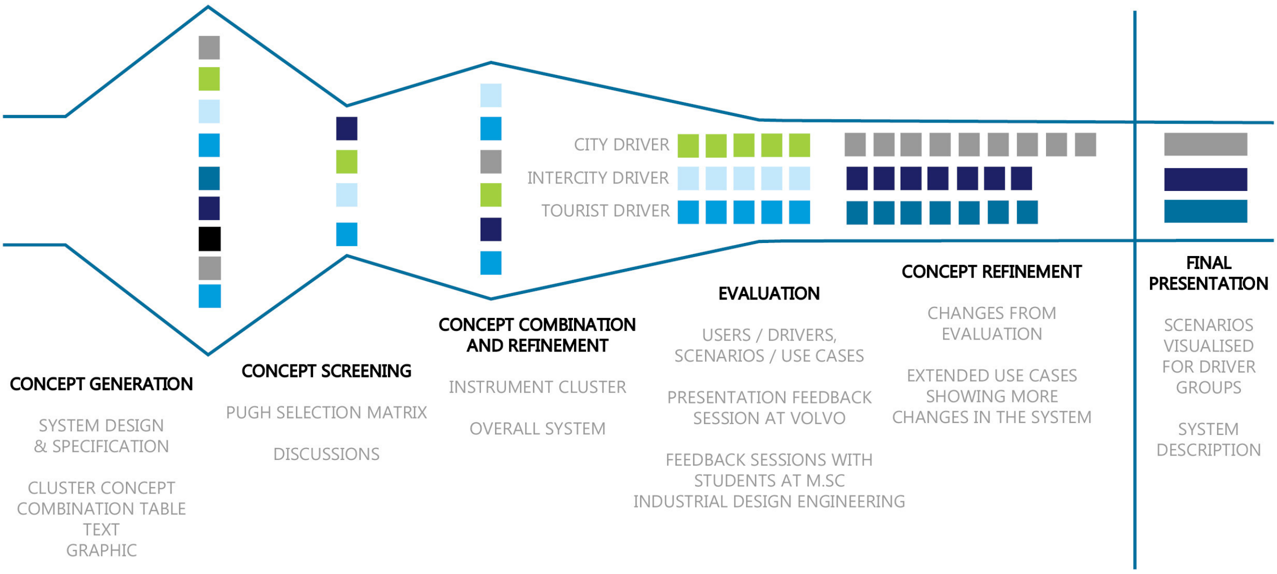


Figure 7: The concept generation process with each step visualised.

5.3.1 CONCEPT GENERATION PROCESS

The concept generation started with brainstorming sessions to come up with the possible ways of designing the solution with aspect to different areas. The second step included combining the functions and areas from the concept combination table/morphological matrix and then narrowing them down through screening and scoring. Concepts were changed and combined throughout the process and finally, three different concepts, with different difficulty and time needed to implement was chosen to represent the design of the instrument cluster. Although these clusters include symbols and details, the concept is focused on showing the overall way of presenting information, and the symbols are not in themselves evaluated and redesigned.

5.3.2 CONCEPT EVALUATION

In order to get feedback on the functions and structure of the proposed concepts evaluation tests were performed. The implementation of the different ways of evaluation is described in more detailed in the coming paragraphs.

Communication of concepts

One of the steps in the concept testing phase is to choose and produce material to communicate the concepts (Ulrich & Eppinger, 2012). This can be done in different ways and a combination of verbal description, sketches and storyboards were used more thoroughly described below.

The pictures of the concept were printed in booklets where one page at the time was presented to the driver. At the same time scripts of a scenario from the use cases were told to the user and the user were encouraged to comment on the concept. The scenarios and settings differed between different driver types even in the same use case. Since the different driver types are exposed of different situations, the concepts were visualised for different use cases depending on driver type, see Table 3.

Table 3: The use cases that were shown for the respective driver types' concepts.

Use Case | Driver type	City	Inter-City/Shuttle	Tourist
1. Start-up	■	■	■
2. Depot to start without passengers	■	■	■
3. City traffic driving	■	■	
4. Country road driving		■	■
5. Exchanging drivers in the city	■		
6. Errors & warning handling	■	■	■

Feedback session with bus drivers

The first step in the concept testing is to define the purpose of the concept test (Ulrich & Eppinger, 2012). Different types of bus drivers got to evaluate different concepts connected to the different use cases presented in the Function and Task Formation Chapter. Questions that were used to get the needed feedback were:

- Is the information grouped in a way that makes sense?
- Is the information visualised in a good way?
- Is the size and format of the information suitable?
- Is the information prioritised in a good way?
- Is personal customisation preferable, or is it enough for the organisation to choose most settings instead of each driver adapting it?

Feedback session with usability scholars

Students at the master program of Industrial Design Engineering at Chalmers University of Technology got to comment on the different concepts through looking at a big poster board with the concepts presented. This informal and unstructured way of collecting information was valuable to get feedback from persons with a lot of knowledge in the area of Usability, Cognitive Ergonomics and Human Machine Interaction.

Feedback session with technical experts at Volvo Bus Corporation

An evaluation presentation and meeting was conducted with 5 people working with the drivers place at Volvo Bus Corporation, to get feedback on feasibility and to reduce risk of misinterpretations and false assumptions causing the concepts to be dysfunctional in some way.

The process and results from concept design 1 was presented in a 30 minutes presentation with pictures, visualisations and description of the systems. After and during the presentation the expertise employees at Volvo Bus Corporation were encouraged to ask questions and comment on the ideas. The total session lasted for about 1½ hour and gave important input presented in the evaluations in concept design 1 (Chapter 8).

5.4 Concept design 2

During the second design phase, further development of concepts were performed with consideration to heuristics and requirement specification presented in the theory and the function and task formation. The check-ups and fulfilment of these were presented in a table and made iteratively to improve the concepts until they reached acceptable levels.

Throughout the second concept design phase graphic visualizations were generated, updated and discussed. The process was iterative and finally resolved in the results presented in the concept design 2 (Chapter 9).

5.5 Final concept

When the final concepts were specified in the second concept design phase, additional material for presenting and visualising the concepts was needed. In order to hold oral presentations more detailed picture slides were created. Texts and flow schemes that describe the system in more detailed were also created and can be found in the final concept (Chapter 10).

6. NEED IDENTIFICATION

The results from the need identification phase are presented in this chapter. The results present knowledge about the user, the system and its environment. Problems identified are presented in different ways to give understanding about the user.

6.1 AREAS OF INTEREST FOUND THROUGH DATA ANALYSIS

From the drivers interviewed and observed through the user study a lot of information was received. Since the data collection was made to consider the whole system, the questions and the discussions was made broad and therefore generated a lot of different knowledge about several different areas that is of concern to a bus driver. The areas which were found to be of most interest to the project mainly evolved driving, but also futuristic ideas as well as knowledge and information about the users and the system as a whole, see figure 8.

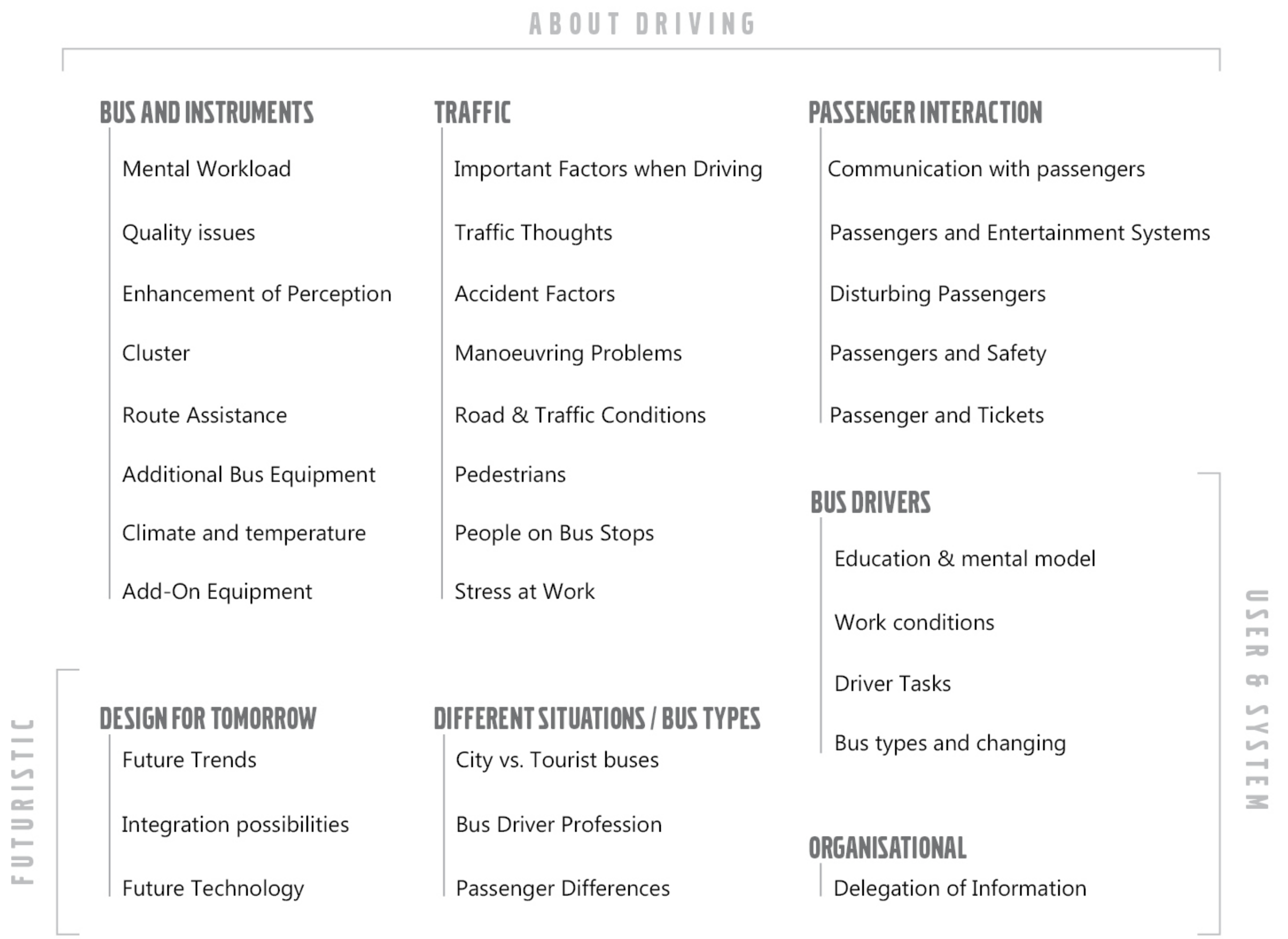


Figure 8. The areas found through the user study that was considered most of interest for the project.

All information was taken into consideration when analysing the data and conclusions drawn from it will be viewed as result involving system and user knowledge, but also the needs and problem areas to explore and develop solutions for. All results will be explained in summarisations in this chapter. For further knowledge of the data collected, see Appendix 10 where all adata is summarised and grouped.

6.2 SYSTEM AND USER DESCRIPTIONS

The overall picture of the system and bus driver is described by differentiating and grouping the user types and factors influencing the system.

6.2.1 USER TYPES

A product and system may have many different types of users (Janhager, 2005). The types of users are chategorised as primary-, secondary-, side- or co-user, see table 4. From a bus perspective the primary users are the drivers and passengers which are the persons using the product according to the main purpose of the product. Secondary users also use the product in some way, not according to main purpose. In the case of the bus these can be the mechanics at the technical support and the cleaners of the bus. The side users are affected by the product without actually using it, such as people nearby the bus. Co-users of the bus are users co-operating with the primary and secondary users without actually using the product. In the case of the bus these co-users are the traffic leaders, the pedestrians, bicyclists, tram/train drivers and car drivers in the surrounding traffic.

Table 4: The users in the bus system and their requirements.

User type	User	Requirement areas of interest concerning instrument cluster
Primary user	Driver	Easy perception of road
		Easy control of entertainment
		Easy and fast handling of technical errors
	Passenger	Safe transportation
		Enable ticket handling
		Comfortable temperature
		Comfortable driving pattern
Secondary user	Mechanics/ Technical support	Easy access to information needed for reparation
		Correct information received
	Cleaners	Enable easy cleaning
Side user	People nearby, not in traffic	Help driver minimise pollutants
		Help driver minimise noise
Co-user	Traffic leader	Correct information received and easy communication with driver
		Easy possibility to redirect driver
	Pedestrian	Avoid accident with bus
	Bicyclist	Avoid accident with bus
	Tram/Train driver	Avoid accident with bus
	Car driver	Avoid accident with bus

6.2.2 DRIVER TYPES

From the data collection it was concluded there were different kind of drivers which are exposed of different traffic situations and therefore have different needs. The analysis concluded mainly three types of drivers: city traffic drivers, intercity drivers and tourist drivers. The main aspect distinguishing them from one another are the traffic situations they are mainly exposed of, hence the type name. In order to solve the situation for all of the driver types, the three types were plotted against a set of parameters and thereby visualising the differences in driver type, see figure 9. Keep in mind though that these visualisations are rough conclusions from the user study and might not be accurate for all type of users all over the world.

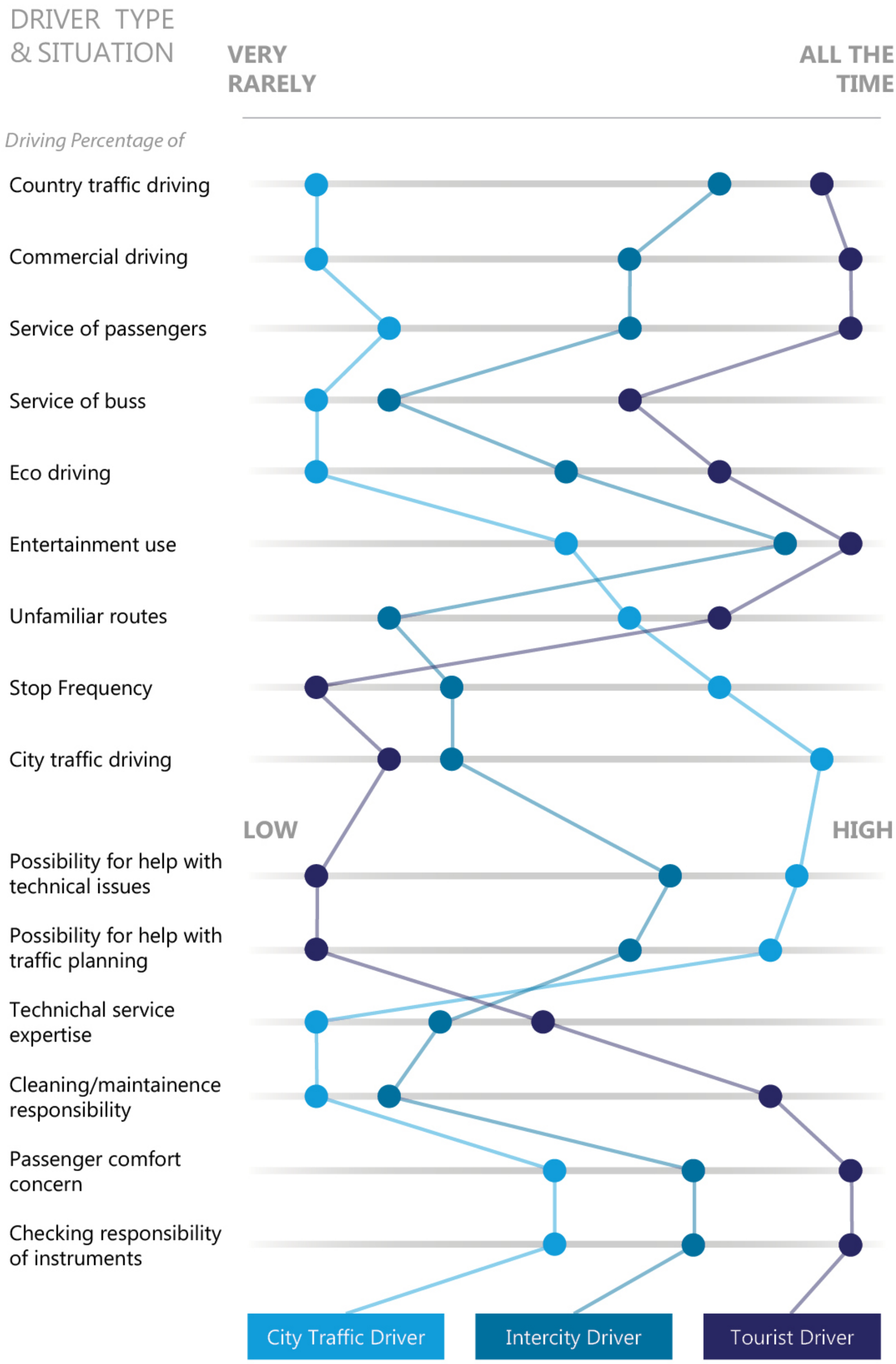


Figure 9: The kind of situations and responsibilities the three types of drivers are distinguished by.

The user study gave information about differences in work for different type of drivers. Figure 10 aims to capture these found differences in the drivers' day and work. One aspect very important to have in mind when designing the instrument cluster is the frequency of stops to load and offload passengers. The need for different functions in the instrument cluster can differ depending on what type of traffic the driver is exposed to.

The degree of responsibility for the bus and technical problems also varies a lot and tourist bus drivers have to manage technical problems themselves to a larger degree.

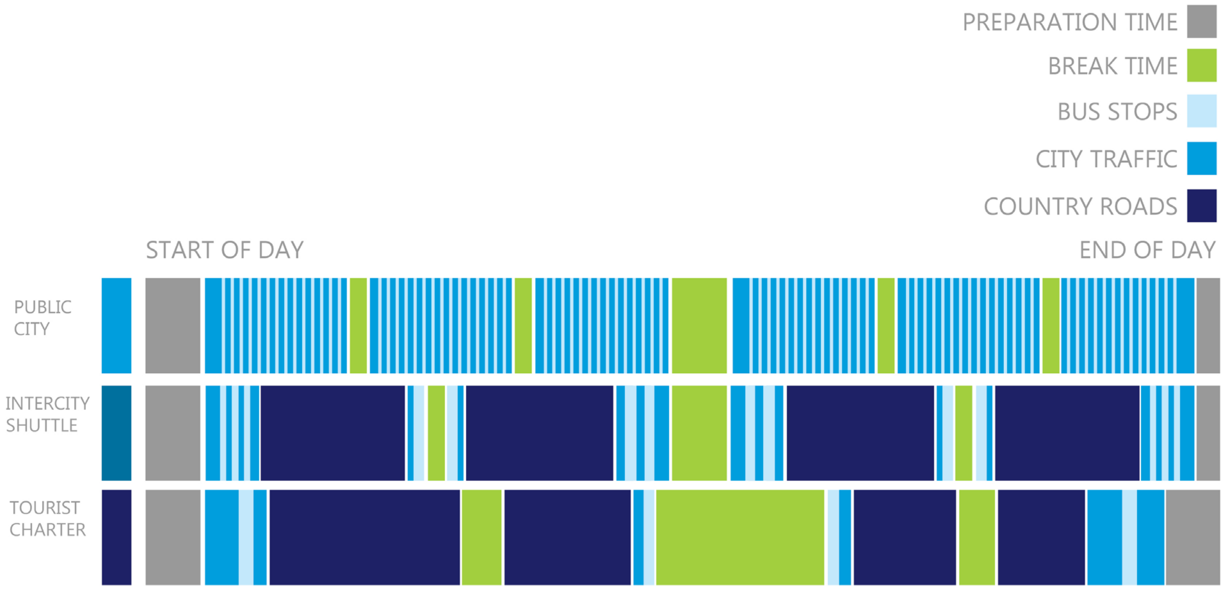


Figure 10: The differences in situations the drivers are exposed of during a work day.

The bus drivers do not only drive the bus, depending on the organisation, they have different responsibilities to check and prepare the bus. At the start of the day all bus drivers need to perform check-ups to see that all systems are working. The tasks included in this can be found in the HTA, appendix xx. Furthermore, the tourist bus drivers are often more responsible for checking the state of the bus in the end of the day. Often they are not ending the day in the garage, and the condition and amount of support available for them can vary a lot.

6.2.3 SYSTEM DESCRIPTION

In order to understand the relationship between different users, parts of the bus, drivers place, instrument cluster and the environment, knowledge of the system in its totality was researched. A visualisation of the current system can be seen in figure 11. When designing the instrument cluster it is important to consider all the other functions the bus drivers interacts with. The instrument cluster is merely a small contribution to the information the driver perceives and process when driving. Depending on type of bus the driver has to cope with different ticket systems which can have varied number of screens and control panels. An important area of interest when mapping the system was the way in which the driver, traffic leaders and technical service personnel is communicating. The system is not currently working in the most effective way and might need re-design in the new concept solutions. Factors in environment and other parameters influencing the driver are further described as performance shape factors.

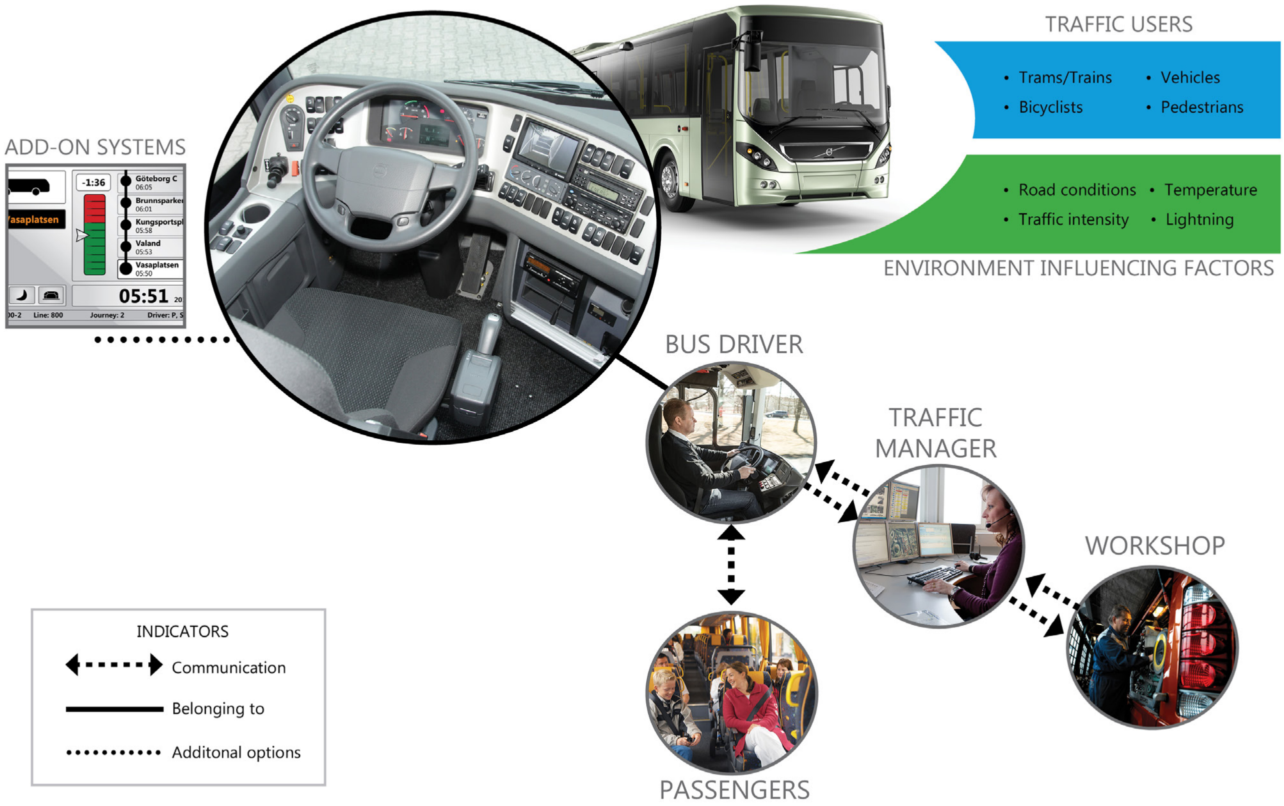


Figure 11: The system model explained with the bus and its driver at its center and the help functions he comes in contact with as well as factors influencing his daily work. Images adapted from: http://images.volvobuses.com/#1402496694089_0.

The traffic manager work as a communicator between the workshop and the bus driver. They also manages the bus driver schedule and keep track of the traffic through traffic cameras. When an error occur in the bus or a symbol lits that the driver is unsure of, it is the traffic manager the driver call for assistance. Errors that are told to the traffic manager is registered and sent to the workshop for knowledge. Since the workshop does not have direct contact with the drivers and communicates technical problems with them, the information has a tendency to be misinterpreted along the way to the registration.

6.2.4 PERFORMANCE SHAPING FACTORS

Mental workload for the bus drivers at work seems to be very varied depending on situation. During the user study the drivers explained that they feel quite satisfied with the workload as long as the bus is functioning well and the traffic situation is normal. Instead, it seems to be some factors making the work task more difficult. Some of the most important physical performance shape factors that seem to be related to the perceived workload are:

TEMPERATURE

Some drivers think it is important to not get too hot, and others do not like to be cold and think that their hands get cold easily.

ILLUMINATION

The outside light level is affecting how well they can perceive information on the instrument cluster and how easy it is to see through the windscreen. Blinding effects from reflections in the windscreen or too bright lamps in the instrument cluster increase mental workload.

Noise

A lot of noise from engine, road and whistling of the wind enters the driver's place and increase mental workload. The drivers explain that noise can make you feel a bit dizzy and non-alert after a while. This is especially a problem when the engine is placed in the front of the bus.

Vibration

Vibrations affect the drivers in several ways. They find it harder to focus when looking at something while driving on bumpy roads. The vibrations decrease visual perception. Vibrations are also affecting the body in several ways. A lot of drivers have back or neck pain and can also feel that the hands get numb when driving on uneven roads. Unfortunately a lot of road seems to be very bumpy and are causing a lot of vibrations.

Workspace roominess and comfort

When turning around in the workers place the drivers feel restricted by the seat belt and by the cramped and small space they are confined in. Not all drivers can set the driver's seat and steering wheel in a way they prefer, since adjustments only can be made to a certain degree.

Time of day

They work hours for bus drivers can vary a lot and some of them can affect their schedule and ask for work hours they prefer. But still a lot of drivers have to work early mornings and nights, which they might not prefer.

Time on duty

The work time on a day varies depending on type of employment and how the bus organisation has planned routes.

6.2.5 Personas

Four different personas were made in order to describe the span of different driver types and problems they face in a better way. From the personas, different driver needs were identified and summarised.

Persona 1: Andreas, the city newcomer

Andreas is a 27 year old bus driver that has just finished his vocational education and got his bus drivers licence. He has good physical health, good eye sight and does not get tired often when driving long days.

Problems when driving

- Some weeks ago he finished his 14 days introductions at his employer where he drove some of the trickiest routes together with an experienced driver at the company. Although Andreas is still unfamiliar with a lot of the routes on his schedule. The bus stops are just written down on a piece of paper and there is really no guidance for him to know the way. He thinks it is stressful.
- Also he has problems when changing bus at the bigger bus stops. Then he forgets to look at what spot in the bus stop he should offload and change with the other driver, because often it is not the same place.
- He feels a bit insecure and often has the feeling that he might be missing something important and doing the wrong thing. He really wants to drive the bus correctly and is very attentive not to miss pedestrians crossing the street without warning. He thinks there are so many things to know

and see in city traffic. There are pedestrians, cars, busses, trams, bikes and on top of all he has to make sure he follows the time schedule and gets people in and out of the buss in a good way.

- He does not know how to change the different settings in the bus and instrument cluster and feels that light and temperature is not correctly adapted. He tried to set it once but did not have time to go through all the menus to find his favourite settings.
- When Andreas gets different error and warning messages he does not know the severity of the problem and then he calls the traffic leaders. Sometimes he finds it hard to explain the error to them and it takes a long time before they understand what he means.

PERSONA 2: CARINA, THE EXPERIENCED CITY DRIVER

Carina is a 53 year old bus driver in Stockholm with a lot of driving experience, both in city traffic and tourist bus charter. Her health is not as good as she would like and she experience back and neck pain when driving. The years of bus driving have impaired her hearing and she really dislikes the noises appearing when driving and therefore turn up the radio to block it out. Carina drives with confidence, she has been driving for more than 35 years now and is very familiar with different traffic environment and can cope with high stress in a good way. She knows all the possible routes and knows the city very well.

Problems when driving

- Back and neck pain makes her feel tired when driving and especially when driving the route from the last bus stop to the garage without passengers she feels very exhausted and airheaded.
- She has a laid back way of driving and sometimes loses focus. She accidently hit a traffic sign last week when she was turning around a bit uncarefully. Another time she just forgot which route she was driving and turned in the wrong direction. The passengers were so mad because they got late and Carina thought it was a bit embarrassing.
- When Carina is driving at night time or in the evening she is sometimes worried and afraid of people about to enter the bus. Some people use alcohol and drug in a way that make them threatening and sometimes she needs to be able to close the doors and hinder them from entering. The automatic sensors of the doors do not work then and she uses manual mode. With the manual mode she has to bend forward and stretch when pushing the buttons which is not ergonomically friendly.

PERSONA 3: MAJA, THE INTERCITY/SHUTTLE DRIVER

Maja is a 35 year old bus driver in Gothenburg, driving the airport shuttle bus. She has to be very service minded at work and help the passengers buy and check in tickets and answer their questions. She thinks her workday is really busy and there are always a lot of things going on with the traffic, passengers, tickets, and all the equipment and screens in the bus. She thinks it is easy to find her way because it is the same route every time, so the navigation requires no extra thought.

Problems when driving

- Sometimes Maja cannot take breaks in between driving because of tight schedule and delays on the route. Then she does not have time to eat or go to the bathroom if needed.
- The passengers have a lot of questions and sometimes try to stress Maja to drive faster so they do not miss their flight.
- Maja has up to 7 different screens and equipment she has to check and log in to. She manually has to set and change routes and sometimes equipment is out of function and she gets no error messages on the instrument cluster, since the systems are not connected.

PERSONA 4: GÖRAN, THE EXPERIENCED CHARTER DRIVER

Göran is 47 year old bus driver from Helsingborg, owning a small charter bus organisation that arranges tours for companies and tourists. He drives from Sweden to places around Europe and has to be careful to follow the rules about driving times that are recorded in his driver card. Göran has pretty good health, but starts to feel some back pain after long working days.

Problems when driving

- Days when Göran has to drive long distances with the sun in his eyes and a hot drivers place, he gets really tired.
- Göran is an experienced driver and only gets stressed in traffic situations where he cannot do anything about the situation, for example in road blocks.
- He is really concerned about his passengers and their comfort. He gets stressed sometimes because he knows the passengers hates to be late and at the same time he has to comply with the rules of driving hours. He wants to keep his passengers calm and does not want them to see warning signals and ask him what is wrong.

TOP NEEDS OF THE PERSONAS

The conclusions drawn from the personas are in terms of the personas' top needs, identified from the problems they faced on a daily basis. These needs summarises some of the needs the different drivers have, see table 5.

Table 5: The top needs identified for the four personas.

PERSONA 1: ANDREAS, THE CITY NEWCOMER	PERSONA 2: CARINA, THE EXPERIENCED CITY DRIVER	PERSONA 3: MAJA, THE INTERCITY/SHUTTLE DRIVER	PERSONA 4: GÖRAN, THE EXPERIENCED CHARTER DRIVER
Increase feeling of control when driving	Help keep driver alert in situations with low mental workload	Faster login and decreased tasks needed for manual changes and settings	Technical support and Problem solving
Enhance perception and make traffic easier to overlook	Increase situational awareness to reduce risk of lapses	Enable passengers to be more self-serviced and have access to information	Avoid road blocks
Lower mental workload in intense situations	Enable possibility to drive in more ergonomically friendly way		Keeping alert during long drives
Enable guidance to know route			Support for managing driving times on time recorder
Enable fast customisation when starting up the bus			
Clear information in good time if he has to stop by a bus stop.			
Effective and efficient communication in order to get help with technical issues			

6.3 Market Trends and Available Improvements

An adapted PESTEL analysis shows different trends that affect the development and design of the instrument cluster and information system for bus driving. These trends are presented in the different areas; Political, Economic, Social, Technological, Environmental and Legal.

6.3.1 Political Trends

In different parts of the world governments are announcing ambitious traffic safety goals (Bishop, 2005). Since over one million people all over the world are killed in traffic accidents each year traffic safety has been increasingly prioritised by many governments. In the industrialised nations there has been an increased focus on preventing actions through intelligent vehicles. One example is that USA aims to have Intersection Collision Avoidance Systems supported in 50 % of the vehicle fleet in by 2015. The European RSAP explains the overall European strategy for road safety and one important part of this is active safety (eSafety) and this can be promoted through regulation and fiscal incentives for purchasers of the active safety systems. In Japan, the ITS program run by the National Institute of for Land and Infrastructure Management works with a navigation system that combine digital road maps that both guide the user and provide information in real-time about congestions ahead, road surface conditions, road work and restrictions ahead. Already in 2002 54 % of the passenger cars sold there were equipped with this navigation system.

Example of the active safety systems visioned are:

- Collision warning
- Mitigation
- Active braking
- Lane-keeping
- Vulnerable road detection
- Driver condition monitoring
- Improved vision
- Automatic emergency calls
- Adaptive speed limitation
- Traffic management
- Parking aids

Some of the systems require communication between vehicles and the infrastructure. To decrease fuel consumption and emission levels from vehicles is also another area getting higher political focus. These trends in prioritizing traffic safety and reduced environmental impact puts pressure on the manufacturers of vehicles to produce products satisfying future legal requirements.

6.3.2 Economic Trends

The bus organisations aim to become more profitable through lean and efficient organisation, delegation of tasks and management of the bus fleet. To keep up with the demands in the agreed contracts with public transport, the busses cannot be late by technical problems. When not providing transportation as agreed the bus driving companies face severe fines or reduced payment from the customers. Therefore it is essential to reduce risk of technical problems and provide means to solve problems in a fast and efficient way. The instrument cluster can affect the way the driver understand and reacts on problems and is therefore important to change from these aspects.

The bus driver profession is not limited to the old-fashioned ownership anymore, the driver responsibilities is rather being divided into different professions, where the driver more and more only have to take care of the driving and passenger service. Cleaning and service of the bus is already out of the driver's responsibilities and the future might hold more industrialisation of the driver profession. The driver tasks will change depending on what is the most economical task delegation for the bus companies (see the data collection summary in Appendix 10).

6.3.3 SOCIAL TRENDS

The intensity of traffic situations is rapidly increasing due to urbanisation. There are more obstacles to consider and additional vehicles on the road with different basic conditions (Appendix 10). Bus drivers also find that the behaviour of pedestrians have changed through the latest decades. When freestyles, and then later mp3 and mobile phones with music were introduced they noticed how the pedestrians got unaware of the traffic. The drivers experience how they have to take over increasingly more responsibility in traffic and how pedestrians and bicyclists behave risky and expect the professional bus driver to save the situation and react in order to avoid accidents. The bus drivers can trust less on the co-users of the system to take their responsibilities and have to compensate for that by being more attentive.

Bus driving is a type of work where the novice driver is getting high responsibility and is expected to perform as good as an experienced user. Routes are given out with no consideration towards different drivers and their experience and there is no room for driving in the wrong way, or getting late. At least in public traffic, the company get fines if a route is not driven as defined. The bus companies find it valuable to be sure that a new driver can perform the route correctly through assistance in different ways (Appendix 10).

This driver trend makes assistance functions interesting. It is important that these functions support the beginners or drivers that feel insecure in a new situation, but at the same time does not disturb or decrease situational awareness of the experienced drivers that need to stay alert.

6.3.4 TECHNOLOGICAL TRENDS

By analysing the different brands and news in the vehicle industry of today, a few technology trends were concluded. The data was collected from varying references and conclusions were drawn from the totality of the data, which is why no specific references toward the findings are given in most cases. Some of the technology trends found might become standard in the near future and therefore need consideration in the new instrument cluster.

PASSENGER SERVICE MINIMISING

With new technology easing self-service through smartphones and pay cards, the passenger service responsibilities will minimise and might not concern some drivers at all. Where drivers before had the responsibility to check and sell tickets to passengers, the driver task will minimise or might even be taken away and replaced by self-service systems.

NEW ASSISTANCE FEATURES

In a world where innovation and new technology breakthroughs is increasing, solutions to problems never solved before can be made available and assist drivers in difficult situations. Technological assistance features institute new integration possibilities in the instrument panel and needs considerations. Especially in the car industry, where technology features is consistently being developed, there exist today assistance solutions that solves problems bus drivers state limit and hinders their work (Appendix 10).

- Passenger Spotting Enhancement/Night Vision Camera

With a screen showing a night vision camera, passengers waiting at bus stops would be clearly visible for bus drivers (Daimler, 2014). That could solve the problem with drivers missing to stop and add to the bus company credibility.

- Back sensors

Sensors in the back of the vehicle warn if the vehicle comes too close to an obstacle when backing or parking etc.

- Front sensors

Sensors in front help the driver to not hit upcoming obstacles by warning or even use an automatic alarm brake to stop the vehicle from causing accidents.

AUTOMATION

A trend in the industry is that responsibilities and tasks usually included in the bus driver work is being taken away or eased by automation. Though automation is integrated in order to minimise driver concern, it might turn out the other way around since drivers lose the control of functions they normally are in control of. When the automatic functions stops working or gets too worn to work, the bus will not be able to be driven due to safety reasons and the driver cannot fulfil his work responsibilities in the timetable given to him, see Appendix 10. Automation must therefore be handled with consideration.

INSTRUMENT CLUSTER GOING DIGITAL

The biggest trend in the making of instrument cluster is the digitalisation of them. The brands in the car industry have already started to use screens based on only or partly digital technology for displaying instruments in their cluster.

ADDITIONAL ASSISTANCE THROUGH DIGITAL SCREENS

In addition to the newly-built digital instrument clusters, many vehicles in the industry have started to incorporate digital screens for additional assistance or easy settings of the functions and entertainment of the vehicle. The car industry is in the top of this trend and has developed different assistance screens depending on the car brand.

The screens replace the traditional buttons and menus for vehicle settings and can be used to implement maps, GPS, entertainment in form of music etc.

VEHICLE VISUALISATION

Most of the digital instrument clusters found has a representation of the vehicle it used in on the screen. The visualisation of the vehicle could be used to give further knowledge to the driver of what vehicle he is driving. On the visualisation of the vehicle, needed functions could be visualised where they are situated to give further understanding of the vechicle system, see next section.

INFORMATION GROUPED IN RELATION TO VEHICLE PLACEMENT

The information symbols representing warnings for functions are in some instrument clusters in today's vehicles with digital instrument clusters grouped and visually presented in the place on the car where that information is considered to belong. The symbols are in some cases also connected to each other to show the relationship the warnings symbolises have to each other and might also indicate the resulting consequences the warning might lead to, if ignored.

For example, on the visualised vehicle in the instrument clusters, the symbols representing the engine and the battery were often placed together on the places in the vehicle they are situated with a visualised line showing the connection between them.

This is a positive trend as it gives the driver more information only by the visualisation. If the driver have trouble remembering what the warning symbolises, the placement of the symbol in relation to the picture of the vehicle might give the driver a hint and can lead to deeper understanding of what might actually happen if the symbol is ignored.

Geographical or direction visualisation

Through the analysis of the vehicle industry a trend towards geographical visualisation has also been concluded. An external GPS is not needed in the newest vehicles of the industry since it is already integrated in the vehicle's information visualisation (that is, if it is bought with the vehicle). The difference in visualisation is great, some vehicles show a big view of the whole geographical area while others only visualise the needed information at that point, which is what the next action is in order to get to the destination (visualised by direction arrows and text).

Taking advantage of wheel

Vehicles like formula 1 cars and yachts use the space on the wheel to have buttons and screens for easy use and interaction. Using the space which are nearest the drivers and easiest to access is a valid point to consider even in buses.

Automated highway systems

There is research going on about Intelligent Transportation Systems (ITS), which is an area focusing on improving efficiency of current transportation systems (Lee & Hsu, 2006). One part of this area is Automated Highway Systems (AHS) which is based on a tightly spaced group of vehicles following a leading vehicle.

To achieve coordination of the vehicles advanced technologies, communication between the vehicles is needed. These new possible technologies have to interact with the driver in a good way and the instrument cluster could be an important way of showing information needed for this technology. To provide adaptable screens that could shift information during normal drive and AHS drive could be of interest in the future.

6.3.5 Environmental trends

Eco-driving education is becoming more common and it is becoming increasingly important for organisations to show their environmental concerns by lowering carbon dioxide and particle emissions.

Several of the bus companies included in the qualitative study used some form of system for evaluating eco-driving and fuel consumption (Appendix 10). These factors were so important for the companies that they have bought in or made own systems and screens just to provide the driver with this information. In these systems the aim is to lower fuel consumption as well as reducing emissions by using engine brake instead of stepping hard on the brake which cause particles to disperse. The instrument cluster could provide information and reduce the need for external systems developed by the bus driving companies themselves.

6.3.6 Legal trends

Active safety is an important area of interest for many countries in the world and this makes it important to make it possible to include new functions which might become mandatory in the future. Some countries already has regulations about driving time for drivers and in order to follow that in a good way the instrument cluster needs to provide information about that to the driver.

6.4 SWOT

The SWOT analysis method was modified to concern areas relevant for the development of the instrument cluster and information system. An overview of the result is presented in figure 12 and described more thouroghly in the relevant paragraphs.

STRENGTHS	WEAKNESSES	OPPORTUNITIES	THREATS
Exsisting services at Volvo Bus Corporation Volvo Action Service with global presence Good reputation among drivers, Current instrument cluster percieved as easy to overview	Difficult to coordinate strenghts and technologies required for big changes	Customer increasingly thinks high availability is important New technology can expand the volvo bus offer and be more cost effective for the customers.	If change creates more expensive instrument cluster and custom-ers are increasingly cost sensitive, they might prefer more simple systems

Figure 12: The SWOT analysis visually described.

6.4.1 STRENGTHS

One of the internal strengths is that Volvo Bus Corporation belongs to the Volvo Group, which is a big organisation with a lot of technical expertise. Volvo Bus Corporation can take advantage of knowledge and solutions developed at for example Volvo Trucks and there is knowledge exchange between these divisions. Another strength of Volvo Bus Corporation is that Volvo seems to have a good reputation among bus drivers in comparison to other brands (Appendix 10).

6.4.2 WEAKNESSES

One of the weaknesses is that Volvo Group does not seem to fully take advantage of knowledge sharing between its different product groups. Another weakness is the low prioritisation of resources to perform significant changes of the buses (their products) and the instrument cluster. The instrument cluster and drivers place needs to change for the future but the changes can be difficult to implement without enough resources and openness for big changes in the products.

6.4.3 OPPORTUNITIES

The biggest opportunity identified that would benefit the bus system and the new instrument cluster is the integration of the systems and technologies Volvo Group already provide for their products. To use the whole Volvo Group technologies in order to get a good telematics system would provide great benefits for the bus companies and Volvo Bus Corporation, as well as improving information handling for the drivers.

The bus companies and customers of Volvo busses emphasis a lot on price and availability of the busses. If the new system could decrease downtime and time for repair, that could save a lot of money for the companies and they will find the investment of buying a Volvo bus worth the initial payment.

If a better way of communicating information about errors in the bus was available, support and service Volvo Bus Corporation provide (like Volvo Action Service) could work in a more efficient way. The system as it works today is sometimes much more expensive than using the companies own workshops. If error could be handled by Volvo Action Service in an efficient way, charges for the service could become lower and utilised in a better way. If the whole service offer made buses from Volvo more cost effective in the long run, that could persuade more customers to buy Volvo busses.

6.4.4 THREATS

One of the threats is that competitors' products might be cheaper to buy and the number of competitors might increase. If that happens, an expensive but driver friendly company like Volvo, might seem like a bad investment. Often it is not the driver that affects the choice of bus to buy to the company.

Therefore, improvements in the instrument cluster and drivers' situations might not be as prioritised for the management of the bus companies as reducing cost of the busses.

6.5 HIERARCHICAL TASK ANALYSIS

The hierarchical task analysis (HTA) created after the data collection visualises the bus system and the tasks done through it, see Appendix 3. By analysing the tasks through the data collected, some areas was determined to not function in an effective or efficient way. These areas are marked in orange colour and are prioritised to solve in the new concepts. Handle technical problems and perceiving the information was found to be goals on a high level that need improvement, due to problems found in achieving the sub goals and performing the tasks in these categories.

6.6 USE CASES

In order to understand the bus driver profession as a whole, with the task and situations the driver is exposed of, the most common situations have been concluded and form six different use cases. These use cases will define the driver work and task in different situations in order to understand the driver as a user better and conclude problems to solve. The use cases have been divided in

- start-up of bus,
- driving from depot to start of bus route without passengers,
- driving with passengers in city traffic,
- driving with passengers longer distances on country roads,
- exchanging of bus in the middle of work and
- error problems.

The use cases cover all three distinguished driver types and the tasks a driver in general are exposed of, regardless of their main situation and driver tasks. All use cases are thoroughly described in Appendix 4. Since different users have some similar tasks and some different ones, the need of information in the instrument cluster is task-based rather than user-based. Due to this, the use cases will be used as a ground-base when developing concepts of redesigned instrument clusters.

6.7 NEED FOCUSES

Through the need identification phase, many conclusions of bus driver needs were drawn due to the broad view and scope of the investigation. Even though the project scope only concern the instrument cluster, the investigation covered questions of all problems and needs bus drivers in general have.

By analysing the data collected, there were two main focuses found to be most needed enhancement. These two areas concern the perception of information and technical problem handling.

- Perception of Information

  Bus drivers perceive a lot of information during driving that they need to keep track of and know how to handle. Traffic situations is getting increasingly complex with more vehicles and obstacles to keep track of while the service of passengers and the bus itself is still of importance. The perception of information is an important focus to enhance in the driver area.
- Technical Problem Handling

  All bus drivers need technical support, while the busses get increasingly complex with electronic errors needing specialist knowledge to fix. In the system today, fixing a problem takes time and is not as efficient or effective as it should be. Having technical problems was the most common problem in the user study.

The two problem areas were divided and elaborated into sub-problems collected by the users in the need identification. The problems are listed in Appendix 5 and are coordinated with the use cases for an easy overview of the spread of the problem through the driver tasks. The problem lists, as well as the main focuses they describe, will be used and considered through the project process.

6.8 Need Identification Conclusions

The bus driver is the end part of the system. The driver is the face of the companies which the customers (passengers) sees and are charged with the responsibility of both being functional in tasks and time precision as well as being service-minded towards his passengers. The driver has a lot to keep track of and depending on his driving position he can be categorised into being either a city, intercity or tourist driver, which all have different needs. To solve these needs and understand the situations and tasks drivers come in contact with, use cases have been drawn. Analyses of trends, the market and technologies and services provided by Volvo Bus Corporation concludes information to consider that could solve problems and needs stated by users.

The bus driver needs found to be of most use for the project to explore concerned the perception of information and technical problem handling. These two areas of problems will be the focus of the project and the basis of which the system will be changed to enhance.

7. FUNCTION AND TASK FORMATION

In the function and task formation chapter it is described how the system should be functioning to solve the problems and needs of the drivers. Modified system descriptions, redesigned use cases, information rearrangement and additions as well as listing of system functions and user requirements together specify the new system.

7.1 SYSTEM CHANGES

The system in its whole needs changing towards better handling of information and technical problems. Here the ground-ruling changes will be stated, which the concept generation will be based upon. A visualisation of the new system model is shown in figure 13.

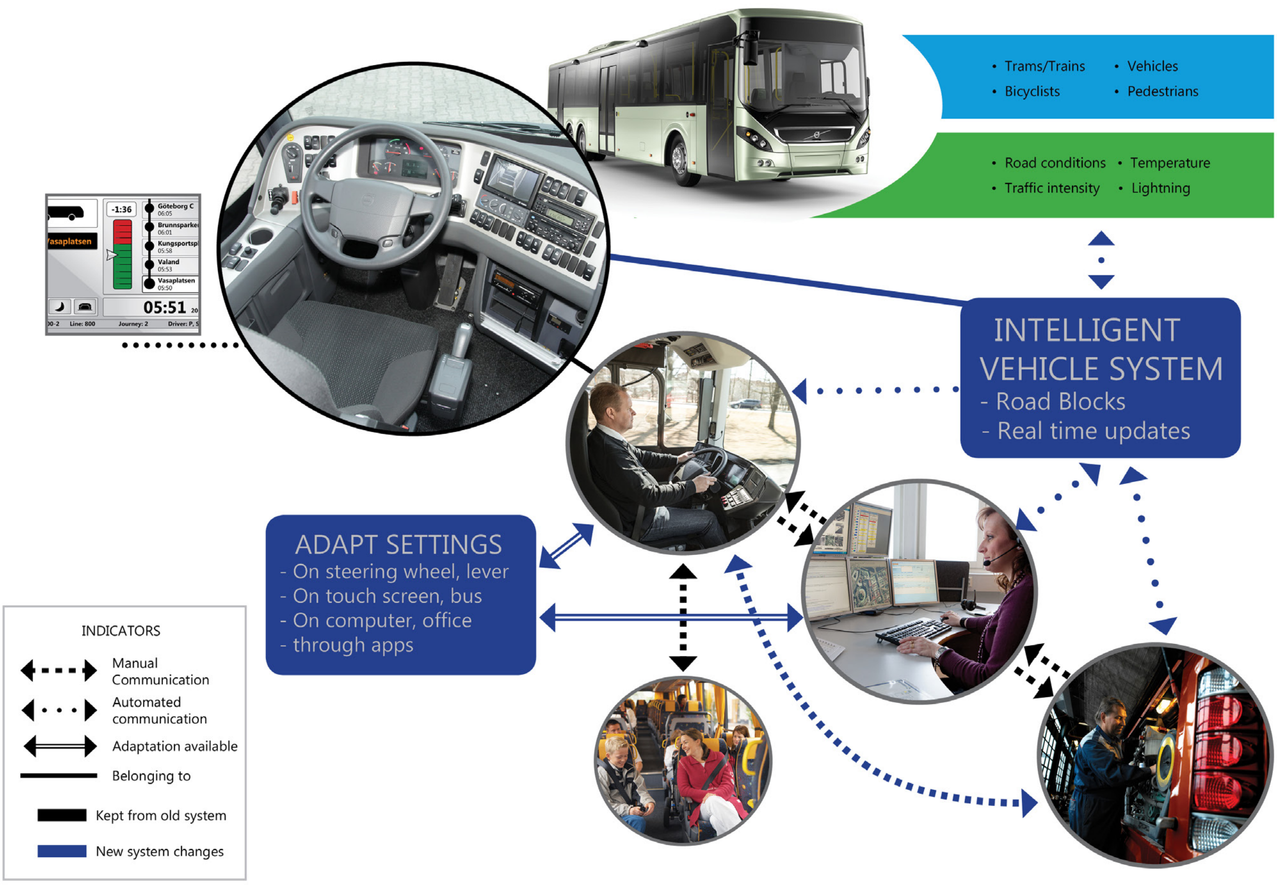


Figure 13: The system model with the new system advantages which enhance the communication between the functions and heighten the adaptation of settings. Images adapted from: http://images.volvobuses.com/#1402496694089_0.

7.1.1 INFORMATION PERCEPTION

One main aspect of improving the drivers' information perception and processing is to work with existing and future available supporting functions. The PESTEL analysis in the need identification

(Chapter 6) showed how new technologies are available and will be further developed in the automotive industry. These functions need to be taken into consideration and balanced and varied in a manner that gives the driver information in a good way. It is important though to balance the information given due to risk of overload as well as giving the information in such an easy perceived manner that the time spent receiving the information should be at its minimum. The time spent looking at the instrument cluster takes away attention from the road and traffic. The function table, table 6, categorise the different desired technologies that should be available for the driver.

Table 6: A function table visualising how the technologies and functions are used to improve the bus system.

INTELLIGENT VEHICLE SYSTEM	USE TELEMATICS AND SUPPORT PLANNING	PROVIDE DIGITAL MAPS WITH INFORMATION	SEND INFO ABOUT ROAD BLOCK	SEND INFO ABOUT ROAD CONDITIONS AHEAD	SEND REAL TIME INFORMATION	
BUS	DETECT	INFORMATION PERCIEVED IN INSTRUMENT CLUSTER	INTERACT WITH OTHER TRAFFIC	DETECT AND WARN FOR COLLISION	INFORMATION RECIEVED BY TELEMATICS	DRIVER CONDITION MONITORING
	ENHANCING TECHNOLOGIES	ENHANCE PERCEPTION OF TRAFFIC AND PEDESTRIANS	LANE KEEPING, DRIVING ASSISTANCE	FRONT, BACK AND SIDE VIEWS OF BUS FROM CAMERAS		
	CONTROLLING TECHNOLOGIES	ADAPTING SPEED LIMITATION	ACTIVE BRAKING	AUTO CALLS TO TRAFFIC MANAGEMENT IF OFF ROUTE	AUTO CALLS TO SERIVCE IF TECHNICAL ERROR IN BUS	
	ADAPT AND CUSTOMISE	PERSONAL DRIVER LOG IN CHANGING SETTINGS	PERSONAL FAVOURITE FUNCTIONS VISIBLE	EASY ON/OFF OF AD ON FUNCTIONS	HARDWARE LIKE SEAT AND MIRROR CHANGED AT LOG IN	
	SUPPORTING MENTAL MODEL & UNDERSTANDING	VISUALISATION OF BUS AND TECHNOLOGY	SHOW POSITION OF ERROR	REMIND OF BUS TYPE AND ROUTE		
	INFORM & UPDATE ABOUT	SPEED	AIR BRAKE PRESSURE STATE	COOLING LIQUID TEMPERATURE STATE	TIME AND SCHEDULE	START UP INFO SCREEN
	MOTIVATE	ECO FRIENDLY DRIVING	SAFE DRIVING	COMFORT DRIVING	ERGONOMICALLY FRIENDLY DRIVING	

RECIEVE INFO BY: VISUALISE AUDITIVE SIGNAL HAPTIC FEEDBACK

The functions (table 6) solve many of the problems and needs of the drivers and enhance the system in accordance with easy perception of information and problem handling. Many of the functions are already available in the system today and other functions are identified in the trend analysis as being feasible in the future.

7.1.2 TECHNICAL PROBLEM HANDLING

Problems with error handling was found in the need identification. The new way of handling errors involve several different actors in the organisation. The bus is connected with real time update and traffic management and technical service can both get information from the bus as well as send information to the instrument cluster and to the bus computer. This enables remote support and helps to decrease the downtime when there are technical or traffic problems. The flow of information from problem detection to problem solvation is described in table 7.

Table 7: A visualisation of how the technical problem handling will be improved in the system.

	PROBLEM DETECTION						PROBLEM SOLVED	OUTPUT
BUS	PROBLEM FOUND BY SENSORS	INFORMATION SEND TO CENTRAL COMPUTER	INFORMATION SEND BY TELEMATICS	PROVIDE EASY COMMUNICATION INTERFACE	INFORMATION RECIEVED BY TELEMATICS	CONTINUE TO SEND REAL TIME INFORMATION	PROVIDE INFORMATION & EFFICIENT REPARATION INTERFACE	STATISTICS AND INFO OF PROBLEM SAVED IN BUS
DRIIVER		INFORMATION PERCIEVED IN INSTRUMENT CLUSTER	PERCIVE INFO ABOUT SENT MESSAGE	EXPLAIN PROBLEM BY PHONE	INFORMATION RECIEVED BY PHONE & CLUSTER	DIRECT COMMUNICATION WITH TECHNICAN	RECIEVE INFORMATION ABOUT STATUS OF BUS	CONFIRMATION OF SYSTEM CONDITION
TRAFFIC LEADERS			PROBLEM INFORMATION RECIEVED	PROCESS INFORMATION & DECIDE ON ACTION	EXPLAIN SOLUTION & ACTION BY PHONE	PLAN HOW TO IMPLEMENT FIXES & HANDLE SITUATION	RECIEVE INFORMATION ABOUT STATUS OF BUS	STATISTICS AND INFO FOR BUS MANAGEMETN
SERVICE TECHNICAN			TECHNICAL INFORMATION RECIEVED	RECIVES FURTHER INFOMRATION FROM TRAFFIC LEADER	IMPLEMENT UPDATES AND FIXES BY REMOTE CONTROL	PREPARES EQUIPMENT FOR REPAIR	GO TO BUS AND REPAIR	STATISTICS AND INFO FOR FURTHER BUS SERVICE

7.2 INFORMATION REARRANGEMENT

The information perceived by drivers from the current instrument clusters from Volvo busses were analysed in order to evaluate what parts works in a good way and other parts that might need change. Information was found to be able to be grouped depending on when the driver actually needs it. The current information could be arranged in information needed while driving and information only needed when a critical or semi-critical state appear. Additionally, there are information that are of greater importance to check at times during driving, though this information should be able to be hidden to drivers not feeling the need of checking them as for example city drivers in busy cities.

7.2.1 INFORMATION NEEDED WHILE DRIVING

Information that the driver will need continuously during driving, regardless of traffic situation, is information belonging to the vehicle mode activated and functions frequently activated on and off. This information will be visualised in the instrument cluster at all times due to the frequent use of them to minimise consistently changing of visualised information.

Vehicle Mode Information

- Gear mode
- Light mode
- Parking brake activation
- Left and right indicators
- Speed

Passenger Related

- Stop signal for passengers
- Entering or exiting of handicapped or passengers with prams
- Activation of On/Off Functions
- Open doors
- Curtsy activated
- Pre-heating on
- Screen mirrors activated
- The switch for increasing load on the drive axle (bogie lift) of the bogie is on
- Differential lock activated
- ABS not functioning

Additional information

- Current time
- Driven distance

7.2.2 Information needed to check while driving

The driver further need to check the status of some information that is of higher importance. This information will best be displayed by a continuously showing level indicator. These indicators include information about

- Fuel
- Air Pressure to brakes
- Temperature cooling liquid
- Turbo meter
- Oil

These level indicators could be chosen to be shown at all times in order to be in higher control of the vehicle, which intercity and tourist driver request, but could also be chosen to be hidden and only shown when critical statuses appear.

7.2.3 Information given at critical state

Information involving functions that are not of frequent use and only needing knowledge of during critical states will remain hidden in the standard cluster unless critical or semi-critical levels appear. The information will be available to be checked if needed, but otherwise stay hidden. This information concern error types such as

- Battery not charged
- OBD – On-Board Diagnostics
- Fault in the doors

7.2.4 Unnecessary information

Information in today's system is not in all cases relevant to the new buses due to enhancement of technology and usability. Some information has only been kept due to traditional mechanical designs which are in this project being replaced, hence unnecessary information will be taken away, such as;

- Tachometer
- Check the tachograph.

The tachometer is no longer useful since merely all buses in today's system have automatic gears instead of manual ones. The tachograph keep check of the driver's driving time but this is now monitored automatically by the driver's card which is swiped at the beginning of a work day and when needed to, information will be given to the driver instead of him needing to check the tachograph himself.

7.3 INFORMATION ADDITIONS

During an analysis of the data collection, information that could be useful for the driver, but is not existing or hidden in the current instrument cluster was identified. This information concern basic knowledge about the bus type and driver identity as well as the individual settings the driver put in in the start-up of the work day. During driving the driver could benefit of perceiving information about ecological driving hints and technological options that could help the driver in difficult situations. Furthermore, additional screens that are now installed by third parties in buses concerning timetables and payment methods, can also be integrated in the instrument cluster.

Bus type and Driver knowledge

- Bus type visualisation
- Type of driving route; for example the specific line number in city traffic
- Driver identity; name etc.

Favourite Settings

- Change of settings
- Comfort settings
- Feedback on changes on comfort settings activated
- Entertainment

Technological Options

- Map visualisation and bus position
- Direction of route visualisation
- Night vision

Added screens

- Cameras of front, end, sides and passengers
- Time schedule and stops in route
- Payment methods
- Eco driving levels

7.4 REDESIGNED USE CASES

The use cases from the need identification chapter are updated to fit with how the new system is supposed to work, see table 8-13. These are not complete descriptions of the system, but can give indication and overview of how the driver's day works in the new system.

Table 8-13: Use Cases, after redesign

Use Case 1	**Start-up of bus**
Summary	The user prepares the bus to leave depot and takes off to start route.
Actor	The bus driver
Goal	To check the state of the bus and prepare it for driving

Use Case 1	**Start-up of bus**
Precondition	The bus is parked at the depot and connected to external heating/electricity.
Description	1. The driver opens bus, put out electrical heating enters the bus and hangs jacket behind the driver's seat and places bag there in the assigned space.
	2. The driver puts in the drivers card with the login information. That automatically changes settings in the instrument cluster, chair and mirrors according to predefined preferences.
	3. The driver blows in alco-lock in order to be able to start the bus and can at the same time inspect the POP up start screen with all essential information
	4. The information is easy to overview and when the bus is ready for take-off the drivers clearly understands this by the information on the instrument cluster.
Alternatives	3. There might be an error which the driver perceives clearly.
	3. Error information is directly sent to traffic management and service, they either contact the driver through screen message or telephone call, depending on the type of error found.
Post condition	The bus is rolling out from garage and the driver can feel confident about it working correctly and have information about in what state the bus is in.

Use Case 2	**Driving from depot to start of bus route, without passengers**
Summary	The driver starts work by driving the bus from the bus company depot to the starting point of the route scheme.
Actor	The bus driver
Goal	To transport the bus safely from depot to route start in the planned time.
Precondition	Bus has gone through service checks and cleaning and is ready to be driven. Bus driver is prepared for work and has checked that the bus is in order. Bus driver sits in starting position in the driver's seat and has started the bus.
Description	1. Driver starts driving of the parking space in the depot. Settings and lights are set automatically according to preferences predefined and outside light conditions.
	2. Driver drives the bus from the depot to the first stop of the bus route. As there is almost no traffic, the coaching and information screen is active providing the driver information evaluating eco driving and other areas of interest and the driver stays alert.
	3. Driver constantly perceives bus route information on the login information on the instrument cluster.
	4. Driver drives bus to first bus stop
	5. Driver opens doors for passengers either by automatic sensors or manual mode, depending on predefined settings
	6. Driver starts the official route work.
Alternatives	5. Driver gets a reminder to turn off from the highway since the route system thinks the driver has forgotten about it.
	5. Driver is really tired and unfocused and accidently drive off lane, the bus warns about this and make driver alert again.
Post condition	The bus rolls out with its first passengers of the day.

Use Case 3	Driving with passengers in city traffic
Summary	The bus driver transports passengers inside city traffic and have to stop at bus stops very frequently and make sure all passengers is on and off loaded in an efficient and good way.
Actor	The bus driver.
Goal	To transport passengers in city traffic and keep time schedule through efficient on and off loading of people at bus stops.
Precondition	Bus driver has come to bus stop to load off passengers
Description	1. When approaching the bus stop the driver receives reminding information about that a passenger wants to jump off.
	2. The driver manoeuvres the bus slowly through the crowd and checks forward and side rear mirrors. Enhancing vision is enabled when the system detects threats close to the vehicle.
	3. The driver stops at the first stop. Drives into side of road at bus stop.
	4. The driver checks in the inner rear mirror to see if some passengers need extra time to offload prams or wheelchairs.
	5. The driver opens the door.
	6. The driver checks the inner rear mirror again if door can be closed.
	7. The driver closes the doors.
	8. The driver starts driving again (Repeat all steps).
Alternatives	1. When checking stop button indicator that might not be activated and bus driver has to decide if it should not stop at all and looks in the inner rear mirror to make sure no passengers are prepared to get out.
	3. When stopping at bus stop the bus driver might want to lower the side of the bus for better accessibility to passengers. This mode is clearly displayed in the instrument cluster.
	5. Doors are opened automatically by sensor signal.
	7. Doors are closed automatically with shutting lock if person in the way.
Post condition	The bus driver arrives at final bus stop before break.

Use Case 4	Driving with passengers longer distances on country roads
Summary	The driver starts and stops the bus very seldom and drives longer distances on country roads with few intersections of city traffic
Actor	The bus driver
Goal	To follow a route plan and transport passengers long distances without delay. To stay alert during low mental load and drive eco-friendly.
Precondition	Bus has been loading on the first passengers on the route and bus has come out outside the city

Use Case 4	**Driving with passengers longer distances on country roads**
Description	1. Driver checks mirrors and turns out on a big country road.
	2. The driver manoeuvres the bus in a safe and comfortable way.
	3. The driver gets constant updates on the road ahead and possible blockage and interruptions to the planned route on the instrument cluster through Intelligent Vehicles Systems.
	4. The system gets information about a road being reconstructed and computes a different way the driver can take which is suitable for large heavy vehicles and have not yet been exposed of too much traffic. In this way, the driver avoids road interruptions and saves important time.
	5. The intelligent detection system detects a road block ahead and warns the driver through a visual representation. The driver can then plan to stop the vehicle without alarming the passengers.
	6. The driver arrives at a rest stop and gets information about it and how to get there through a visualisation on the instrument cluster.
	7. The driver can evaluate how smart the driving is, according to a driving coaching screen situated on a secondary information display. This coaching is indicating how the driver could drive in order to be more eco-friendly.
	8. The driver drives to the end destination and gets information along the way about directions, rest stops and road blocks.
Alternatives	3. The driver gets information about vehicles around, being too close and evaluates the safety issues.
Post condition	The bus arrives at destination

Use Case 5	**Exchanging of bus in the middle of work**
Summary	The user exchange another bus driver at a bus stop in hectic traffic
Actor	The two bus drivers exchanging bus
Goal	To change driver of the bus in as little time as possible and make sure the bus is setup in a correct way for the new driver.
Precondition	Bus is stopped at bus stop in hectic traffic
Description	1. The new bus driver finds the bus and says hello to current driver.
	2. The other driver jumps out and new sit down in chair
	3. The new driver puts in drivers card and it automatically logs in and change seat, steering wheel, mirror, climate, music and instrument cluster settings according to predefined settings.
Alternatives	1. If bus is not in correct place reminding information with digital maps automatically gives that information to the driver
Post condition	The drivers have exchanged each other and the bus heads out to continue the route.

Use Case 6	**Error message / warning from bus**
Summary	The bus driver perceives a warning, interprets the meaning of the message/symbol and gets help from traffic a planner to solve the problem.
Actors	The bus driver, traffic planner and service workers

Use Case 6	Error message / warning from bus
Goal	To conclude problem and its severeness as fast as possible and the according action the bus driver needs to take.
Precondition	The bus is driving in the city and has about 20 minutes' drive left on route. Before the warning there has been no indication of deviations from normal mode.
Description	1. Driver perceives a warning on the instrument cluster which clearly explains the problem with visualisations and text on the instrument cluster.
	2. Depending on nature of problem information is sent to traffic management and service which process information, decides on action and contact the driver.
	3. Driver acts according to traffic management's decision.
Post condition	The problem is solved and the bus driver can continue the last part of the route.

7.5 REQUIREMENT SPECIFICATION

From the need identification phase and analysis of data, a further summary and discussion resulted in a requirement specification of what the new system should fulfil, see table 14. These requirements are quite abstract, due to that only early phases of the product development process are covered in the project. Most of the requirements needs to be validated in usability tests and can somehow be evaluated towards theory. The theoretic heuristic evaluation will partly be performed in the second concept development chapter. The requirements are grouped in areas that were identified as key aspects during the need compilation.

US/KJ: *Information from user study presented in User Study Summary, Appendix 10*

HE/TH: *Information from heuristics and design guidelines in Theory chapter*

TA/NI: *Information from Trend Analysis in Need Identification Chapter*

ECO: *Basic principles for eco-friendly design*

MAN: *Basic principles for cost effective manufacturing*

Table 14: The requirements defined during the analysis of the data collected.

Requirement Specification	Source
Universal Requirements	
Enable easy understanding and perception	HE/TH
Enable information perception in a natural manner	HE/TH
Enable intuitive interaction	HE/TH
Enable easy perception of information needed regardless positioning and posture used	HE/TH
Minimise number of actions to complete a goal	HE/TH
Enable fast learning of technical functions	HE/TH
Enable universal understanding regardless of culture and reading capabilities	HE/TH
Enable adaptability for all types of possible users	US/KJ
Provide user with correct mental model of how the system works	HE/TH
Function well during all types of outside light conditions	US/KJ
Customisation	

Requirement Specification	Source
Enable easy customisation of information	US/KJ
Adapt whole drivers work place according to driver	US/KJ
Prohibit misuse and inappropriate settings	US/KJ
Enable settings to change depending on situation	US/KJ
Provide information on how to set climate system	US/KJ
Enable adjustments of visibility and brightness of instruments	US/KJ
Driving assistance	
Enable driving assistance functions to be on and off activated	US/KJ
Enable safe and efficient driving for inexperienced drivers that are unfamiliar to either route, bus type or situation	US/KJ
Avoid automation that prevents the user from working in the preferred way	HE/TH
Support driver with information about accidents or road work	US/KJ
Physical ergonomics	
Use information that is not corrupted by bumpy roads and bad traffic conditions	US/KJ
Not hinder storage of bags and jacket which can be in the way otherwise	US/KJ
Support ergonomically friendly work postures	US/KJ
Not disturb view by blinding effects on windscreen	US/KJ
Enable use with sunglasses (even Polaroid type)	US/KJ
Futuristic integration	
Enable possibility to integrate ad-on systems in a non-disturbing way	TA/NI
Take future traffic situation and vehicle technologies in consideration	TA/NI
Take perception enhancement technologies into consideration and evaluate implementation	TA/NI
Take advantage of touch screen possibilities	TA/NI
Investigate head up for conveying information	TA/NI
State of Bus Functions	
Provide information of gear mode	US/KJ
Provide information of current speed	US/KJ
Provide information of water level	US/KJ
Provide information of air pressure level	US/KJ
Provide information of temperature inside and outside bus	US/KJ
Provide information of motor temperature	US/KJ
Provide information of fuel level	US/KJ
Provide information of oil level	US/KJ
Provide information of battery status	US/KJ
Ease slow driving in shared spaces (pedestrian streets)	US/KJ
Mental workload	
Let driver focus on driving and passenger interaction	US/KJ
Avoid need for constant supervision of instrument cluster	US/KJ
Enable access to information if needed	US/KJ
Minimise stress feelings when driving	US/KJ

Requirement Specification	Source
Support driver alertness	US/KJ
Keep driver alert when driving to and from garage without passengers	US/KJ
Support good situational awareness of surrounding traffic	US/KJ
Keep driver in control	US/KJ
Prioritisation	
Prioritise use and perception of frequently used functions	HE/TH
Access functions used during driving from seated driving position	US/KJ
Prioritise perception of important and significant functions	HE/TH
Minimise instruments on instrument panel	HE/TH
Remove instruments with the same function to enhance perception ease	HE/TH
Technical Engineering	
Support effective and efficient manufacturing	MAN
Support possibility to design solution with minimum weight	MAN
Manoeuvring assistance	
Enable easy driving in intense traffic environments	US/KJ
Support optimised visualisation of environment outside the bus	US/KJ
Bus start and change	
Enable faster and more efficient bus start-up check	US/KJ
Reduce time and effort for setup of drivers place	US/KJ
Reduce time and effort to adapt settings when changing bus during work or change outside garage	US/KJ
Environmental impact	
Encourage environmentally friendly driving	ECO
Support possibility for solution with small environmental impact through lifecycle	ECO
Provide long aesthetic and functional lifetime	ECO
Provide possibility to update software in solution as traffic needs change	ECO
Support possibility to create robust and durable solution	ECO
Safety	
Support safe bus and pedestrian interaction	US/KJ
Support safe driver communication with passengers while driving	US/KJ
Provide security measures towards unsafe situations of drivers	US/KJ
On/Off loading	
Minimise on and off loading time at bus stops	US/KJ
Enable manual access to door opening and closing	US/KJ
Provide information of passengers jumping off at next stop	US/KJ
Entertainment	
Consider communication equipment, both related to work and personal issues	US/KJ
Enable entertainment equipment to be used in a safe manner	US/KJ
Integrate entertainment possibilities	US/KJ
Passengers interaction	
Avoid alarming passengers	US/KJ

Requirement Specification	Source
Enable overview of passengers in the bus	US/KJ
Make it easy to show passengers how to use the entertainment system in chartered busses, without losing focus on driving.	US/KJ
Expression	
Use suitable aesthetics that supports comprehension	HE/TH
Convey a sense of importance to driving	US/KJ
Convey a sense of quality and robustness of the system	US/KJ
Inspire happiness and proudness	US/KJ
Create trust for the bus	US/KJ
Legal	
Fulfil legal requirements	US/KJ
Take trends in traffic regulation into consideration	TA/NI
Encourage to drive legal and safe according to speed limits	US/K
Problem handling	
Distinguish problems depending on if the driver can fix them or if the workshop needs to fix it	US/KJ
Enable problem feedback to those concerned about it	US/KJ
Enable information perception to those concerned by it	US/KJ
Enable feedback of an action to those concerned by it	US/KJ
Enable support for evaluating problem severeness	US/KJ
Ease information transfer between driver, traffic planning and service functions within bus organisations	US/KJ
Provide information rich and specific enough to understand error messages	HE/TH
Provide easy service access	US/KJ
Alert driver if in critical situations	US/KJ
Enable easy perception whether bus is drivable or not and express what next action is	US/KJ
Enable efficient handling of technical bus problems	US/KJ
Maintenance	
Enable cleaning with disinfectant and paper (possible to keep clean and hygienic)	US/KJ
Consider standardised instruments in new design	HE/TH
Minimise aging effects	ECO

7.6 FUNCTION AND TASK CONCLUSIONS

In order to solve the problems stated in the need identification, the system as a whole needs to change. The modified system should work with fast and easy communication through traffic leaders and technicians in the workshop out to the drivers. The drivers' task should in the new system flow as easy as possible due to the time restrictions they work under, and when problem do occur, the information should be instantly and automatically sent to those concerned, to optimise the time spent on communication in between work functions.

The system is based upon that the driver card is used as an identification card with predefined settings which the individual driver has set to own preferences. When the card is swiped, all this information is automatically registered through the instrument cluster and settings and information is adapted to the person, including current driver schedule. The information given to the driver has been rearranged in accordance to when the driver needs it to be given; depending on situation, continuously at all times or not at all if not activated manually. Additionally, information that could solve current problems has been made available for use. How the new system work in relation to driver task is explained through a redesign of the use cases. The system with its functionality and tasks descriebed, will be the basis of which the concept designs for the instrument cluster will be developed on.

8. CONCEPT DESIGN 1

The findings from the first conceptual development phase, based on the earlier chapters, are presented in this chapter. The results in terms of conclusions, matrixes and early concepts created in the early concepts stages as well as evaluation of the same is the outcome from the concept design 1 phase.

8.1 OVERALL SYSTEM DESIGN

The system depends a lot on connectivity to sub-systems at the bus organisation and centralised national traffic systems, as the Japanese IVS system described earlier in the PESTEL analysis. The system is adapted to enable future enhancing technologies and is based on ability to adapt in a quick and effortless way, see figure 14.

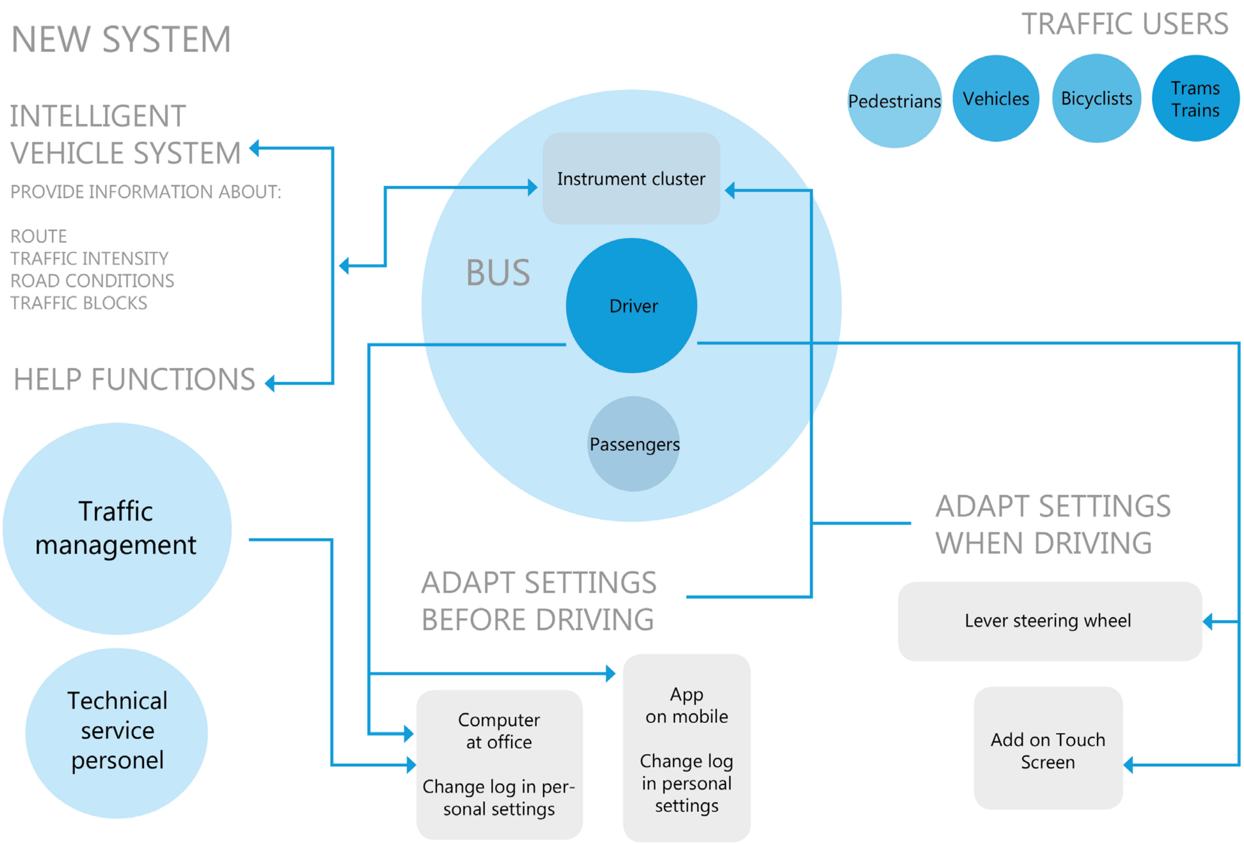


Figure 14: Picture visualising the control system.

The overall information system is extended from the current system with the integration of an add-on screen and personal driver log in system. The system and settings of the instrument cluster could be controlled by the driver both inside the bus (by the current stalk and touch screen) during the workday and with login either by phone as an app or by the system at the bus company office. Depending on the type of organisation, other work functions might need access to settings and control of the cluster. For example, some of the settings might be predefined by the individual organisation, so the driver does not have to choose the information and look on the instrument cluster. Other settings of the instrument cluster that is required at certain events or circumstances could be changed by traffic management in real-time and it could be possible to give remote help to change and adapt the instrument cluster.

When entering the bus, the driver swipes the personal log in card and the desired settings are adapted, both in hardware (driver's seat settings, steering wheel, mirror positions) and in software (instrument cluster settings, climate settings etc.). This reduces waste time.

If sensors for failure could be trusted, a start-up screen could display errors and state of the bus instead of the driver having to go through the safety check. Even if the driver feels the need to go through with the check, the driver has already been given an overall knowledge of the state of the bus and can choose to look deeper into the instruments which the screen displayed needed checking.

8.1.1 Extended Volvo Product Offer

The new system and instrument cluster is more integrated to other equipment in the bus. Hardware, like steering of rear mirrors, seat position and steering wheel position should be controlled by the preferred settings the drivers has chosen. Even if other secondary information displays and other screens are used in the system, these should be connected to make sure the driver does not have to perform extra tasks to log in the same information in the different systems. The tasks and settings the driver has to perform in the bus should be minimised and most settings can be updated through the log in and work schedule information the organisation has about the driver. These kind of systems need to be further supported and extended from the current Volvo offer.

8.1.2 Easier Passenger Interaction

Some of the drivers that need to perform tasks with check in and sales of tickets can get distressed by a lot of passenger questions. To automatically give the passengers more and better information about the route and time through screens could take off some of the mental load put on these types of drivers. As seen in the trend analysis, the tasks of selling and checking tickets are increasingly delegated to the passengers. If these systems are developed in a user friendly way that the users understand without asking the driver, it would benefit the driver in terms of minimising the mental workload.

For tourist drivers with passengers that want to use entertainment systems in the bus, equipment needs to be easy enough for the passengers to set. Since the bus driver cannot set these entertainment systems when driving, the interface to set movies, music and other equipment might be placed away from the drivers place. Instead the driver should just be able to unlock the functions so the users can set everything themselves during the drive without disturbing the driver.

8.2 System Concept Generation

By referring to the initial questions posted in the project, system sub concepts were generated through brainstorming and idea generation. For each possible system question, options in form of sub concepts are stated in the concept combination table, also called morphological matrix, see, Appendix 6. When developing the overall concepts this matrix shows possible combinations to choose from.

When developing overall concepts the use cases described were used to combine different sub concepts. To structure information in the best way, the use cases will be used as a theoretical basis where important points will differ depending on case, see table 15. This will enhance the concept development and build a strategy towards presentation of information in the new development of the instrument cluster.

Table 15: For each use case, different points of focus in terms of information have been stated to ease the concept generation.

1: Start-up	2: Depot to Route driving	3: City driving	4: Country driving	5: Exchange of bus/driver	6: Error Handling
easy overview of bus state	information that keep driver stimulated	on/off passenger loading information	information that keep driver stimulated	easy overview of bus state	error indication, error type
easy access to specific instrument information	information that uses all senses	interactive route directions	interactive map of surroundings	easy access to specific instrument information	next action towards solving it
feedback on settings adapted to driver	grouped information in a natural way	information that supports safety in hectic environments	information that supports safe planning of route	feedback on settings adapted to driver	notification of where information has been sent
	information that increase mental load	information that uses all senses	information that uses all senses		feedback on sending of information
		grouped information in a natural way	grouped information in a natural way		
		information that decrease mental load	information that increase mental load		

8.3 Information Grouping in Instrument Cluster

When developing the new design of the instrument cluster, the first step was to create the different groups of information and decide where they could be presented in the best way. Some of the functions are only interesting to display at certain situations and should therefore not take up space and increase mental workload when not active. Other functions are important to show at all times in order to make sure that the driver's situational awareness is high and that the driver can plan the route in advance.

The information the driver need can be grouped into three different stages of need:

- Start-up/Check-up stage
- Standard Driving stage
- Error stage.

During these stages the driver need different information as well as different visualisation of information. These stages will each have their own screen which differs in information due to the functionality of the stage/screen.

8.3.1 Instrument Cluster Space

In order to understand the space that can be used, the instrument cluster in front of the driver as well as the driver panel are visualised below, including wheel and spaces on the side, se figure 15.

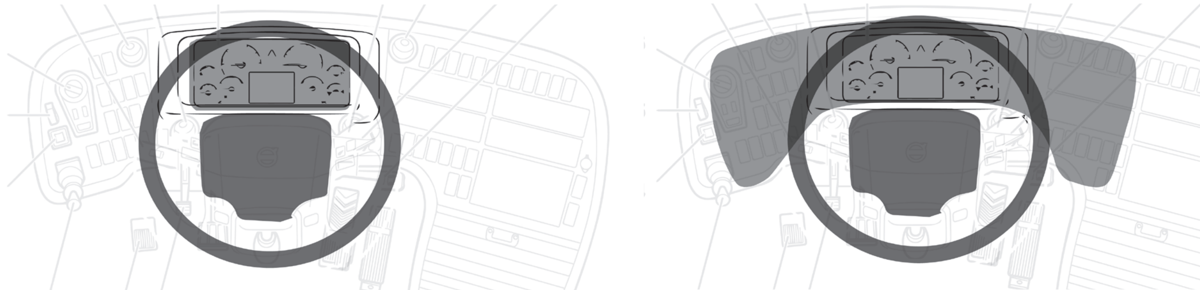


Figure 15: The instrument cluster and its surroundings on the instrument panel. The highlighted area shows the area used for today's system (left) and what is suggested as a possible future area worth exploration (right).

The information needed to drive should be perceived at the most natural place for the information to be in order to support easy understanding of the information conveyed. The current system uses only the instrument cluster's current position and area to show this information, see left part of figure 15. Though, in some cases, lamps and other equipment are added to the dashboard to dubbel the effect of important functions already shown on the cluster. For example, the stop button is both shown on the cluster as a symbol and when used also visible as a lamp on the dashboard. If the functions and information on the cluster could be conveyed more naturally and be easier overviewed, the functions used now on the dashboard to double the effect could be taken away in favour for a bigger instrument cluster.

If the area of the instrument cluster was to be broadend to include spaces on the right and left side of its current position (see right part of figure 15), secondary information displays with additional information used today might not be necessary. All information needed could be conveyed digitally through the expanded instrument cluster. In this project though, the area of the current instrument cluster will only be used in order to conclude how this area could convey information most efficent. Expanding of the cluster area should however be further investigated in future projects, in order to conclude the most optimal solution for information handling in buses.

8.3.2 Start- and check-up screen

When the bus first is started, a start-up screen should be visible, visualising the state of the bus and the levels of functions of importance. The information in the start-up stage concerns all the information that needs checking in a bus. That is all the information shown on the cluster, see figure 16. The state of the instruments should be clearly visualised, which could be done either by highlighting the symbols themselves in different manners or by using the area around the symbols of the functions to differentiate the state.

During a start-up or check-up of a bus, a clear visibility over all the bus functions and critical levels is needed. Depending on if the knowledge given to the driver only need to be if it is working or not, or if a higher knowledge in terms of level indication is needed, the visualisation will differ among the presented information.

8.3.3 Standard driving screen with customisation abilities

The most effective manner of perceiving information is having the information on standard places in the instrument cluster. Too much moving around means more time to process the information visible. Therefore, a standard screen is the optimal choice. It will show the most prioritised functions that are most frequently used as well as available customisation of functions easy accessible and visible when needed. The functions are grouped depending of use, need of visualisation and prioritisation. They are described further in the paragraphs below as well as in figure 16-17. The information groups include both features which are not currently in the system of today as well as functions kept from current instrument cluster.

When driving, the driver only needs information about the vehicle state and driving functions that is activated and deactivated as well as information that is critical for the planning of the route. Information about errors that are critical enough that the driver need to take an action to avoid it, will appear in the separate error stage.

IMPORTANT FOCUS

Information that is very important during driving includes driving indicators, activated lights, current speed, stop signal and the time. This information should always be visible on standard screen in a centered section that is easy visible.

ON/OFF FUNCTIONS

Information about functions that is either activated or not should be visible through symbols at all times, but lighted when activated, in order to give continuous feedback whether they are on or off. These functions may differ between bus types, which is what the red lined square visualises in figure 16. Tourist buses for example have visualisations of passenger service needed (the symbol in the square, figure 16), which is a function not included in the city bus and the city driver's responsibilities.

LEVELS OF INFORMATION

Information that, if critical, can ruin the planned route severely and that some drivers feel important to keep track of continuously when driving will be visualised by a level indicator of some kind, see figure 16. This information should be visualised at all times to make it easy for drivers to check up on critical data during driving and support safe driving (because today, the drivers access the levels through the display during driving and they should not have to do that).

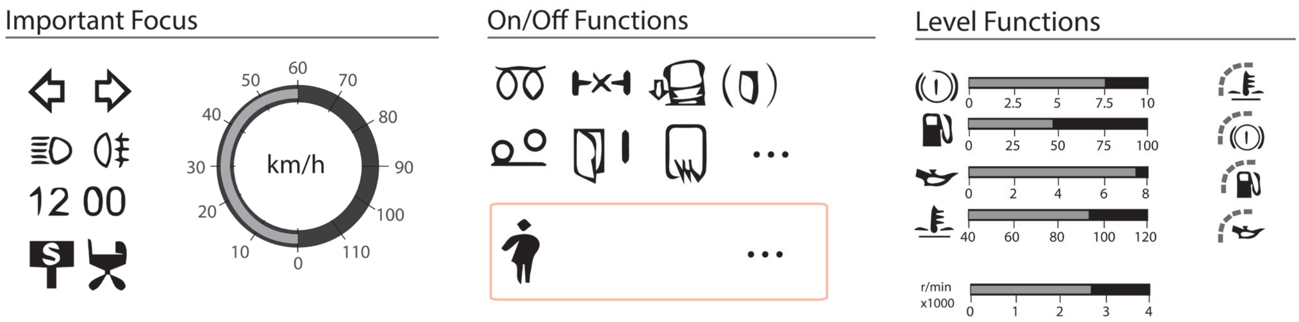


Figure 16: The information needed on the instrument cluster to be able to drive safely is grouped depending on their perceptive visualisation and prioritisation into important focus functions, on/off functions and level functions.

DRIVING INFORMATION

Information about the vehicle type and driving settings currently used could be visible as a standard on the screen or easy accessible for those who want it visible. This information concerns distance driven, bus functions available to use and the route driving, see figure 17.

DRIVER FAVOURITE SETTINGS

Information about the driver and the driver's favourite settings in terms of climate choices and entertainment could be automatically saved on the driver card and visible through the display either at all times or easy accessible and taken away if need be, see figure 17. Information about the driver currently driving and the driver's tachograph could also be of use to show in order to give continous feedback of a working system as well as supporting laws.

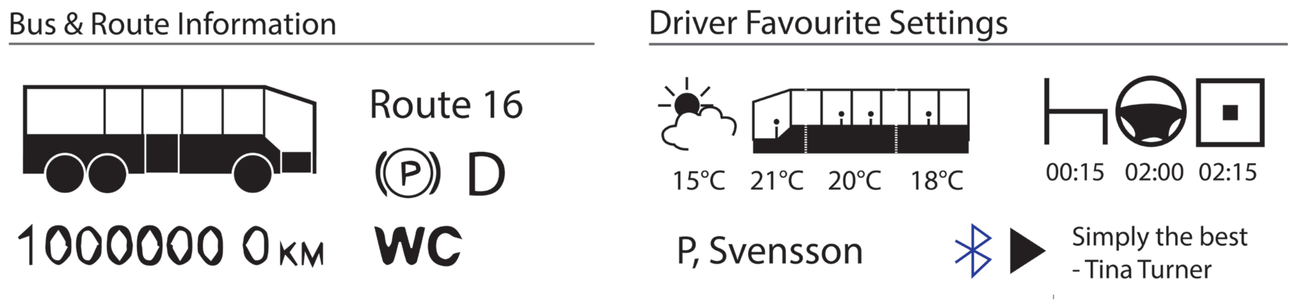


Figure 17: Information that could be of use for the driver in order to drive correct, safely and comfortly as well as staying alert during situations with low mental workload is grouped into information concerning the bus and route facts and driver's individual settings.

8.3.4 AVAILABILITIES IN STANDARD STAGE

Information that could ease the driving should be easy accessible whenever needed. Furthermore, the standard screen could be individualised to show the available information groups the specific driver finds helpful. This available functions that fulfill some of the driver needs in different situations are put as availabilities for the standard screen which should either be visible as a standard, or easy accessible whenever needed.

These available information groups that could be of use concern interactive maps with information about the road ahead, technical options such as pedestrian spotting technology, eco driving levels, directions to destination and the integration of current add-on screens, figure 18.

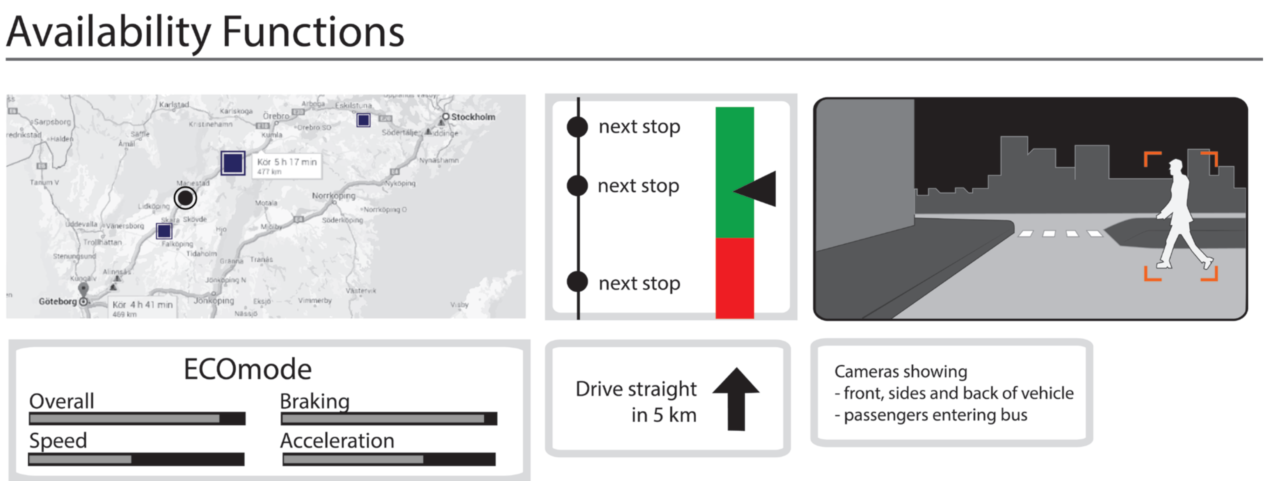


Figure 18: Functions that could ease the driver's work are grouped as availabilities.

8.3.5 THE ERROR STAGE

Whenever there is an error in the bus that threatens the bus driver's driving plan, the standard screen should immediately be switched to show a screen where the error warning should be visible. When an error occur, or when a function gets critical enough creating need for alerting the driver in order to plan the route to avoid negative consequences, a separate information screen will be shown to the driver.

The error screen should clearly state that a problem has occurred/is occurring, what type of error it is, the required next step to solve it and notification and feedback that the information has been directly sent to the person whom it concerns (and who that is).

This screen will clearly visualise

- Problem indication - the fact that a problem have occurred and that the driver needs to deal with it.
- Error type and severeness - what kind of problem has occurred and how severe is it.
- Notification about information sent - information about where information about the problem have been sent.
- Feedback on information sent - feedback that information about the problem has been sent.
- Action towards it - what the next action is, what the driver needs to do.

Information in the error stage concerns functions that are of critical importance to the planned drive. This information is only conveyed through the error screen, that pops up whenever this problem occurs and is not visible on the instrument cluster as symbols of indication as it is today. Information concerned are examplified in figure 19.

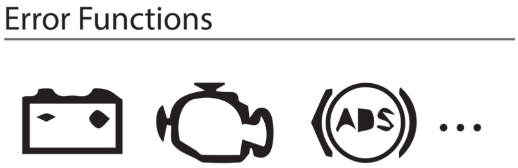


Fig 19: The error functions concerns battery not functioning as well as engine and brake problems.

8.3.6 Exchange of bus screen

When bus drivers change bus, the bus driver uses the driver card, swiping it in order to “log in” to the bus. When this is done, the screen should change into an “exchange of bus screen” which should contain information about the switch, the new driver identity and feedback that changes set in the bus will automatically change into the new driver’s preferences (stated in the driver card). The exchange of bus screen should also visualise the functions of the start-up screen, showing the state of the bus.

8.4 Concept generation

In order to further understand the concluded information groups that should be visible to the drivers in different manners, concepts that visualise these groups in symbols and indicators were generated. These concepts were to symbolise the manner of which the different information could be handled and visualised in the instrument cluster. The purpose of the project were not to immerse in the details of the visualisation possibilities, but rather to show examples of how information groups could be visualised in order to get feedback from users on the conclusions drawn. The concepts were therefore generated to enhance the understanding of how it could look with the different information groups in different places. The concept aims at fulfilling the stated requirements from the conclusions drawn from the user study.

8.4.1 Start-up screen

The start-up screen will be the first visualisation in the instrument cluster that the driver is given after the bus is started. This screen will in some manner show the different functions and instruments that are to be checked by the driver before driving and their status. This status could preferably be colour coded, see figure 20, and it should always be possible to view an enlargement of an instrument with explanations to the symbol and level indication, as shown in the second picture in figure 20. The start-up screen should be visualised on the whole screen since it is the only information needed in that situation.

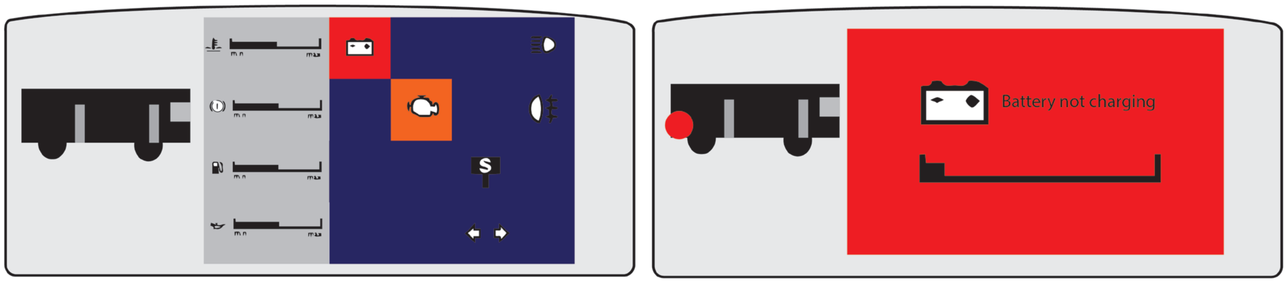


Figure 20. A visualised concept for the start-up screen.

84.2 STANDARD DRIVING SCREEN

The visualisation of the standard driving screen was based on the information groups that were to be used in the driver's daily work. The different concepts, see figure 21, can be called different "themes" of the clusters, since the difference lies in the placement and visualisations of standard driving groups and the size of the availability area. There are surely many more themes to be explored, these are some examples, symbolising the different visualisations the instrument cluster can be given.

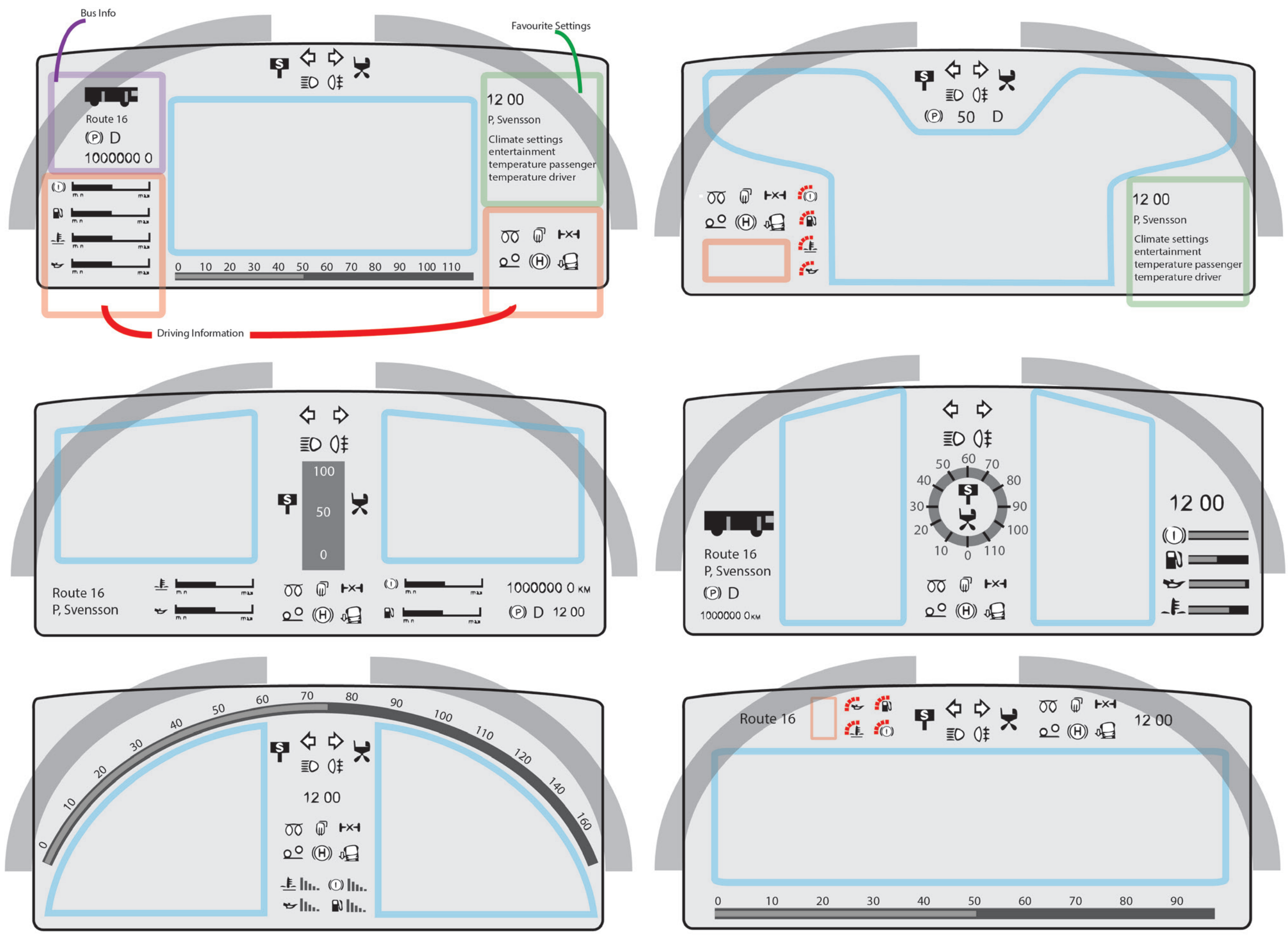


Figure 21: The different themes of the standard driving screen in terms of concepts.

To fully understand the width of the different themes of the standard screen concepts and to evaluate the best visualisation of each information group easier, a morphological table was performed, see Appendix 7. Each information group constitute the rows in the table where possible visualisation options of the groups are graphically displayed. The placement and visualisation examples of the information groups can be combined into different concepts (figure 21) and form endless possibilities of themes and looks of the instrument cluster.

The morphological matrix was used as a mediating tool when discussing concepts and can be used as an inspiration for further studies of the design of the instrument cluster. However, this project will only take the design possibilities into consideration when going through the concept generation and evaluation, thus will not go into details of which looks give the best aesthetic experience and pleasure. It is the system changes and information groups that are of importance, which should be displayed and in what manner of visualisation should they be perceived through. The final placement and detailed design is not the focus of the project and will be left for further studies.

84.3 ERROR SCREEN

When an error occur, which the driver needs to take into consideration, it needs to be informed to the driver as easy as possible. Through the data collection it was found that indications by sound will be hard to distinguish from the loudness of the environment a bus driver is exposed to. Therefore, a visualisation indicating the error should be done. To make it as easy to be perceived as possible, the error information should preferably be presented in large format on the screen, in order to make the driver conscious of the severity of the error and decrease risk of ignorance.

In the error screen, the error should be clearly stated, with symbols and its meaning as well as indicating the level of its status. It should also be clearly stated that information has been sent to whom it concerns that could help with the matter, in order to ease the problem handling for the driver. An identification number that is unique for each error should also be shown in order to ease communication and reduce miscommunication between driver, traffic leader and technical service. According to heuristics stated earlier, the use of identification codes is questionable, but since the problem probably cannot be solved by the driver only, there has to be ways of conveying information in a way that cannot be misinterpreted. The last important thing, which is actually the one the driver needs most, is the statement of the next action, hence what the driver needs to do in order to solve the problem. The error screen could be visualised with this information as figure 22 shows.

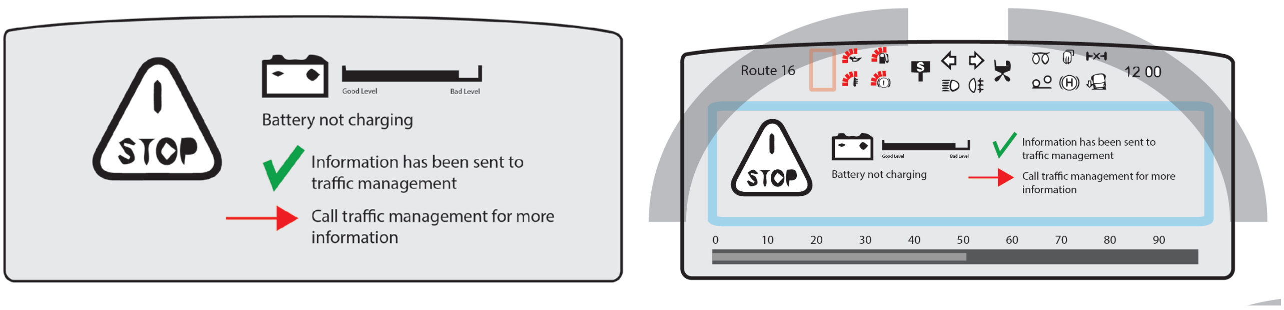


Figure 22: A visualised concept of the error screen.

8.5 CONCEPT SCREENING

The standard driving screen could be visualised in many different manners, as seen in the concept generation. In order to evaluate them against each other and thereby find the one that best fulfil the user needs, the generated concept themes were evaluated using the Pugh concept selection matrix (Ulrich & Eppinger, 2012). The selection criteria chosen were taken from requirement areas stated earlier in the function and task formation (Chapter 2).

The concept selection matrix (see Appendix 8) concluded that some of the concepts were less suitable to use. But when evaluating the concepts, it became clear that concepts with medium high score, could be combined to get rid of the drawbacks of the concepts. Therefore, the screening itself and the rate the concepts got, were not that useful for evaluation. Although, during the evaluation the actual elements giving pros and cons with the concepts were identified, which helped the concept refinement and combination process. One of the main aspects were that the area available for error messages and additional functions were easier to perceive when presented in one area and not divided in smaller areas. The standard driving screen was therefore designed with only one area of availability, placed in the middle of the screen with the other information groups placed on either side of it, see figure 23.

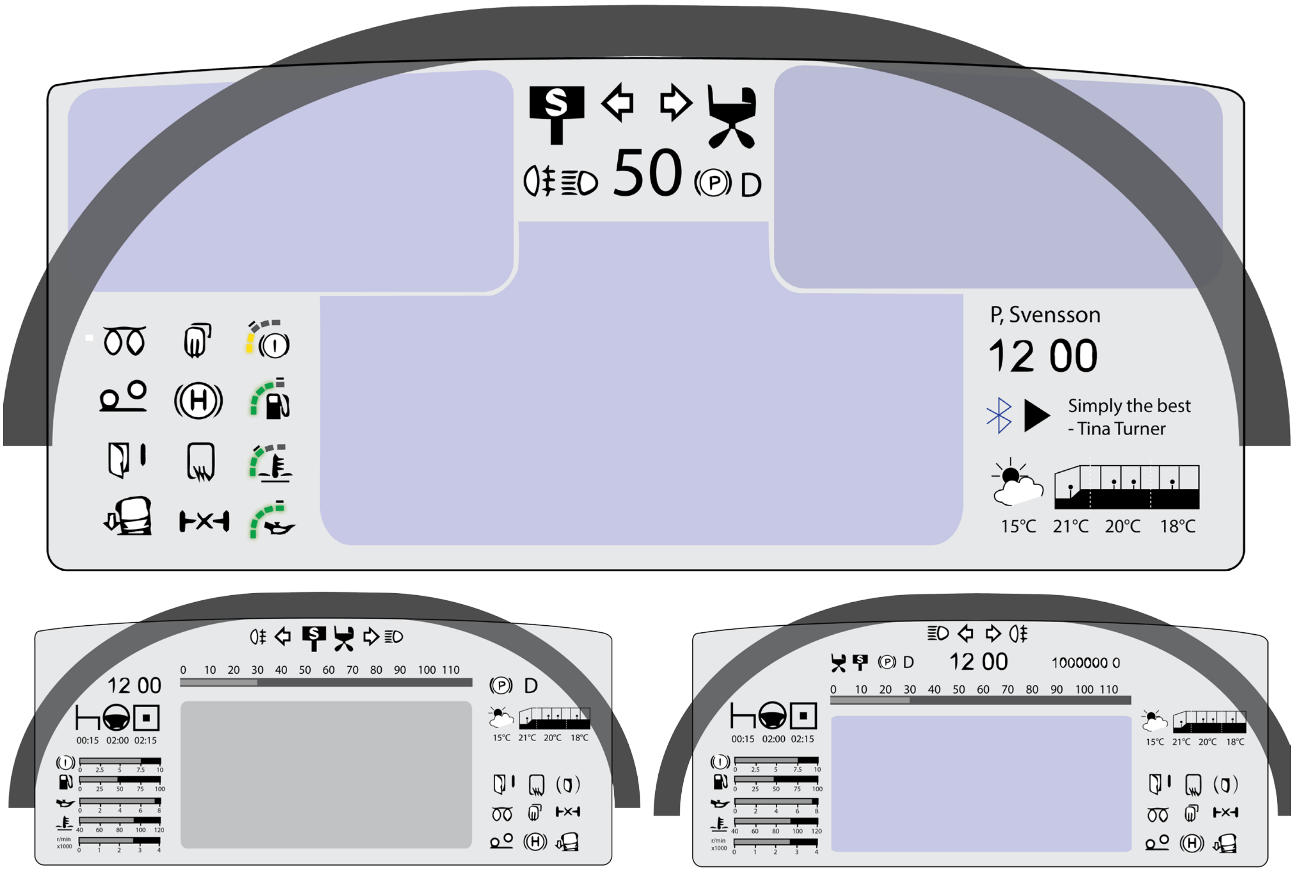


Figure 23: The standard driving screen designed for the driver types: city traffic (top), intercity traffic (below left) and tourist drivers (below right).

The differences between the driver needs are that the longer outside city traffic and help functions the bus drivers spend their work, the more responsibilities they have of the bus and therefore need more technical information. Intercity and tourist drivers therefore have continuous information displayed in form of levels.

As seen in figure 23, the concept for the city driver differs from the two concepts for intercity and tourist drivers. Since city drivers do not have the need for continuous levels of instruments, these was scaled down into symbols with colour codes, in order to promote more space for available information now placed on secondary information displays. In this way, the driver would only have to look at the cluster for the information needed, instead of having the cluster plus several more screens to keep track of, as it is in today's system. The cluster for intercity and tourist was designed similar since the data collection concluded similarities in needs and responsibilities.

8.6 CONCEPT EVALUATION

In order to get feedback on the structure of the proposed concepts, evaluation sessions were performed where concept examples were used to illustrate the different driver type's journey through the (relevant for that driver type) identified use cases. The concepts in the use cases were evaluated with representatives from different users, both bus drivers from different bus companies and technical experts from Volvo Bus Corporation. General opinions were also given from people with knowledge and experience in usability.

Results from the evaluation iterations are explained during the relevant screen it concerns. The start-up screen only concerns use case 1 while the standard driving screen concerns use case 2-4 and the error screen use case 6. The exchange of drivers has its own screen in this evaluation and concerns use case 5.

8.6.1 START-UP/CHECK-UP SCREEN

Figure 24 describes the instrument cluster at different stages in the first use case when a driver starts the bus and checks the instruments. The start-up screen will show an identity confirmation on one side, along with the driver's contained favourite settings. The settings saved on the driver card will automatically be instituted in the bus when the card has been swiped, but for the driver to know that settings that take time to adjust, e.g. climate settings, a visualisation of the shifting settings from previous settings to the new one will be shown.

Figure 24. Use Case 1 visualised for the three types of drivers.

On the other side of the start-up screen all instruments will be shown with status indication, e.g. colour coded, in order to check the status, including levels of important functions. For all instruments it should be possible to view the symbolised meaning, an indication of the current level or status as well as the placement of the instrument, in order for the bus driver to know where it can be found. This information is available to click into view, which is shown in the second screen in figure 24. The third screen that will be shown after the driver has checked the instruments will be a visualisation of the driver's scheduled route, with rest points coordinated with driver schedule and work laws as well as actual rest points along the route. This last visualisation is the only one in this use case that will differ depending on driver type; all other information is concluded to be needed for all kind of drivers.

The start-up screen should be designed to help the driver check the status of the bus and the level and placement of each instrument. It should also be a feature which need an action to be taken away and should not be able to be modified to not be shown when starting a bus. It is important that the driver is forced to check the status of the bus, even if it is not included in the driver's work to do an all-round physical check of the vehicle, it should at least be looked over before the driver drives away. This also makes it important to design the overview of instruments to be very easy to perceive in a quick and easy way.

Evaluation of start-up screen

During evaluation and feedback sessions it was found that the concepts had features appreciated as well as some areas requiring further improvement. The feedback given is listed below with the respective evaluator stated.

Volvo Bus Corporation

- A good thing, nothing to change or add.

City Drivers

- Even though they rarely check their buses before driving, they felt it to be good that the driver gets an overview of the instruments when starting.
- Great if settings already set before driving away, which saves time that drivers' mostly not have.

Intercity Drivers

- Like the overview of the instruments. Have the same feelings the city drivers brought up.

Tourist Drivers

- The start-up screen is useful, especially if it shows exactly where in the bus the error exists, e.g. which lamps that needs to be checked etc. instead of just showing that the lamps needs checking.
- Good to divide the temperature in the bus, having several sensors and be able to set them individually. Passengers are often complaining that it is too hot in the back of the bus.

Usability Scholars

- The start-up screen is easy to understand, the colour coding makes you think there is a need for fixing the things with red colour before going on driving.
- The fact that the start-up screen covers the whole instrument cluster is alright when standing still, then information only needed at the moment is displayed which would make it easier to process. However, it might be clearer to have a constant standard screen to make it clearer where functions are placed.

8.6.2 STANDARD DRIVING SCREEN

USE CASE 2: DRIVING DEPOT-ROUTE START

The driving from the depot to the start of the route (as well as driving to depot after route end) is most affected by bus accidents; the information given to the driver through the instrument cluster should therefore stimulate the driver enough to keep alert. Since this is a time where the driver do not have passenger related things to think of, it is considered the time that is most preferred to show driving related functions, e.g. eco driving levels, as well as entertainment and personal favourite functions, e.g. music playing.

The standard driving screens used in figure 25 differ depending on driver type, partly in order to show how the different screen themes could look in reality and partly due to the different driver type needs. City drivers have more add-on screens and more things to keep track of at a time than both intercity and tourist drivers, which is why their standard screen has been visualised with three availability placements of information. Intercity and tourist drivers have no need to show several things at a time and should therefore prefer a screen with only one big availability placement. The level functions also differ in visualisation for the driver types, intercity and tourist drivers need a prioritised check-up visualisation while city drivers should only need a quick colour coded level of the function. A tachometer as a level function has also been added for tourist and intercity drivers, since these types might need it in harsh or unknown situations where city drivers never have need for it, since all buses are automatic and they have never use for a manual mode.

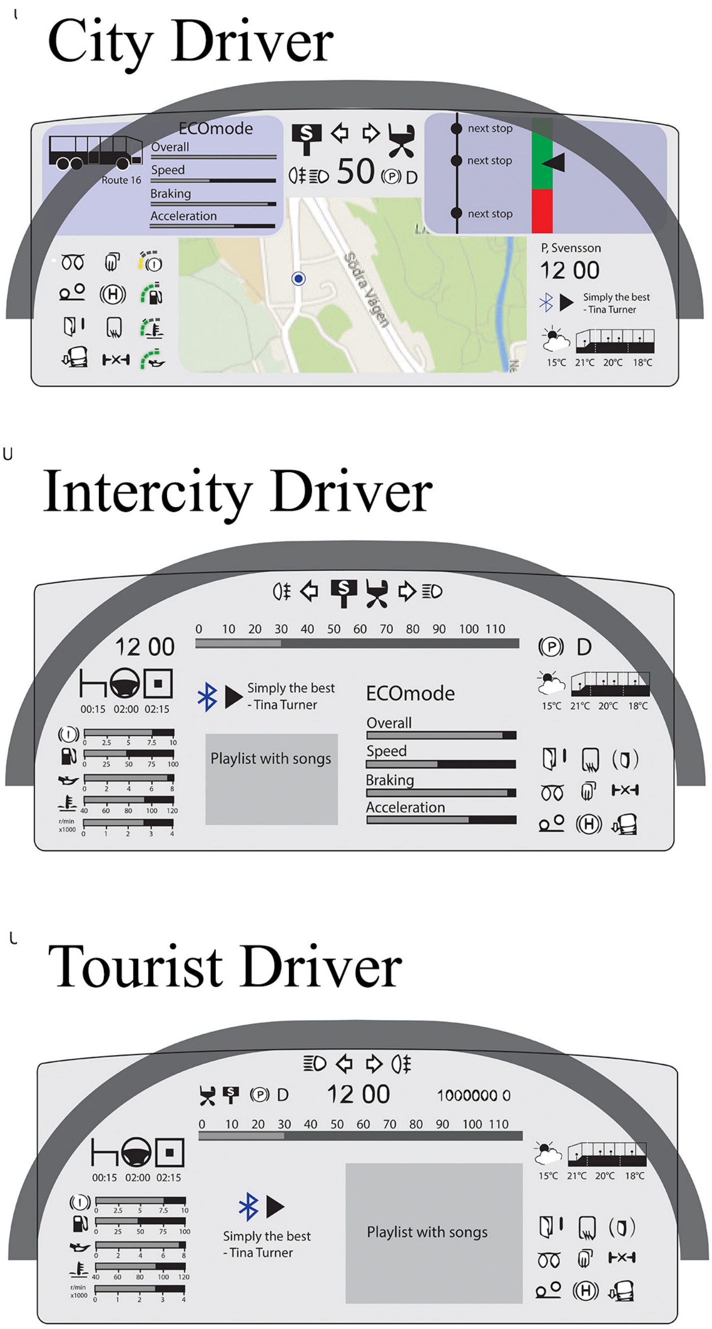


Figure 25: The clusters for driving depot to route start.

USE CASE 3: DRIVING IN CITY TRAFFIC WITH PASSENGERS

City traffic is the most hectic environment for a bus driver to encounter. The bus driver needs to manoeuvre the bus in small and tricky environments while keeping track of obstacles on the road, vehicles and pedestrians. Furthermore, the passengers need to be kept under surveillance and the time plan and bus stops need to be kept in order to keep the system going.

In order to enable the best overview possible of all things considered to be of importance while driving in city traffic, the cluster was designed to implement additonal information shown on secondary information displays in today's system. Thus, the three availability areas in the cluster. It was considered possible that an interactive map showing the current route and the placement of the bus in accordance to it would be preferable to show on the screen, but it was not needed to be the most prioritised function, hence the placement in the upper left corner. In the upper right corner, the visualisation of the timetable provided by the public transport organisation could preferable be placed, since it is a vital part of the work day for a city driver. The most important function that endanger the bus and its surroundings are the people walking near the bus, this problem should be solved easiest by visualising the nearest obstacles through a night vision technique placed in the middle of the cluster.

The difference in the standard cluster between city and intercity drivers remain the same as the cluster for driving from or to the depot, see use case 3. Intercity traffic drivers driving through might have use for a similar standard cluster with three availability placements as the one used here for city drivers, since they also might have a timetable to consider which could be added in the screen. However, since they only drive through the city a small part of the drive and do not need the visualisation of several functions at a time in the same way as city drivers do, it is considered best to only have one availability placement in the middle as before and only show one function at a time. If the individual intercity driver use a timetable screen it could be used on add-on screens as it is now, or it could be integrated into the instrument cluster after the driver's or the organisation's preferences.

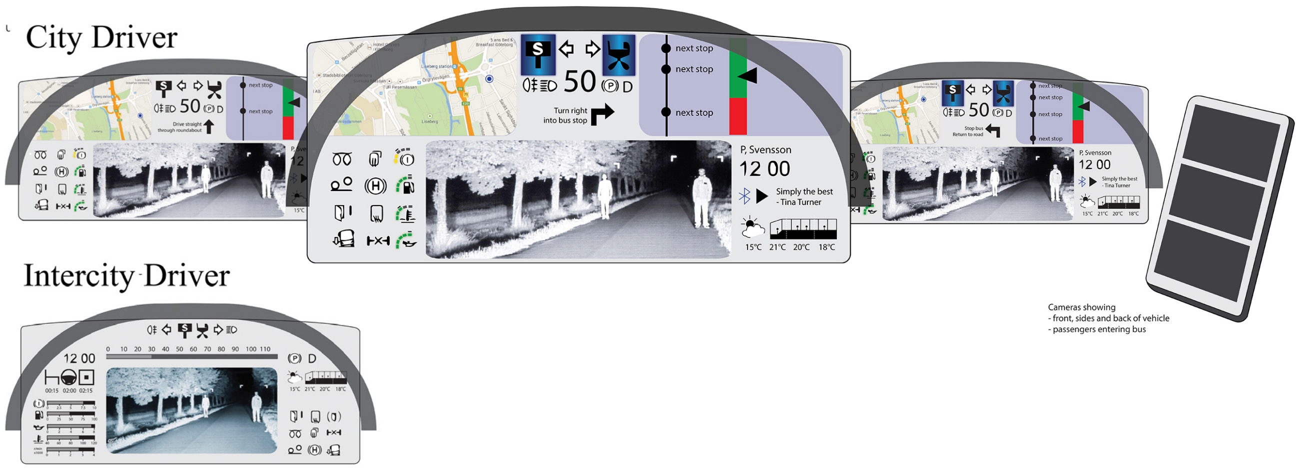


Figure 26: The cluster designs with visualised information for driving in city traffic.

With the use case as a base, the instrument cluster of the city driver could be transformed in a manner as visualised by figure 26. The route is already programmed on the driver card, which has been swiped so that all information about the route is already inside the software. Through the cluster, information about next change of direction is displayed to enable easy driving of the correct way and repress confusion. When a passenger has pushed the stop button, it should clearly be visualised a short time before the driver needs to turn into the bus stop (thus, the visualisation should not be coordinated with the actual push of the stop button, but rather in accordance with closing up to the bus stop), here background colour is used. In addition to the visualisation, directions to turn into the bus stop should be visualised on the screen as an direction indication placed in the centre. While driving closer to the bus stop continuous feedback should be given through the time table, visualising that the bus stop is closing up (and which one will come after that one) and how the driver lies in accordance to the time plan. When entering the bus stop the driver should be given feedback on the placement of the bus and the entering of passengers through camera feeds from add-on screens in the same way as it is in today's system. This is due to the limited space existing on the cluster.

Intercity should have a similar use case scenario, with visualisation of the stop signal big and clear enough to be perceived easily without actually glancing down. Directions could be provided in the cluster if needed, though most intercity drivers have the mind of a tourist driver and might not have the need for directions unless they are beginners to the task. City drivers drive so many and similar routes it might be hard to keep track of which route that goes which way, which makes the directions needed in another way than for intercity traffic.

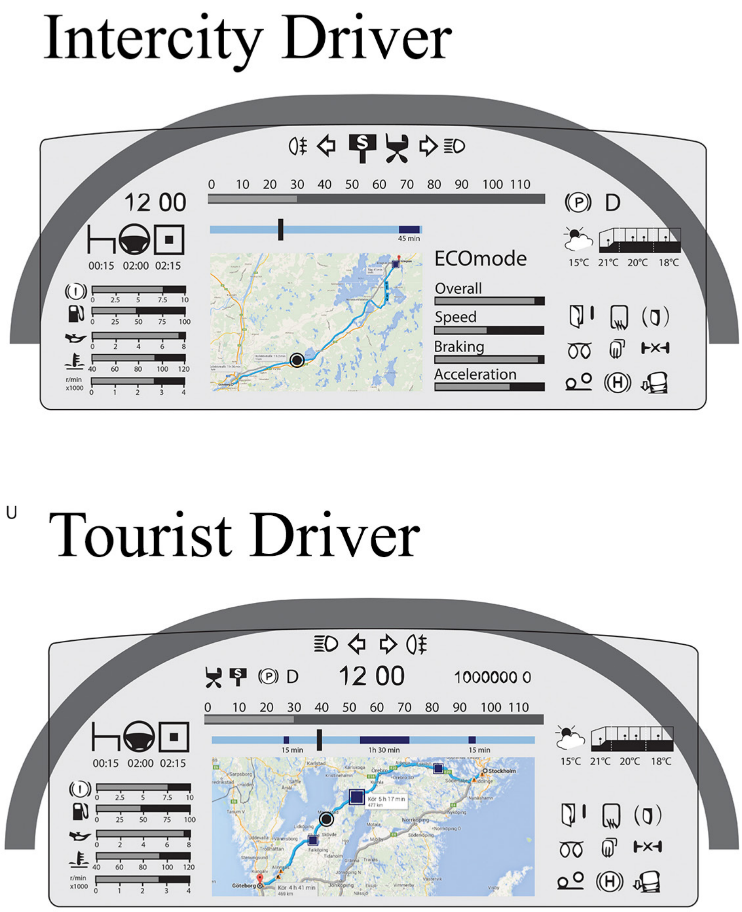


Figure 27: The clusters for driving longer distances.

USE CASE 4: DRIVING COUNTRY ROADS WITH PASSENGERS

To stimulate the driver while driving longer distances, level functions and driver time recorder could preferably be prioritised in the cluster and clearly visualised. Additionally it could be useful for the driver to keep track of the route currently driving and when and where possible rest points are available in accordance with the driver breaks. Furthermore levels of eco driving could be added in the availability placement, though from the user study it was concluded that tourist drivers often have big experience with driving and do not feel the need for eco levels being visualised in the cluster at all. They rather need a clean and functional cluster showing information needed while driving. The most useful function would be an interactive map showing not only the route, but where accidents have happened and where alternative routes exist that are possible to drive with heavy vehicles. As a conclusion, the standard information cluster for driving longer distances could possibly look the way shown in figure 27.

EVALUATION OF STANDARD SCREEN

During evaluation and feedback sessions it was found that the concepts had features appreciated as well as some areas for improvement. The feedback given is listed below with the respective evaluator stated afterwards.

Volvo Bus Corporation

- To change theme is interesting and could be further developed, especially for city traffic.
- Describing how the instrument cluster changes when performing on and off loading and getting closer to a bus stop would be good for the understanding of the concept.
- It would be interesting to see how colours could be utilised to give information in an easier perceptive way.
- The cluster needs to include space for functions that is popping up on the display in today's system, as for example of doors opening.
- Relevant information could only be visibly when needed, rather than all information having its

own space as it is now. The instrument cluster could be even more dynamic.

- The stop button could be shown over the whole adaptive part of the screen when the bus needs to turn into the bus stop.
- Strive to make a cleaner interface; especially the city instrument cluster might be overwhelming.
- The actual size of fonts and symbols could be included in the design, to provide recommendation of what is easy to read and perceive.
- For passenger detection and other functions, maybe the user do not need to see the functions visualised, the system could keep track of nearby threats instead and show a warning when needed.
- It would be interesting to also see how the secondary information displays could be used to control the instrument cluster.
- It is good if the concept can show how the instrument cluster is controlled and accessed.
- To take away the round classical shape of the speed meter is questionable, since it looks good and gives beauty to the instrument cluster.

City Drivers

- It is important that the important things are clearly visible. The displays are often hard to perceive in bad sunlight.
- It is more important to show when something is wrong. And a lot of information can be removed.
- Most things and values are uninteresting for the city drivers, e.g. fuel and oil are refilled by others after the work day.
- Only warnings a bit before critical state is necessary.
- Better to have the time shedule, route and bus stop visualisation on secondary information displays.
- It is important not to be disturbed by irrelevant functions as time recorder, which is now giving reminders and error messages even if city drivers are not obliged to use time recorders and the system is not used.
- Think it is important to think about what can be hidden behind the steering wheel. Depending on the proportions of the driver and if the instrument cluster is not moved when the steering wheel is moved, the view of the cluster can vary a lot. Maybe the instrument cluster can have adjustable height.
- To have the speed as a number is OK, as long as you see it clearly and it is not hidden behind the steering wheel. To have big round scales, that is mostly showing the speed that is not driven, is not necessary.
- If pedestrian spotting, could be nicer if the system warned instead of visualising everything.
- For city driving there is no need to visualise the maximum allowed speed, because you will not even come close to it anyway in the city.
- When the passenger "call" the stop button the current screen and symbols there is not checked. It is only the extra stop lamps that are looked at. So the stop visualisation on the instrument cluster could be removed or become bigger so that the other lamps can be taken away. Although because of blinding effect of the sun, it is currently much easier to look at the other lamps than the screen.
- Also the visualisations showing that the doors are opened is not checked, instead the driver check the rear inner mirrors to check that. But if there is a problem with a door, it is nice if that is visualised in that way, to see where the error is.
- It is not very far to drive to the depot and too much information takes away attention from the road. Might be enough with just simple display and it might be fun to use the eco coaching function to test your driving. Which you do not want to do with passengers in hectic city traffic.
- The screen could be simplified; it is still so much to think about anyway.
- Possible help to visualise route changes that seems to be coming into the industry. As it is today,

when traffic management indicates a street name that the driver do not know about, the driver has a hard time to adjust to the route change. Thus, a map showing the new route could be beneficial.

Intercity Drivers

- Does not need to see driver's time visualisation and time recorded if driving a route no longer than 50 km. The routes are planned and scheduled to be on the safe side, even if there has to be time recorders, there is basically no risk of driving too long time and get fines. The driver does not have to keep track of this. But warnings before going over time could still be nice as a backup.
- Tachometer is unnecessary if in an intercity bus without manual gear mode available. The only time there is some need of the indication is when it is slippery and the wheels are spinning, but then a warning could come up instead.
- To have the maximum speed allowed visualised on the speed scale could be beneficial if driving on country roads.

Tourist Drivers

- In order for the map to be useful, it needs to be interactive and updated in the instant anything happens in order for the drivers to plan long ahead. Road blocks and accidents should be showed but also available alternative routes that can take heavy vehicles.
- Clear visualisation of the drivers drive and rest time got good feedback. Having a total time sum of the time being out with the vehicle is greatly needed. The system also needs to work after stops and not be set to zero after the bus has been left for a break as it currently does.
- Additional functions (availabilities) are better to place on add-on screens than having everything in the instrument cluster.
- Functions showing levels are important and should be constantly visible in order to perceive changes. It is good that the scales have actual values marks.
- The look of the speedometer can be made in any of the showed visualisations, e.g. as a linear scale, it is a matter of habit rather than tradition. So visualise it in the best perceived way regardless of what the history of speedometers have looked.
- Tachometer is a function that is used all the time when driving in unknown areas as tourist drivers do. To look and see if the engine is running as it should and when need to use manual mode in harsh environments.
- The tourist driver needs to keep track of the time recorder and plan for breaks at the right time. The visualisation of the day schedule, and the route map with places to stop and breaks, should be prioritised.
- All level functions are needed visible since that information is very much needed to know as a driver drives long distances. Most drivers also expressed an interest towards the system and wanted the information visible because of that.

Usability Scholars

- The round boomerang shaped scales for the level functions might be too small to perceive in a good way if the driver is interested in the continuous level.
- The circular speedometer is better than the linear scale speedometer, since it is more similar to the archetype of a speedometer and therefore it is easier to understand what it is.
- If there is a number and a scale displaying the speed, the number attract the attention, but since the speed traditionally has been visualised rather than only showing a number, speed without digitally displaying the number is preferred.

8.6.3 EXCHANGING OF DRIVERS

When drivers in city traffic exchanges buses in the middle of the work day (as is often done) it should be done quickly in order for the driver to not lose too much of his break. This system will recognise the driver in the same way it does when a driver starts up a bus and checks its functions and instruments. The same menu will come up that give feedback to the driver about changes in settings that will now be activated and the check-up screen will also be visualised for the driver to get a quick overview of the bus status. The last image of the screen before switching to the standard driving screen is the route information already programmed into the driver card (which was swiped in the switching of the driver).

There is always a possibility to manually change information from the driver card. Additionally, all screens will need an action to be clicked away, forcing the driver to see the settings made and the status of the bus if anything needs modifying or checking up. These screens will of course be visualised when tourist or intercity drivers exchange bus too if the situation makes it necessary, but since this is rarely the case for those type of drivers they are not included in this use case, see figure 28.

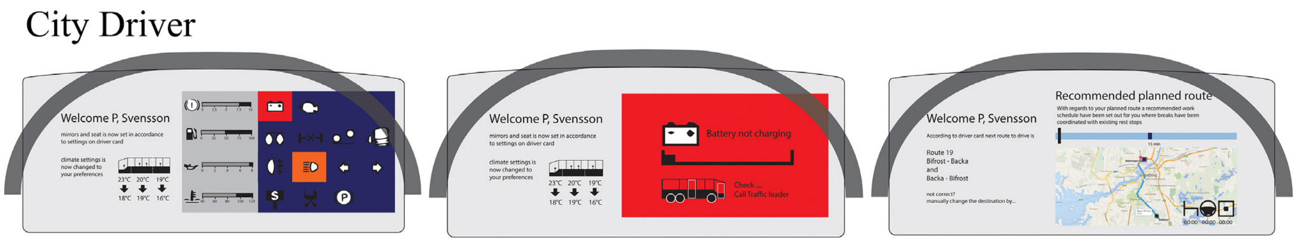


Figure 28. Use Case 5 visualised for the city drivers, since it is in this line of work the task is used.

EVALUATION OF EXCHANGE DRIVER-SCREEN

During evaluation and feedback sessions it was found that the concepts had features appreciated as well as some areas for improvement. The feedback given is listed below with the respective evaluator stated.

Volvo Bus Corporation

- When changing driver the driver could get even more information about where to park the bus and who they are changing with.
- It is good if the concept can show how the instrument cluster is controlled and accessed.

8.64 ERROR SCREEN

When an error occur that is of such a high severity, or is going to be of high severity if nothing is done to prevent it, the standard driving screen will be changed to view an error screen. This error screen could be visualised on the whole instrument cluster in cases where the driver does not need any other information in that moment than that the error has occurred, as is often the case in city traffic. Otherwise, the error screen could be placed in the same area for available functions, enabling the standard functions to still be visible during the error visualisation. In this way, drivers that drive on longer distances will be informed of the problem but have the ability to keep it on the screen while driving to first best stop. City drivers can often stop right away since the stop availabilities are frequent and the passengers in the bus are used to flexibility and can take another bus while that bus is being fixed. Tourist drivers and intercity have a more complicated situation, where they are responsible for the problem on a higher level and need driving information while figuring out what next action should be to fix it. The difference in screens is shown in figure 29.

Regardless of the placement of the error information, the screen clearly show an error indication in form of both the symbol and its meaning and the state of which it is in as well as information and feedback that information about the error has been sent to those concerned. In the screen this is shown with text and green symbol for check. The action that the driver needs to act according to is visualised with text and an arrow to indicate it to be of importance. To prevent miscommunication with help functions like traffic leaders and workshop technician an error indication number has been added after the drivers wishes.

EVALUATION OF ERROR-SCREEN

During evaluation and feedback sessions it was found that the concepts had features appreciated as well as some areas for improvement. The feedback given is listed below with the respective evaluator stated.

Volvo Bus Corporation

- Handling of errors is really interesting and something that is feasible to change.
- The error handling is good and interesting
- The steps and differences between different organisations could be described more thoroughly.
- To see where the error information goes and how to access it is interesting. It is good if the concept can show how the instrument cluster is controlled and accessed.

City Drivers

- Error handling is probably quite good. Already now there is feedback so the driver can see what traffic management has written about the problem to service, but often they describe the error in the wrong way, and that makes the problem harder to solve and identify for the workshop people.
- Now the errors are reported through communication radio or paper, and if that process could be simplified, and they can see the error in real time, that is a good thing.

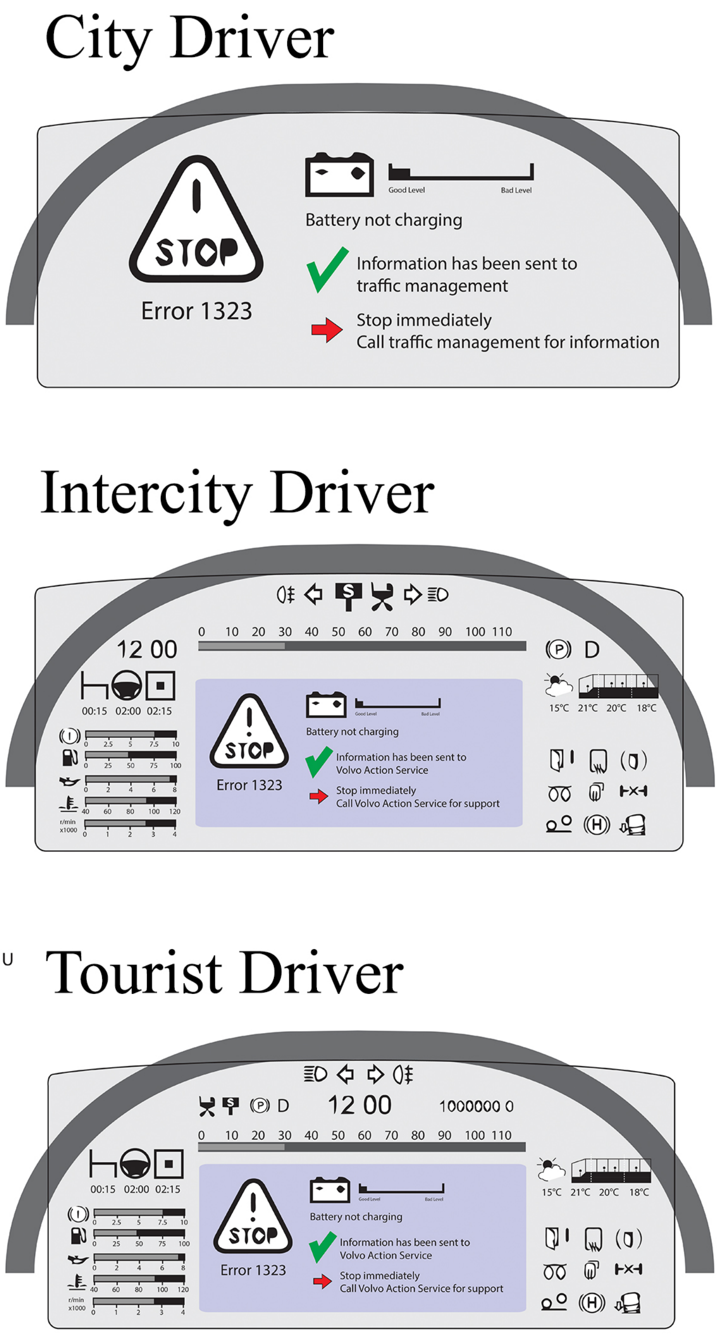


Figure 29: Use Case 6 visualised for the three types of drivers.

Intercity Drivers

- Error handling is quite similar for intercity and city driving. Same feedback for error handling was given from both city and intercity drivers.

Tourist Drivers

- The error handling solution is good; the current system is in much need of enhancement.
- Good if the information goes directly to the ones concerned so if parts of the bus needs changing, the right parts will arrive instead of the wrong ones as it could be now.

Discussion from evaluation result

Some of the feedback suggested filtering away even more information on the instrument cluster for city drivers. This could solve problems with information overload. Although, according to theory and the 8th principle for designing for situational awareness of Endsley et al (2003), filtering of information needs to be performed carefully, since some information is not needed at one time, but the user builds up understanding about the system over time by getting continuous information. A decision to keep level functions and on/off functions even for drivers in city traffic was made in order to support their mental model and global awareness of the system. Although, if the driver does not at all need to predict errors due to better sensors detecting even small deviations and information sent to the traffic leaders that can take the decision, then these functions could be removed from the instrument cluster.

Next design iteration, Concept Design 2, will explore if it is profitable to let situation driven functions be even more interactive and only be displayed when relevant. It will also be looked into if displaying these functions over a larger area would be beneficial to the drivers, balancing easy perception against the ability to see many functions at once.

8.7 Concept Design 1 Conclusions

Based on the intelligent system additions and changes to the system to which the bus driver is the functional key, concepts have been generated with areas of importance depending on the user and the respective user situations in terms of use cases. The concepts have been based on information groups considered necessary to show in the different information cluster screens; start up, standard driving, exchange of driver and error screen. Since the standard driving screen will be the most used, it was the one with most concepts generated. Different themes were generated which visualised the information groups in different ways in order to find the best suited for the different driver types and to leave room and inspiration for further detailed design.

Example of concepts were visualised for the different use cases for the relevant driver type in order to evaluate them and get feedback from users. Drivers, technician experts from Volvo as well as usability scholars were asked to give feedback on the functionality and visualisation of the information groups, their placement and look. Feedback were considered and evaluated against the need identification results and the theory in order to move forward with a solution most beneficial to the drivers and correct with respect to theory.

Concept Design 2 will evolve the concept designs from the evaluation given and explore further situational dependent abilities.

9. CONCEPT DESIGN 2

The concepts from concept design 1 were further developed and combined with regards to the evaluation and screening performed. The further design aims to correct the problems and fault found in the first development phase.

9.1 SYSTEM CORRECTIONS FROM CONCEPT DESIGN 1

The first concept design phase constituted of mainly finding out how to visualise and make room for all the information groups found to be of use for the drivers in the need identification. Through the evaluation of the concepts, a need for a more interactive instrument cluster was stated and will in this chapter be further explored. That is, instead of finding placement for all information, it should be considered that some information could be shown only when needed depending on situation. However, this does not concern information that the drivers already have stated a need for showing at all times, e.g. level functions. Focus will be on in detail describe all the variations and changes in information in the instrument cluster while using it and to show how functions are activated on and off when driving.

Additionally, one of the most important aspects found was that the drivers prefer many of the available functions (availabilities) to rather be displayed at secondary information displays (SID). This was due to the consideration that it was better to have visualisation on several screens than having it all on one that changes according to situation. Therefore focus of the final concept is narrowed to display more general information on the standard screen and limit the concept to not involve all of the additional functions available for usage.

For the final concept, all of the screens were further simplified to decrease amount of information displayed and only show what was absolutely necessary for each driver group.

9.2 CONCEPT REFINEMENT

Based on the evaluation in Concept Design 1, the cluster was transformed after the different drivers' wishes. One of the main differences is the idea that all symbols should be shown even if they are not activated (as in current cluster) in order to give feedback that the instruments do work. According to drivers, this was not necessary. They rather wanted everything black and invisible if nothing was activated or wrong. So that if something happens, they see it clearer due to the cleanliness of the screen.

9.2.1 MAIN THINGS IN COMMON

- All the different drivers need to handle errors in a more efficient way and prevent information from being corrupted or handled inefficiently.
- All drivers prefer most additional functions on secondary information displays
- All drivers can benefit from a login system which eliminates extra work and redundant information.
- The secondary information displays needs to be integrated to reduce things to login to.
- All drivers believe the aesthetics can be quite functional and aesthetic is not prioritised.
- It seems like all driver are open for changes of the visualisation of information, e.g. speedometer. They think they will get used to a new system quite fast.
- All drivers want to remove unnecessary things, but what is unnecessary differs between them.
- That the interface is easy to change also means the bus organisations can identify their own

needs and just choose the right software in the adaptabe hardware to set the instrument cluster themselves.

What separates the drivers and their individual instrument clusters can be read under the respective driver cluster beneath.

9.2.2 City Standard Instrument Cluster

Changes from the last concept design performed:

- Made cleaner
- Taken away information that is not needed
- Only one information on the availability area at a time
- Secondary information displays are used, not much information integrated from around instrument panel into the cluster
- When an error occur it will come in the middle of the screen bigger with information on what to do about it, instead of having symbols blinking among the activation signals. The driver only needs to know when something is wrong or will be wrong
- Improved the stop signals; the symbol has been taken away and instead the screen will light up bigger on the availability area with signals showing that passengers want to get off, in order to take away that the drivers need to check for symbols.

The concept for city drivers is visualised in figure 30, with the stated changes performed.

Figure 30: The standard driving screen for city drivers.

The changes are performed because the city drivers wants to take away everything that is not useful and the signal for stopping at bus stops is highly prioritised. To have guidance when routes are changed can be one of the top priorities for the availability screen, in combination with displaying errors and stops in a clear way.

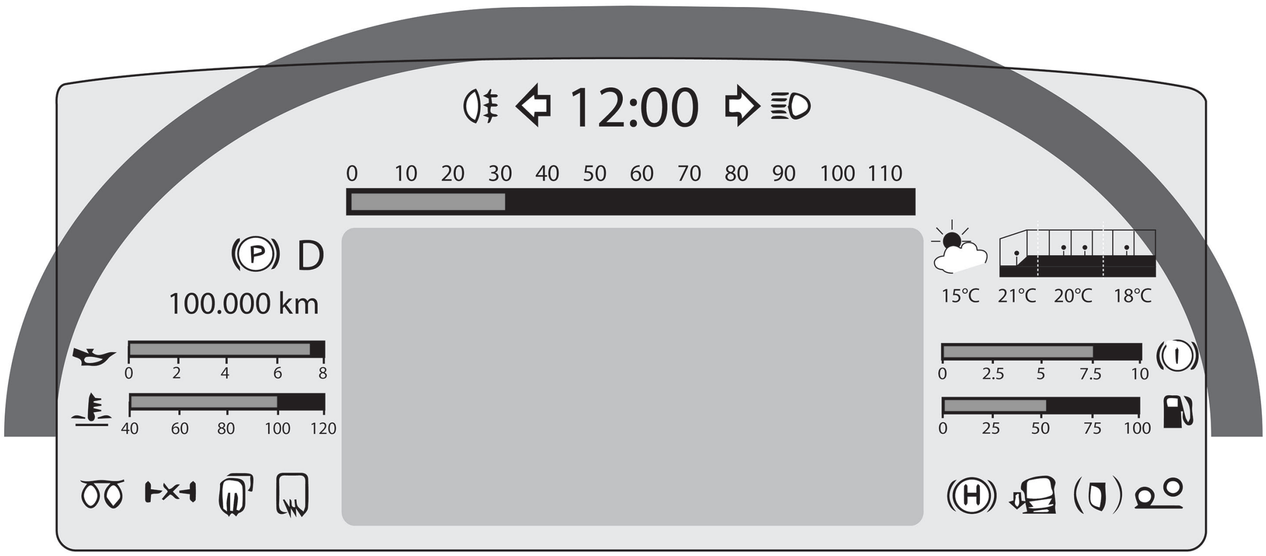
9.2.3 Intercity Standard Instrument Cluster

Changes from the last concept design performed:

- Made cleaner

- Errors will only pop up when they are relevant
- Tachograph is not needed and therefore will not be shown, instead it will come up as a warning in the availability area if they are close to a break or close to breaking the law because of driving too long
- Stop signals taken away, instead it will light up on the middle screen if someone want to get off
- The cluster is designed with symmetry in order to ease the perception of each function and to make it easier to differentiate the functions from one another.

The concept for intercity drivers is visualised in figure 31, with the stated changes performed.



Fgure 31: The standard driving screen for intercity drivers.

The changes are done because intercity have the same responsibilities that tourist drivers have, but wants the cluster to be as clean as possible due to they driving a lot through city traffic as well.

9.2.4 Tourist Standard Instrument Cluster

Tourist drivers needs seem even more different inside of the category. Therefore two examples of how it could look have been selected.

Changes from the last concept design performed are:

- The tachograph and the climate in and outside has been centered due to its high importance
- Speed is highlighted
- Tachometer is added due to their ability to choose manual mode and they do need to see the value then
- The aim for easy perception by symmetry and function differentiation.

When the tachometer is added, it is hard to maintain symmetry in the cluster; it is therefore preferable to bring back the circular look of the speedometer and tachometer. It gives a more fluid and easy perceivable look of the instruments. Though according to drivers, the look and visualisation of the speedometer and tachometer is not of importance, it is rather a matter of habit. Hence, it could look in whichever manner fits, for example a line (as in figure 32) or a circular visualisation (as in figure 33). With the circular visualisation though, it is easier to separate the instruments, level functions and the meters, from each other. Therefore, the concept with the circular levels have been chosen to move forward with, figure 32. In that way, the three different concepts represent different way of visualising information as well, which supports the many different themes suggested in this project.

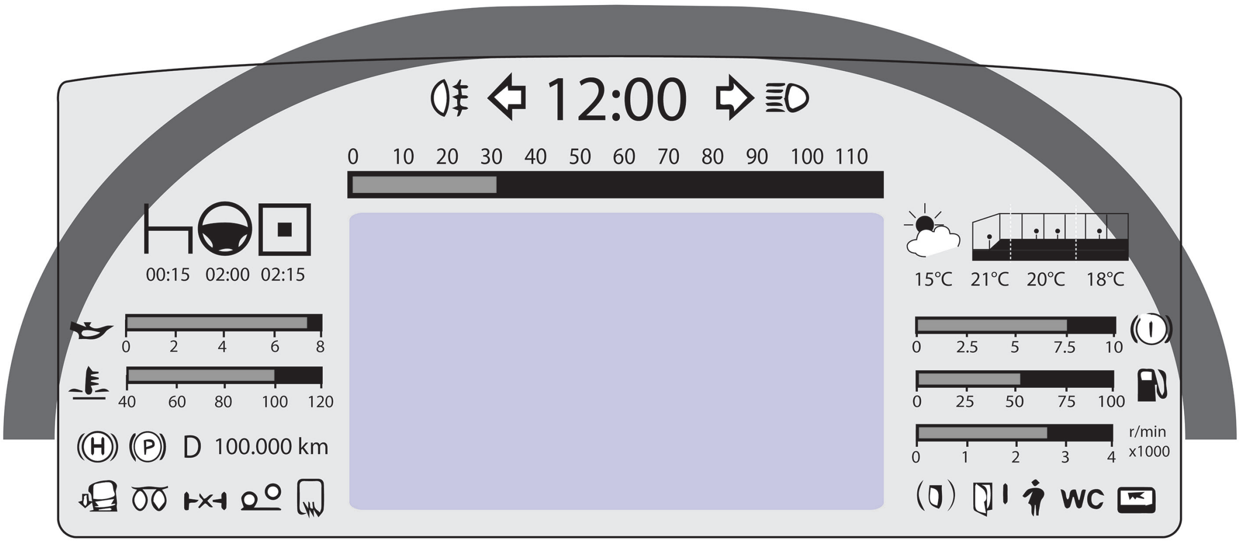


Figure 32: A standard driving screen for tourist drivers with linear scales.

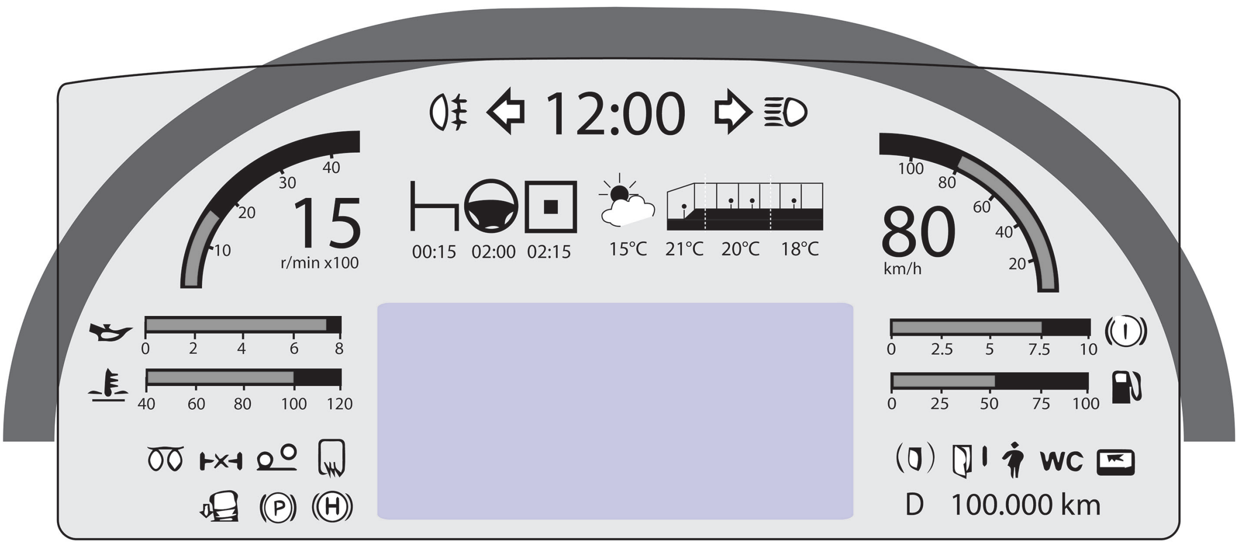


Figure 33: A standard driving screen for tourist drivers with circular scales.

The changes are performed because the tourist drivers state the most important thing beside basic driving functions is to keep track of the driver's time, to not get fines. Additionally the state of the bus is important and they need to keep track of the states to predict errors and faults of the bus. The tourist drivers need external support both with delays and traffic problems and technical problems.

9.3 Concepts and Use Cases Refinement

For further understanding of the concepts and how they will work in the new system, a similar walk-through with the new refined concepts is here described, related back to the use cases.

9.3.1 City Traffic Driver

The scenarios for city traffic is presented in the pictures, with text further describing the situation.

START AND CHECK OF BUS

The first thing the driver should do in the new system is to swipe the driver's card at the indicated area on the instrument panel. By doing this the system gets information about the individual and transform the instrument cluster to the standard screen of the driver's or the organisation's choosing, see figure 34. The left part of the screen will show a login confimation and inform the driver which settings the system has identified as the driver's and that the system is now changing the bus current settings to the new ones. The right and bigger part of the screen will show a system overview to support planning of the work day as well as give the driver a hint of the instruments that need checking before departure. If instruments are okey to drive, it will be visualised by a calming colour (e.g. blue) and if they need checking, a warning colour of orange or red will be used.

If the driver wishes to check instruments further, the driver may enter the menu by the display control stalk (which is also used in the current system). The right menu area will then show more detailed information about the problem indicated, the state it is in, where in the bus it can be located and what action is needed by the driver himself to eradicate the error.

If the system is warning about an instrument that needs checking, it may well be nothing the city driver needs to be concerned with, since the schedule might not be long enough in that particular bus, so that the error gets critical during the route. If the system checks the driver schedule from the driver card and finds that the instrument will not endanger the planned route and can wait to be checked by the workshop in the end of the day, it will be indicated on the screen.

The driver finally perceive a visualisation of the route and schedule to support understanding of the work task ahead, before getting ready to drive.

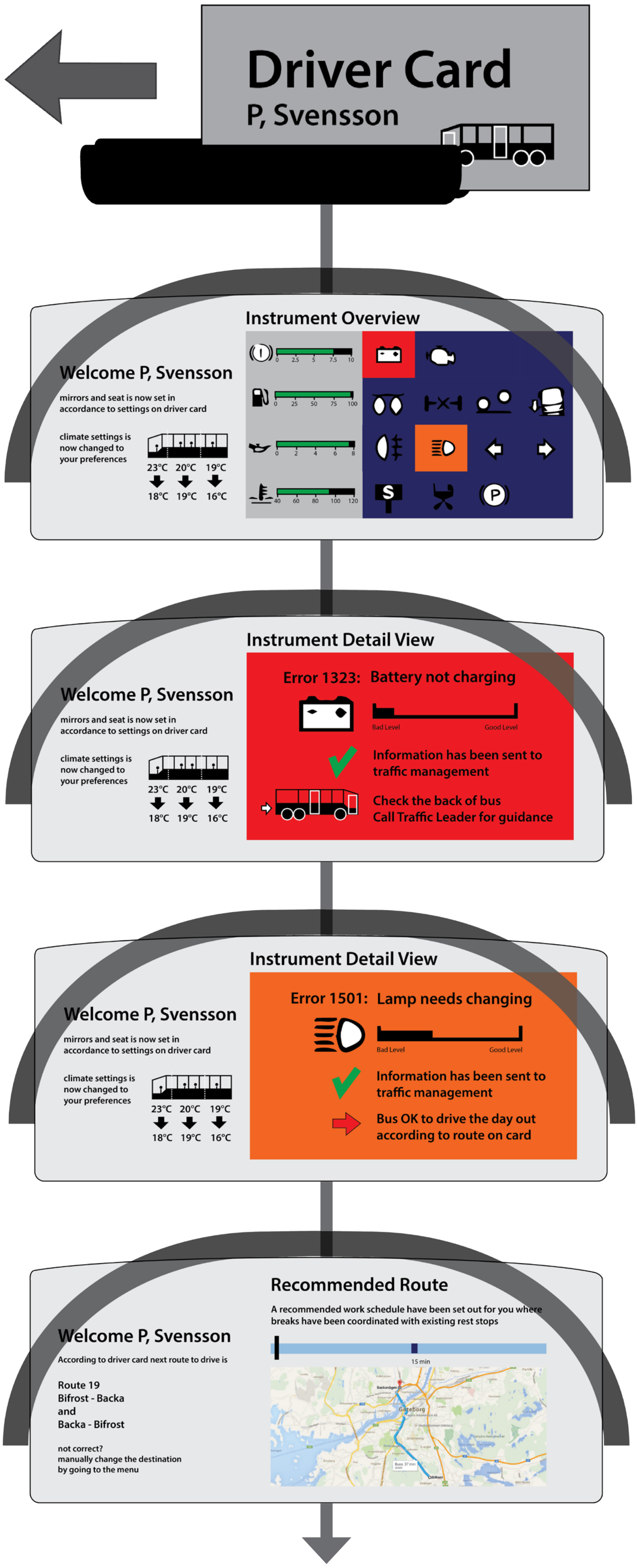
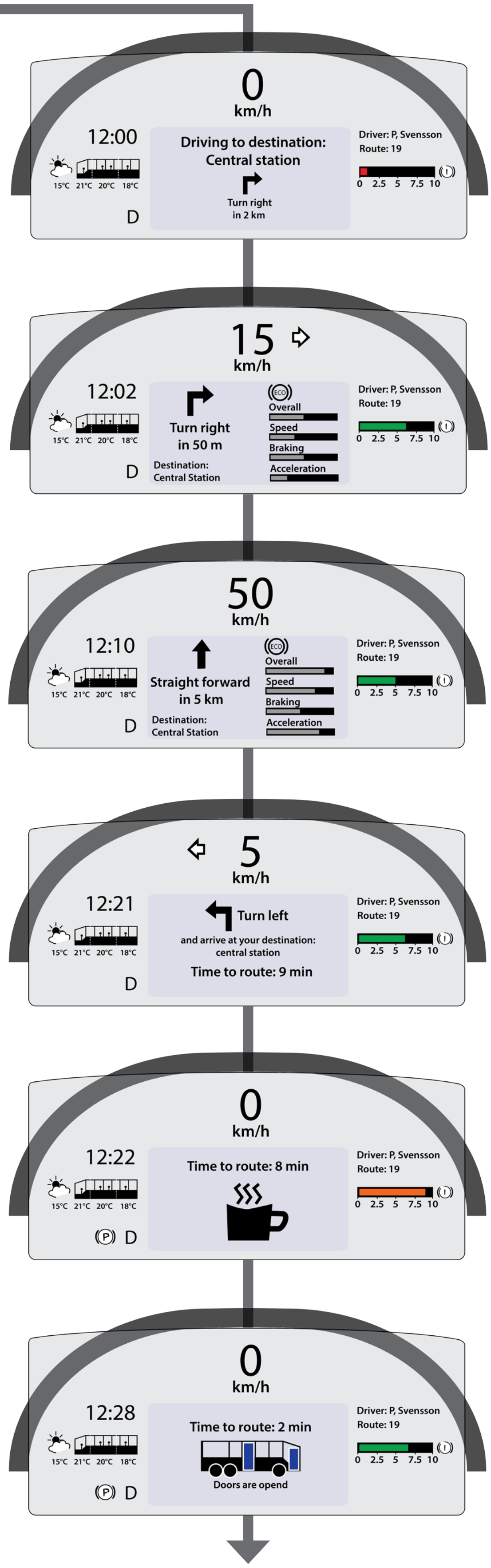


Figure 34: The city driver's concepts for starting of bus.

Figure 35: The city driver's concepts for driving from the depot to start of route and supporting alertness along the way.



DRIVING FROM DEPOT TO START OF ROUTE

After the system overview has been checked, the instrument cluster will change into the standard driving screen with the levels and information needed for the task ahead. This driver's route in the example in figure 35, starts at the central station, which is indicated at the start. Before driving out from the depot, the driver perceive through the instrument cluster that the air level is too low, so the driver knows it is not possible to start driving yet and has to wait until the level rises.

Directions to the route start is visualised on the availability screen as well as information about the current eco driving in order to keep the driver alert. Other availability functions are always selected to be visualised or not and can be found by the display control stalk. To give the city driver the ultimate clean view, all information not activated is hidden. When indicators are activated they are shown and the speed and temperature of the in and outside of bus are continously indicated to the driver.

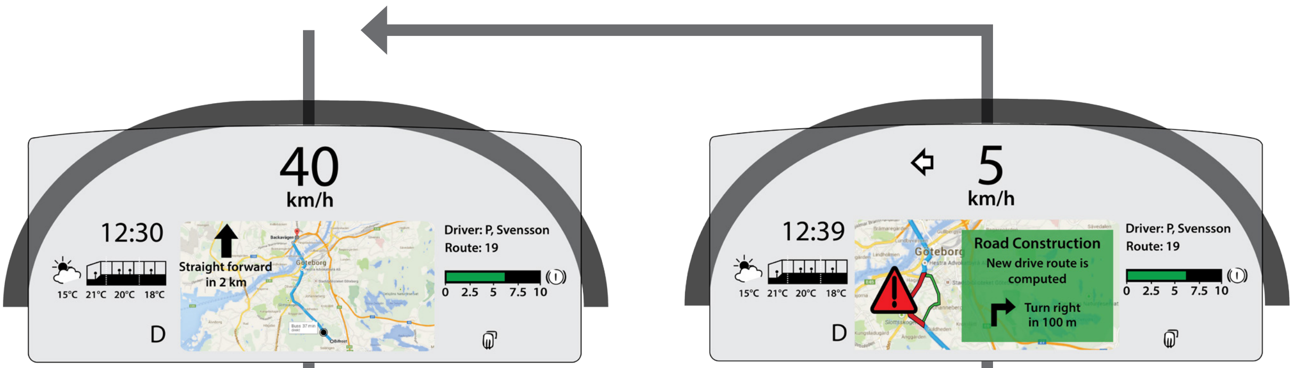
When the driver approaches the destination, time left until start of route is displayed to give the driver a chance of planning the break time during the driving and therby keeping alert. When doors are opend for the passengers it will be perceived through the cluster.

DRIVING CITY TRAFFIC WITH PASSENGERS

When driving in the city, the availability area will automatically show route support through an interactive map and, on the side, detailed indications on next direction in order to follow the route correctly. Information on secondary information displays such as route stops and time to next stop are perceived continously during the drive and the driver uses the inside mirror as well as side mirrors to keep track of the environment in- and outside the bus. The driver's position and area can be seen in figure 35.

When a passenger presses the stop button in the bus it will be indicated to the passengers as it is in today's system, but the driver will be informed of the stop signal when it is needed, some time ahead of the bus stop to avoid forgetting about it. It will be visualised big on the availability area instead of having a small symbol along with the others on the standard screen area. In that way the driver does not need to check for the symbol before stops, it will be indicated big and clear when it is relevant. It will also be indicated in the directions on the screen that the driver should turn into the bus stop.

To heighten safety and help the driver in environments with a lot of moving road blocks, a system for pedestrian spotting is included in the bus. On the cluster it will be visualised a warning when a pedestrian is too close, see figure 36.



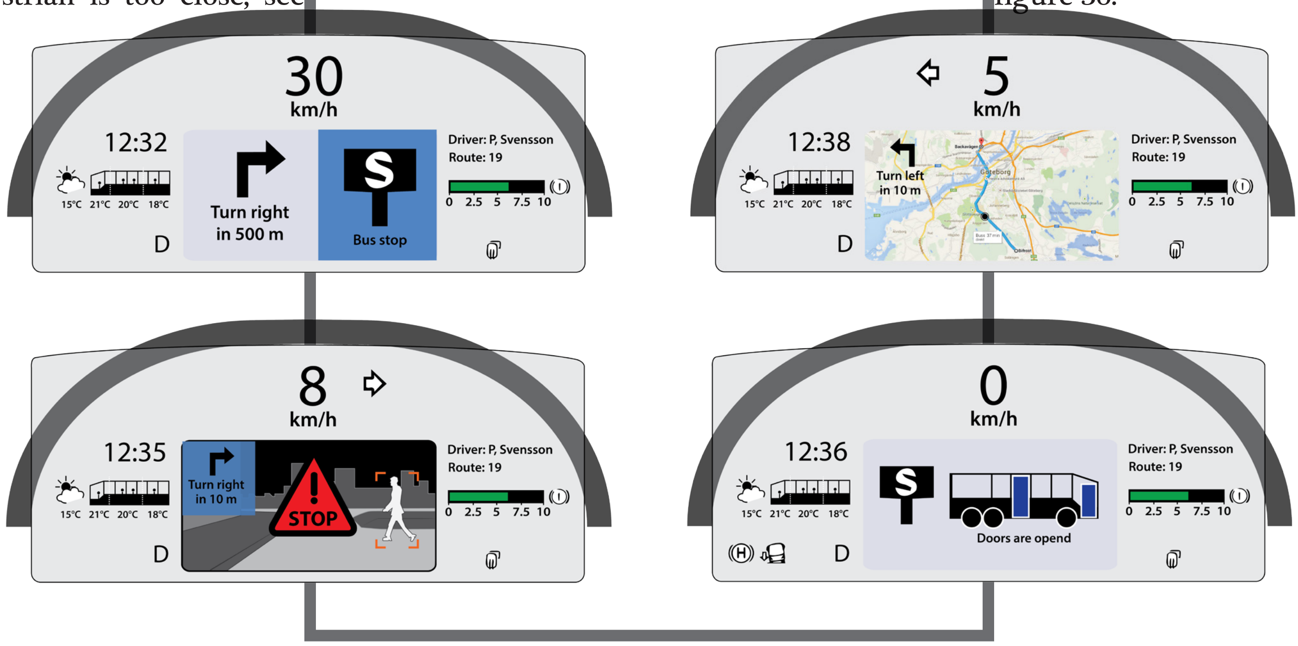


Figure 36: The city driver's concepts for driving in the city with passengers.

When the driver has turned into the bus stop, stopped the bus and opend the doors, this will be visualised on the cluster. Functions activated at the time will light up in the same way as the indicators does on the screen. The screen goes back to show the route and directions when driving away from bus stop.

In city traffic there might be interuptions on the normal route and the driver needs to consider possible route changes, it can be planned ahead, e.g. construction, or be due to an accident. Either way, the system will get information about the route problems and inform the driver through the cluster on how to move past the interruption. In this way the organisation does not need to give oral explanations and directions towards changes, it can just be put into the system to inform the driver the moment it is needed.

The information visualisations will be repeated when the different subtask are repeated and the cluster will continously change after the information needed in that moment.

EXCHANGE OF BUS AND DRIVER

When the schedule shows it is time to exchange bus, the system will remind and inform the driver through the screen, see figure 37. It will be clearly indicated directions to the exchange place with details of the number of the bus stop position to take away problems with bus drivers stopping at the wrong bus stop number.

The new driver is informed to swipe the driver card in order to log in into the system. When the card is swiped the new driver's settings will be set into the bus automatically and inform the driver of this in the same way as it does on the start-up of a bus.

Important information is displayed again, since that information might be important for the exchanging driver. The new driver also gets information about the route before driving away.

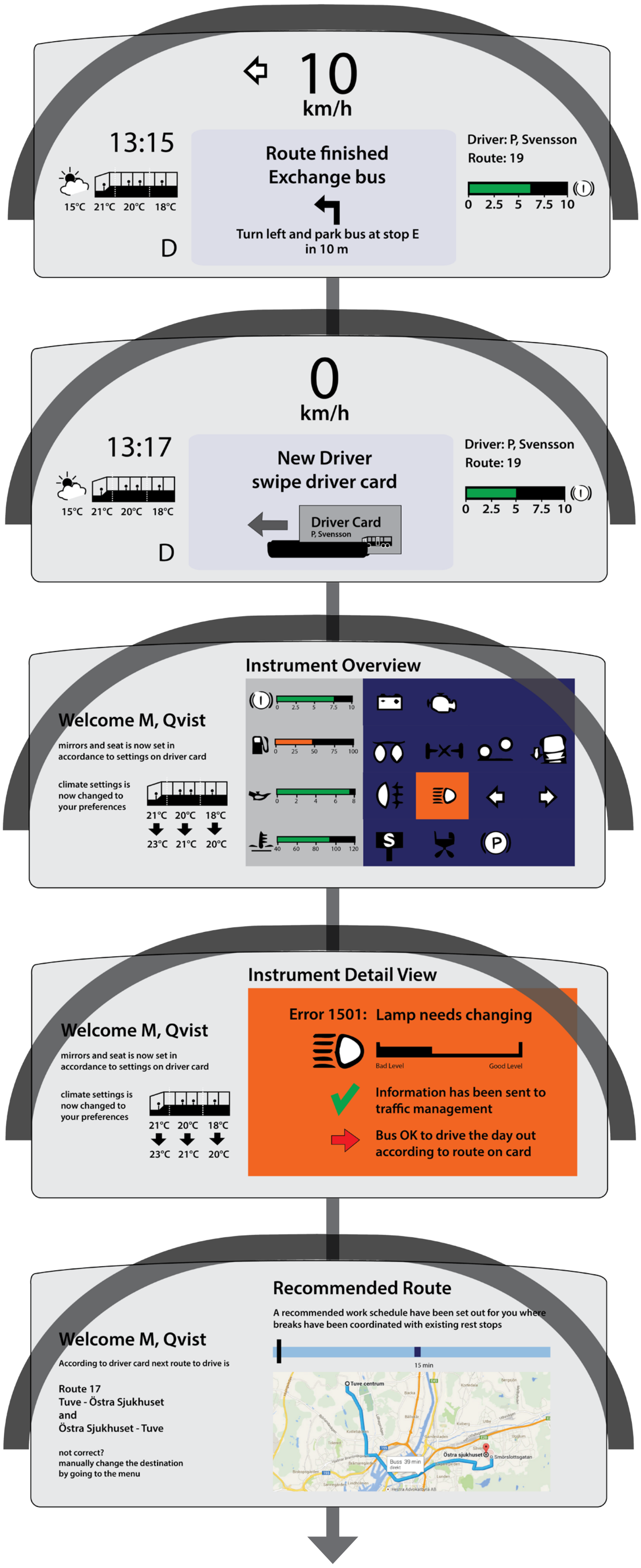


Figure 37: The city driver's concepts for exchanging driver and bus.

ERROR HANDLING

When the system detects an error, the driver gets information required to inform the driver of the problem and how to best proceed to avoid or fix it, see figure 38. The evaluation in the first design phase showed that all drivers rather prefered to have this error screen presented in a smaller part of the screen instead of it replacing the whole standard driving screen. In this way the problem indication can be looked upon and considered during driving and the driver does not have to use the menu through the controller to shift between the instruments needed while driving and the error information. Other than this change, having the error information on a smaller part of the screen, the information is the same as in concept design 1. Information about the error, it's status and what to do about it is clearly perceived. Feedback of information sent to needed help functions is visible as well as an error identification number which ease the communication between the driver and the management functions.

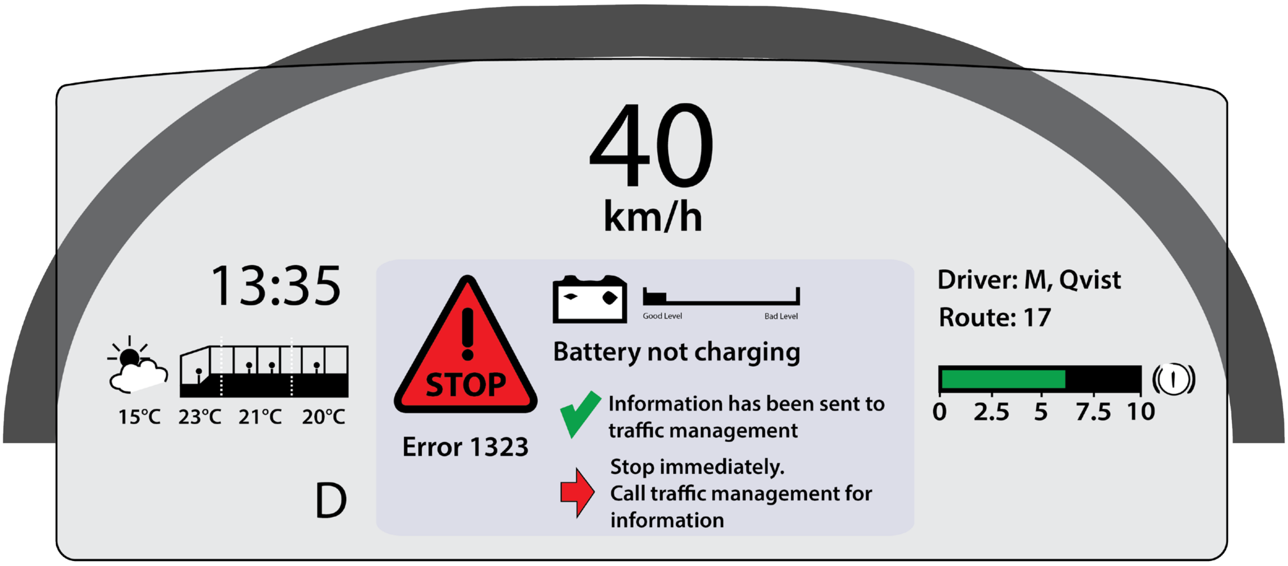


Figure 38: The concept for city drivers showing information about an appeared error.

9.3.2 INTERCITY DRIVER

The scenarios for intercity drivers are here explained in further detail with visualised concepts to help the understandig of the system and how it functions.

START AND CHECK OF BUS

The driver logs in into the bus using the driver's card and the system will recognise the identity of the driver and the preferences and settings that is registered on the card. In the concept example (figure 39) the state of the bus is fine, there is nothing needed to look into more in detail and the driver can move forward and perceive the schedule for the day with the route visualised on an interactive map.

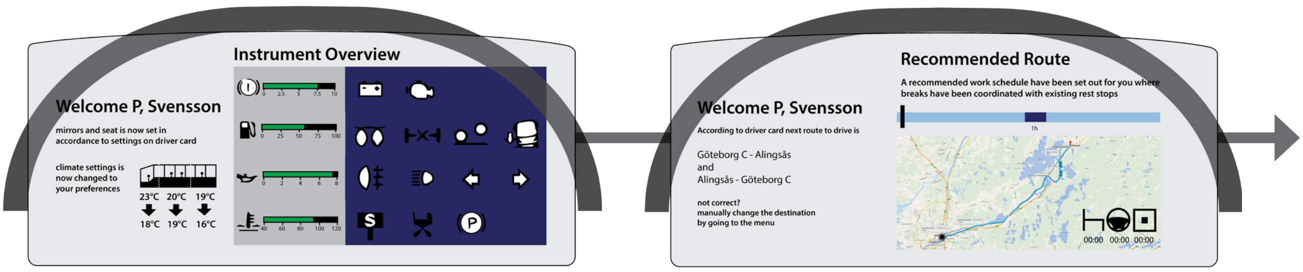


Figure 39: The intercity driver's concepts for starting of bus.

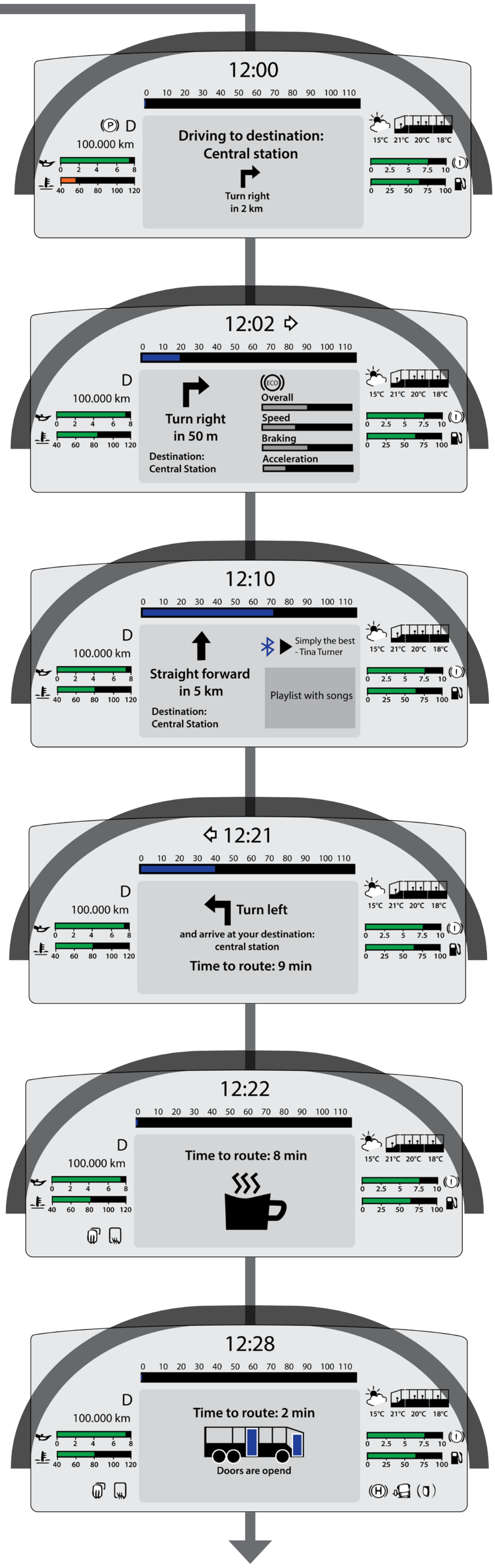


Figure 40: The intercity driver's concepts for driving from the depot to start of route and supporting alertness along the way.

The difference from the city driver's concept lies in the last information about the driver's route schedule. For drivers driving longer distances it is interesting to perceive the tachograph and keep track of that during the driving. This is shown in the final step in the start-up concept screens.

DRIVING FROM DEPOT TO START OF ROUTE

Since the intercity driver have a higher responsibility of the bus than the city drivers, they have need of more information about the state of different instruments. Where the city drivers only need to keep track of the air level, intercity driver gets further information about the oil, temperature and fuel continously during the drive, see figure 40.

During the drive, the driver is informed about the destination being set from driver card, directions to the destination and, when arrived, time to route start. On the availability area, information about eco-driving levels as well as entertainment being used can be showed depending on the driver's preferences. What information to show can be programmed on the driver's card or changed through the control stalk.

Instruments activated during the drive is shown on either side of the screen and visualisations of break time and doors being opend are perceived when relevant.

DRIVING CITY TRAFFIC WITH PASSENGERS

As city drivers, the intercity drivers frequently use the inside and outside mirrors to keep track of the environment, see driver area and position in figure 40. They drive both in high and low mental workload environments and need to be flexibel for any changes around.

During the route driving, see figure 41, the availbility area will automatically show a route visualisation through an interactive map on the standard screen in order to give the driver continous feedback of the work schedule. This is a substitute for the timetable that is used on secondary information displays in intercity buses. Intercity drivers have a route schedule with fewer stops than city drivers and therefore has a less detailed timetable than a city driver, which is why it is easier, and chosen, to be implemented in the cluster screen.

When a passenger wants to get off, it is indicated by showing the symbol for bus stop big and clear on the availability area when the bus closes up to the bus stop, and not when the passenger actually presses the stop button. Instead of the driver having a pedestrian detection system always shown, the system detects road blocks in the driver's stead and inform the driver when blocks have been registered, e.g. pedestrians. Directions are always shown to support the driver to drive in the correct way. When the bus stops at the bus stop, visualisations of door openings are perceived on the screen along with the symbol indicating bus stop. When driving away, the interactive map is shown again along with indications of directions and the tasks are repeated, as they do in city traffic.

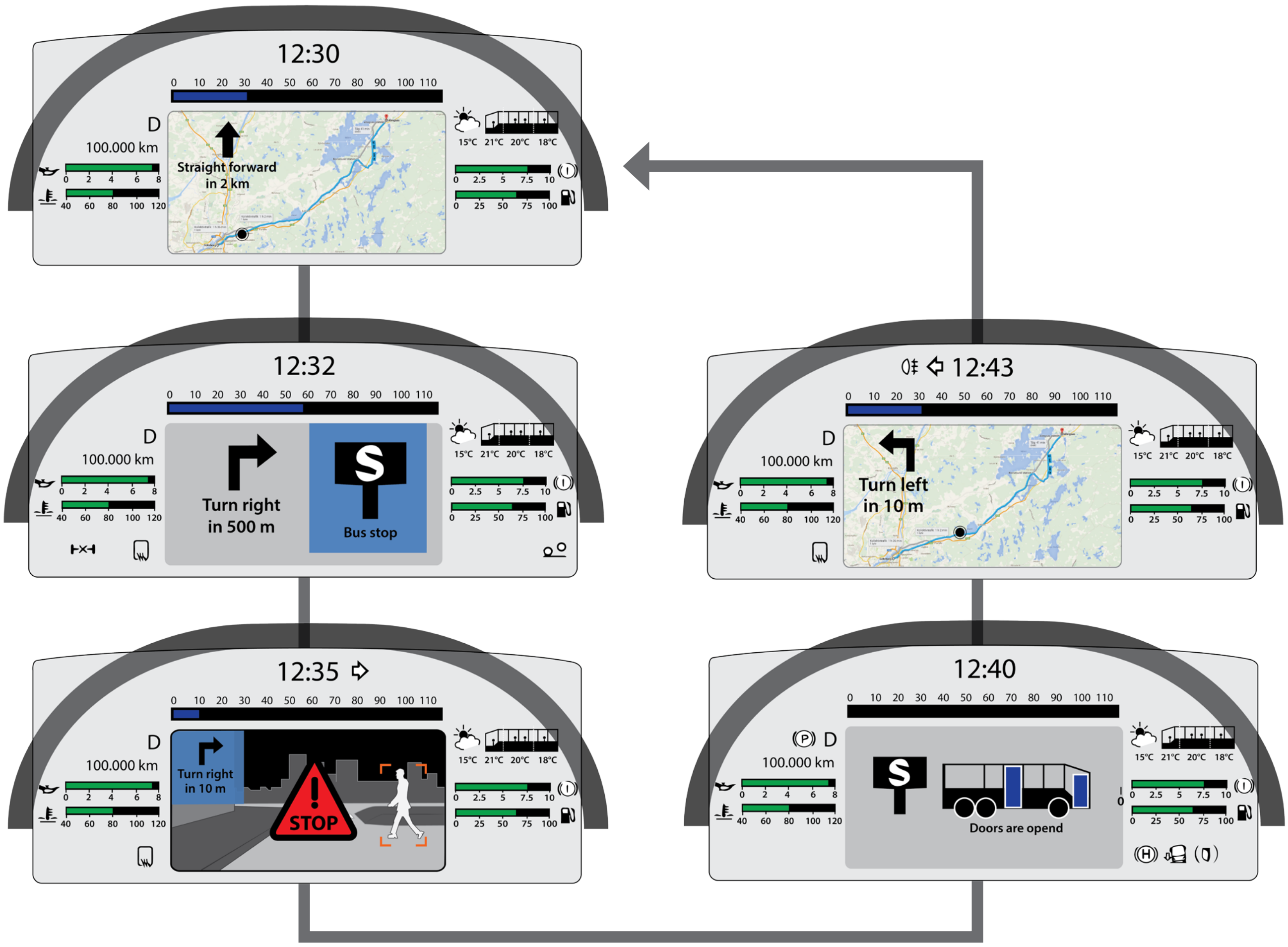


Figure 41: The intercity driver's concepts for driving in the city with passengers.

DRIVING LONGER DISTANCES WITH PASSENGERS

Driving longer distances usually means there is a low mental workload on the driver and to keep alert, route visualisations will be shown on the availability area which gives the driver something to think about during the drive, e.g. planning the route ahead, see figure 42. Information about eco-driving and entertainment used and connected to the bus can also be of use for the driver and can be activated by the menu controlled by the control stalk.

Interuptions on the road and the planned route is visualised on the screen with warning symbols as well as text describing the situation. For example, in the event of a road construction, a new route has been planned and described in order to avoid cues and save time. When driving during bad environments where lightning or wheather restrict the visual perception of the outside, the road block detection part of the system alerts the driver of upcoming movement or blockage that the driver can not yet perceive.

Information about the tachograph as well as the tachometer are not considered to be of use for the driver unless reaching or getting close to reaching a high state that risk safety or regulations. Information about that will be shown as an error indication instead of continously be visualised on the standard screen.

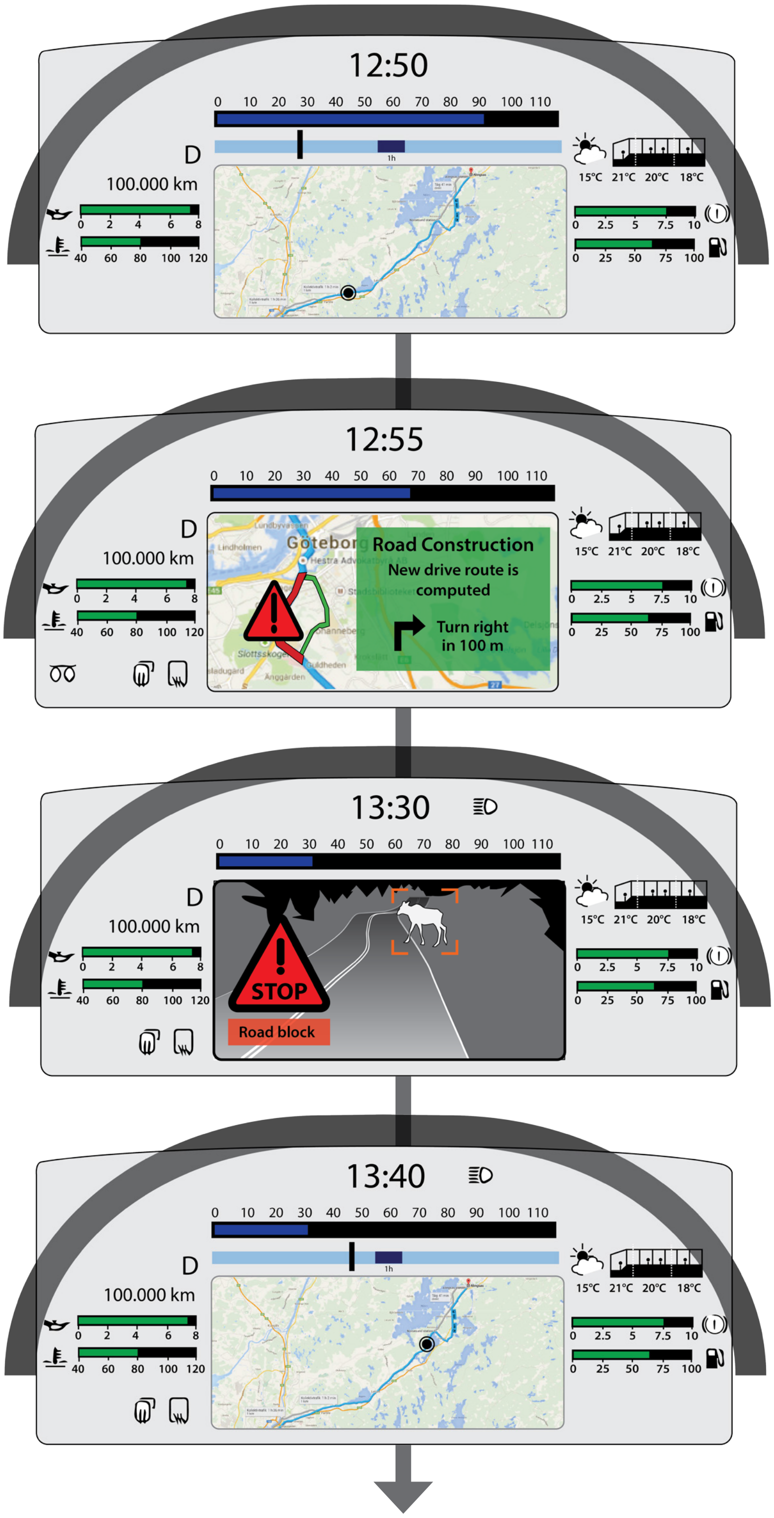


Figure 42: The intercity concepts for driving longer distances.

ERROR HANDLING

Indications about appeared errors will be visualised on the availability area to support easy perception for both the error indications and the standard driving information that is needed during driving, see figure 43. Information about the error, its state and action towards it will be clearly perceived though symbols and describing text. Feedback that inform about the error being sent to help functions will be indicated and an error identification number has been added to ease communication between the driver and the help functions.

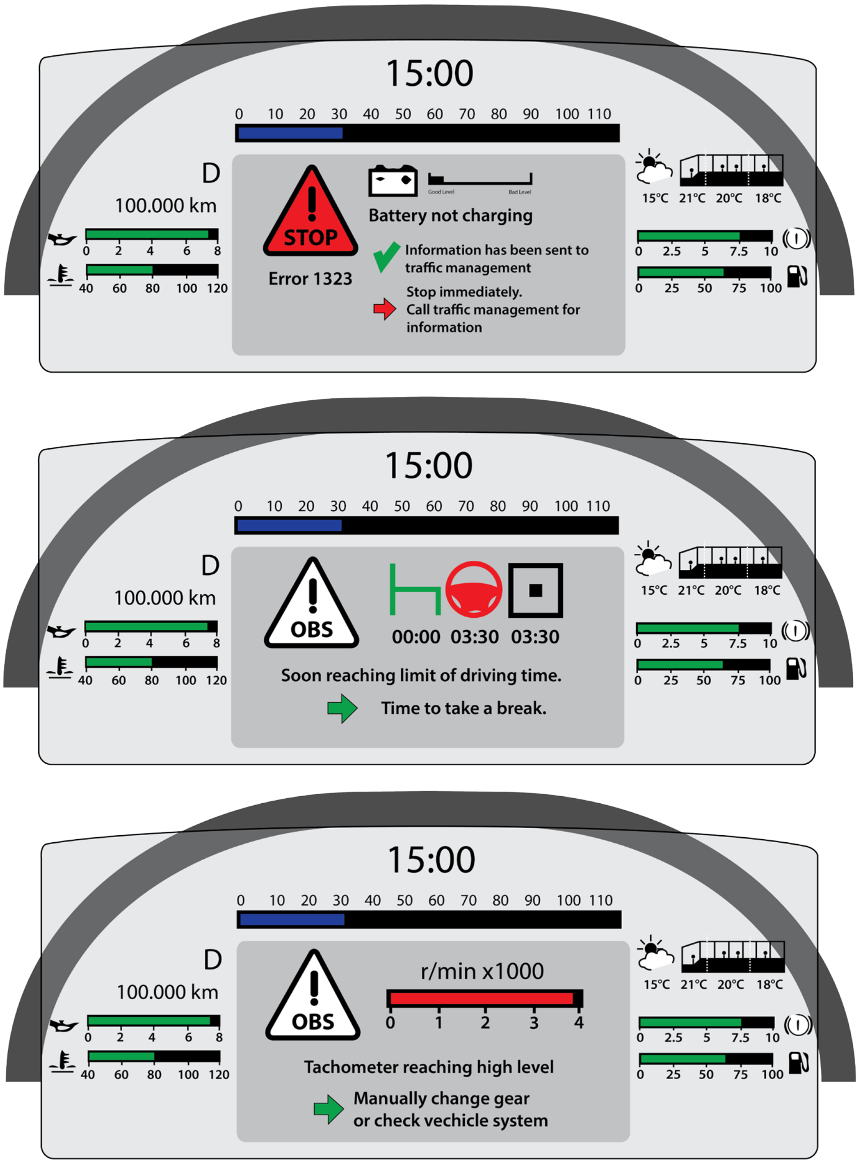


Figure 43: The intercity driver's concepts for error handling.

In addition to the error screen that is presented in the figure 43 and has constituted the error handling up until now, another type of error screen has been created for intercity drivers. This screen concerns information that is not pre-sented on the standard in-strument cluster but need to be observed if the level gets too high. For example a high level of the tachometer or a too long driving rate without break. It is presented in the same way as the first error screen but does not have a stop indicator since the infor-mation is not as severe as the error indications. Instead it is indicated, observ or obs, on the screen along with the rel-evant information as well as the correct action towards it.

This screen is needed for the intercity drivers in another way than for city or tourist drivers. The intercity drivers have the responsibilities (e.g. a need for tachograph infor-mation) and availabilities (e.g. possibility to manual gear) as the tourist drivers, and there-fore need to keep track of this information. City drivers do not need the information at all and tourist drivers will have it continosly on their standard screen.

9.3.3 TOURIST TRAFFIC DRIVER

The scenarios for tourist and charter driving are presented in the pictures, with text further describing the situation.

START AND CHECK OF BUS

When entering the bus, the tourist bus driver swipes the personal driver's card to log in and then the bus automatically change to the driver's saved preferred setting. Before performing the safety check on the bus, the driver looks at the start up screen that comes up and directly see if there are errors already identified by the sensors. In this case, see figure 44, the lights might be a problem needed to look at. Also, it seems like the fuel is not refilled recently, and the driver gets aware of that. The refill of fuel needs to be planned into the work schedule, if not possible to perform at the depot.

The driver enters the warning information about the lights by using the lever by the steering wheel. Depending on type of error, it might be possible to use the bus anyway. The driver gets information about that information has been send, to whom and what action the driver needs to perform.

When all errors have been checked, information about the planned route comes up on the instrument cluster start up screen. The information about the drive is taken in from the organisations own traffic planning system and compared with available stops, road blocks and traffic information from national or third party navigation system. The driving time and breaks are extremely important to plan and take in consideration for the tourist drivers, to make sure they comply with the driver's time regulations and still fulfils the passengers' requirements. The recommended route start up screen is a good tool to visualise and support the prediction and planning of the drivers. This is updated, to make sure road blocks or other obstacles affect the driving negatively as little as possible.

DRIVING FROM DEPOT TO START OF ROUTE

When leaving the depot, the tourist bus driver sees the information on the standard tourist instrument cluster together with navigation information. In the standard cluster for tourist buses, the tachometer is clearly visualised, se figure 45. This is important since the tourist drivers need to drive in manual gear mode sometimes, and many of them like to keep track of what is going on in the engine, to see the small deviations that could indicate the initiation of a technical problem.

The driver's time schedule is also visualised, and additionally to available functions in the current system, the total driving time is visualised. The driver does therefore not need to take notes about the time before it resets, which was needed in the current system. Other important factors like time, weather and temperature is displayed.

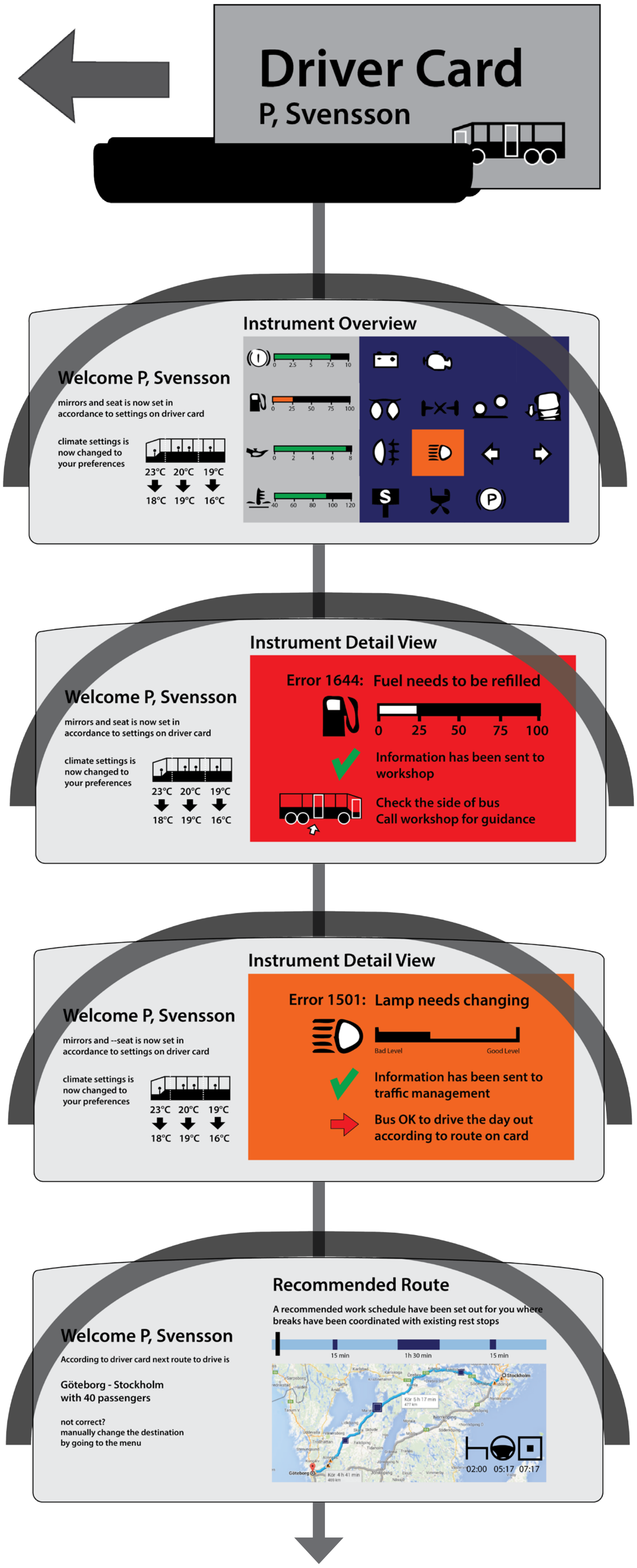
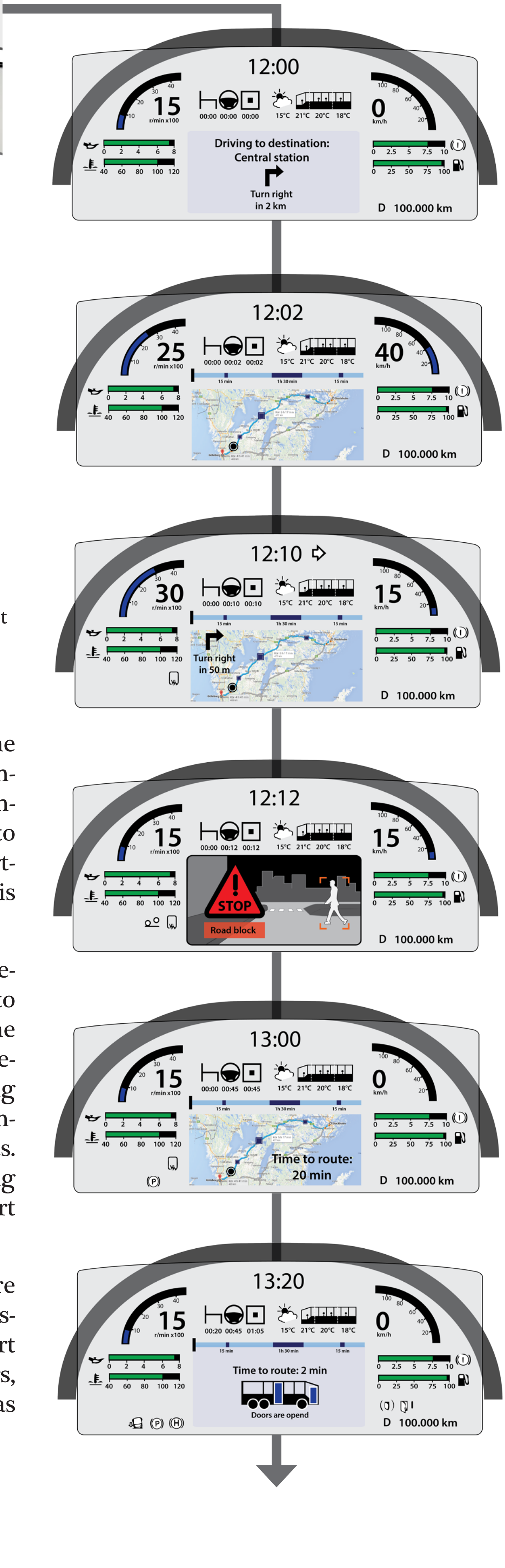


Figure 44: The tourist driver's concepts for starting of bus.

Figure 45: The tourist driver's concepts for driving from the depot to start of route and supporting alertness along the way.



Most of the time when driving, the driver can see the time and map visualisation of the route, which is important for the situational awareness and supports planning and alertness. The map can be set on navigation, to support finding the way. In this case, the driver is starting the route at the central station and the destination is automatically set in the system.

The system uses sensors and warn the driver when pedestrians or other road blocks appear in close range to the bus. This was a wish from the drivers during the evaluation of concept design 1, that the system itself detects blockings and warnings instead of the driver using the pedestrian spotting technique and constantly (manually) checking for blockings and close movements. This system detection is useful aspecially when driving without passengers since the driver might be less alert in those situations.

Sometimes the driver needs to drive a long time before reaching the route start and can start loading the passengers. Time until route start is visualised to support planning. When stopping the bus to load on passengers, time is again visualised to support planning, as well as the state of the bus, for example opened doors.

DRIVING LONGER DISTANCES WITH PASSENGERS

When the passengers are on the bus, the driver takes off on the planned route and the route and schedule is visualised on the availability area, see figure 46. If there is some disturbance on the route, a warning and information message about that comes up and a new route is automatically computed. The new route takes the available stops and times in consideration. Also, only routes suitable for bus traffic is programmed to be alternative routes.

When the system encounters road blocks it is visualised on the screen by the spotting technology implemented in the system. The system detects both movement blockage in close range in city traffic and movement blockage on a longer distance, which is of great use to the drivers driving longer distances in the dark. Then a clear, red warning and information message will come up on the instrument cluster to inform the driver of the upcoming blockage.

When driving without situational dependant information needed on the availability screen, the visualisation of time and route comes up automatically as a standard. The route schedule is implemented in the system and is connected with information about current surroundings, including rest stops. When the bus comes close to a rest stop, the driver will be informed through a visualisation on the instrument cluster.

ERROR HANDLING

When errors occur, this is visualised in the availability area in a large format for easy perception, see figure 47. In order to describe the problem for help functions, in a way that decrease risk of confusion, an error code is provided. The problem is indicated in a way easy to understand, with a symbol and describing text and the state of the instrument is displyed visually with a level indicator.

Furthermore, the screen gives feedback about if and where information has been sent for easy communication between bus

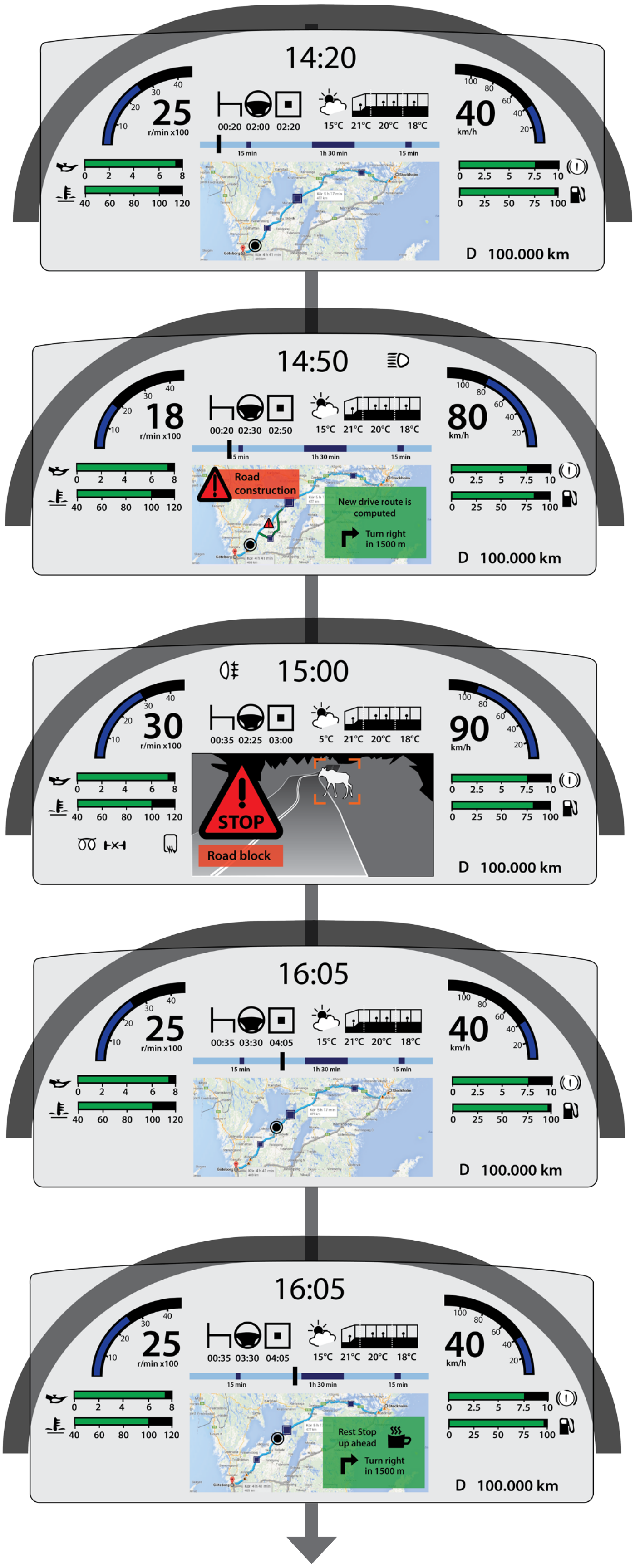


Figure 46: The tourist driver's concepts for driving longer distances.

driver and help functions. Finally, the action needed to be performed by the driver to fix or ease the problem is stated by the green arrow. At the same time that the error screen is visualised, the functionalities in the standard tourist instrument cluster is provided, to make sure the driver does not miss any other important information when perceiving the error information in the availability area.

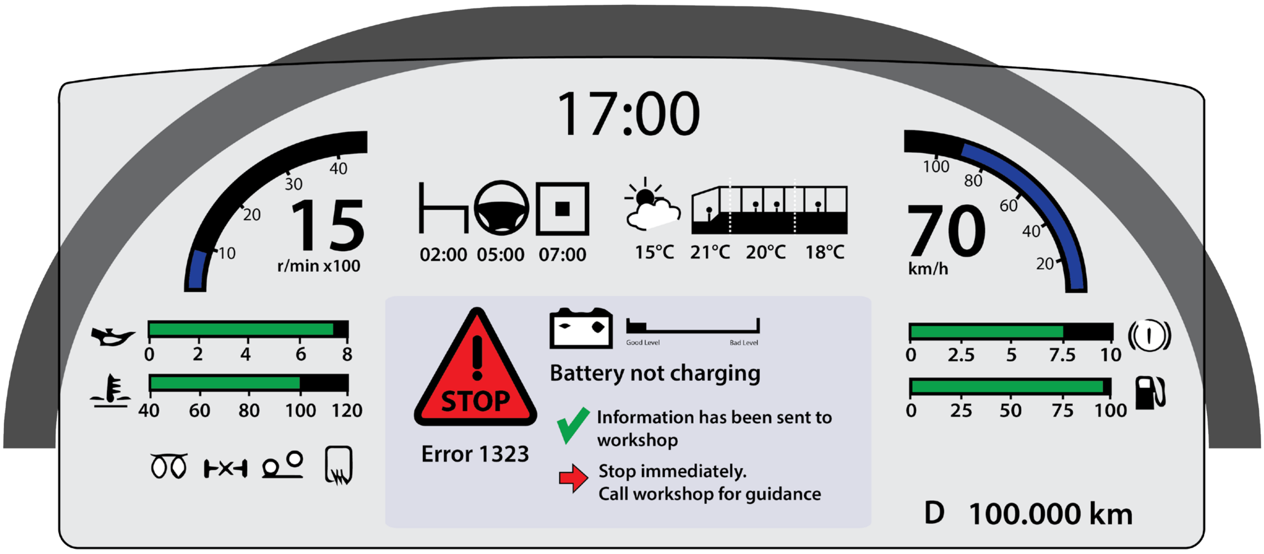


Figure 47: The error screen shown on the standard instrument cluster for tourist drivers.

9.4 Heuristic Evaluation

The heuristic evaluation performed showed that the different concepts follow the guidelines and heuristics presented earlier in the theory chapter quite well. The colour coded table (Appendix 9) shows that most areas got approved in green colours. Some guidelines describe areas which are not yet worked with in the concepts and will need to be taken into consideration during further development of the concepts at Volvo Bus Corporation.

9.5 Validation to Requirement Specification

An evaluation similar to the heuristic evaluation, but with the requirement specifications as guidelines, showed that the new concepts are fulfilling most needs of the users. Although, in some areas, the concepts are not detailed enough to validate towards the requirement specification. During further development, these requirements could still be fulfilled, depending on the detailed design and manufacturing of the concepts.

9.6 Concept Design 2 Conclusions

The concepts and system changes evaluated in the first concept design phase has been redesigned and changed according to the evaluation into the revised concepts presented in this chapter. The instrument cluster is concluded to be designed with a standard look and placement of the instruments, but only with the activated instruments visualised at a time. The use cases have been used more in detail to describe how the information and representation of information shift according to situation, though even further use situations could be possible to look into. The concepts were evaluated according to heuristics and the requirements specified. The evaluation concluded the concepts to suit the theory and requirements stated, hence the revised concepts described here will be the final solutions of the project.

10. FINAL CONCEPT

The final concept is presented in its total in this chapter. To support the findings from the need identification and solve problems stated (appendix 5) the system has been changed and include sub-systems which ease the driver's work with focus on information handling by easy perception and ease of technical problem handling.

10.1 SYSTEM IN TOTALITY - HOW IT WILL WORK

The bus driver will work in close connection to the help functions, that is the traffic management and workshop, in order to ease problem handling and daily sharing of information, see system visualisation in figure 48. The driver perceives information about the bus state and the surrounding environment through different channels; the instrument cluster and secondary information displays (SID).

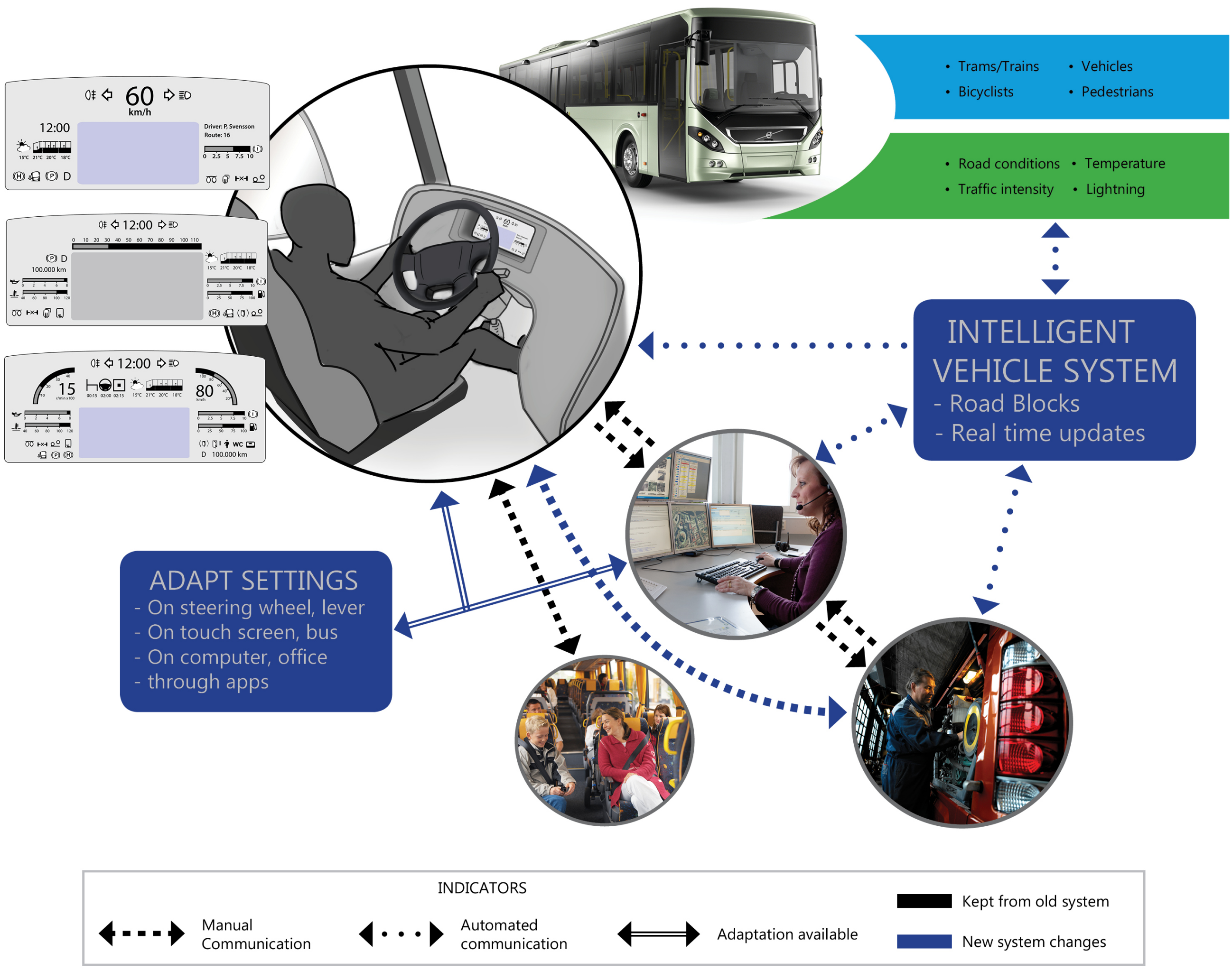


Figure 48: The bus system with communication between functions and information systems.

The information showed on the screens is adaptable and choosable to fit different individuals and organisational needs. The information needed through the channels, especially the instrument cluster, depends on the driver, its responsibilities as well as the type of situations and tasks the driver deals with. Three driver types have been distinguished; city drivers, intercity drivers and tourist drivers. The instrument cluster have been redesigned to fit the different types' needs concerning information needed and displayed functions, resulting in three concepts which are displayed in figure 49. The information needed on the screen and the theme of visualisation can be adapted to the wishes of the driver or the organisation.

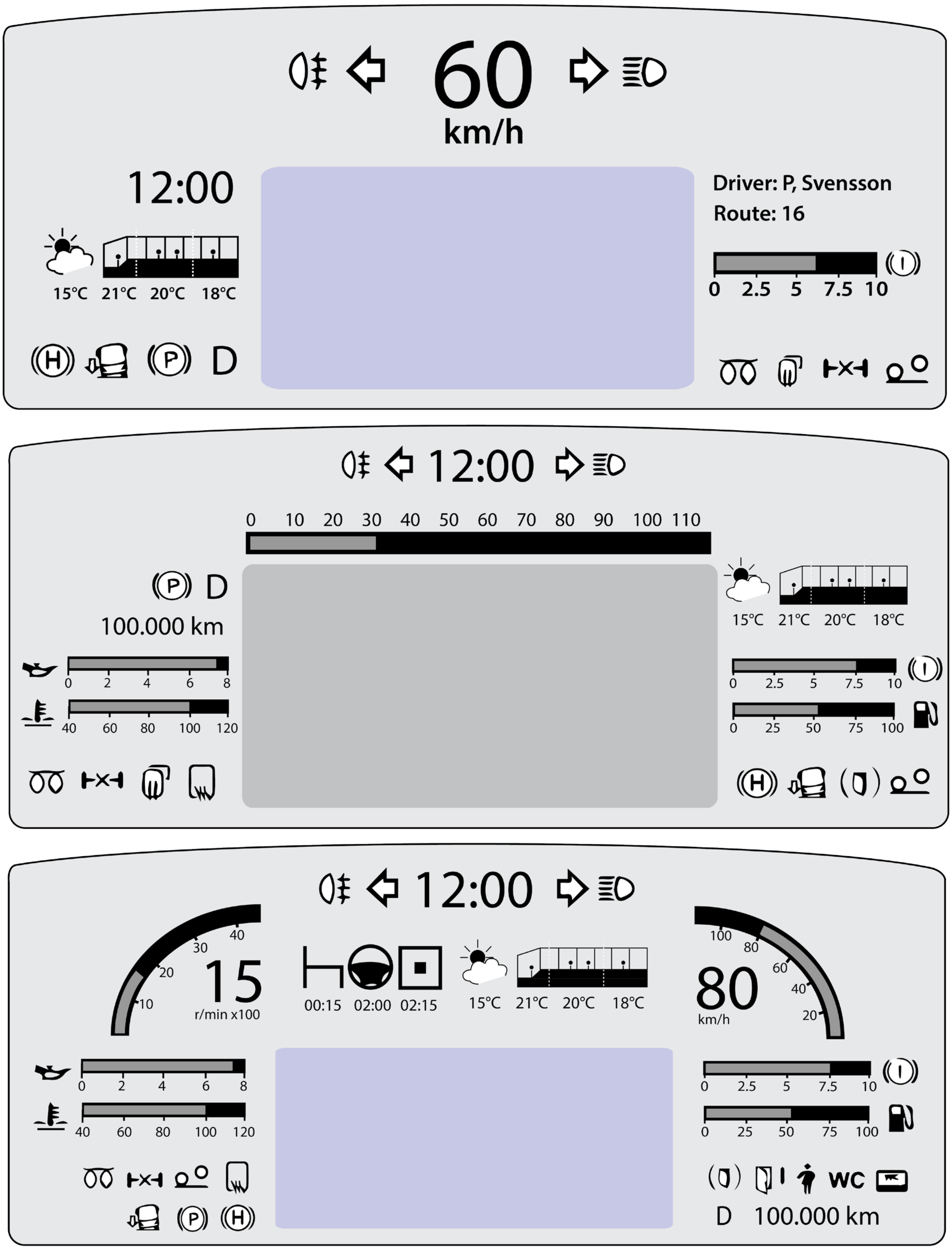


Figure 49: The instrument clusters for the three driver types; city (top), intercity (middle) and tourist (bottom).

Information relevant to the individual driver is programmed on the driver's card which is used to log in into the bus in the start of the day. The information saved on the card include driver schedule as well as his preferences concerning climate and settings to the driver area, including driver seat settings and automated mirrors setted to his preferences. The theme of visualisation as well as which instrument cluster and the information stated on it is needed to the individual driver and his current schedule tasks can be programmed by the individual driver himself through different channels, see figure 49, or the organisation can have it as a standard already chosen for him.

In the new bus system, an intelligent vehicle system is connected to the bus, which works partly as a communicator to the driver about information needed to plan and maneuver the bus in a safe manner and partly as a communicator betwen the bus driver and the traffic management. When triggers of errors occurs in the bus, the system automatically send information to whom it concern, in order to ease the driver work and save time on manual communication. The system inform the driver about blocks found on the road as well as updates the route schedule after changes in traffic due to interruptions such as construction or accidents.

10.2 Information handling in instrument cluster

The information in the system is directed to the persons that are able to act on the information or somehow is affected by it. Error information is both displayed to the driver and send to traffic management and the workshop. The organisation itself chooses which ways the information is supposed to be sending. The bus system can distinguish between problems able to fix by driver, by traffic management, by workshop, or if external technical specialist is needed. The driver always receives feedback about which information that has been sent and where it has gone.

10.2.1 Information presentation

Information given to the driver through the instrument cluster is grouped and coordinated with the driver type and its situational need. Information important to the driving, e.g. speed, direction indicators and light, is shown at all times and focused in the upper centralised portion of the instrument cluster, in order to make it always visible at an easy glance. Information about important parts of the bus that the driver feels the need to continously check will be presented by level indicators on either side of the screen which is centralised and always easy percepted. The levels provide information over time and is constantly displayed and supports planning and situational awareness. Information concerning functions that is either activated or turned off will be placed on the lower part of the screen, since when they are not activated they are not shown and then the cluster will have all needed information in the easiest percepted parts of the screen; the center. Additonal functions, e.g. climate information, tachograph or driver and route information, important to different driver types are placed where they are needed depending on prioritisation. The middle part of the screen is an area for situational available information which is the only part of the screen that will be changing due to situation which supports the need of drivers keeping track of a lot of information at a time.

10.2.2 Availability area functions

The area of available and situational information constitute partly of functions which can be set individually by the driver or the organisation, depending on their preferences, and partly of information and visualisations that is needed in certain situations. The functions that could be shown on this part of the screen include

- information that supports functionality and efficiency
- information that keeps the driver alert
- information that warns the driver of harmful situations or inform the driver about importan-

troute plans or redirections.

Functions that support functionality and efficiency are shown in figure 50 and concerns information that is presented due to the system being connected to the driver's schedule as well as important functions that need to be visualised clearly to the driver.

By giving the driver continuing information about route schedule, the time to start and scheduled breaks, the system gives the driver easy overview of the work time and the driver can spend it effectively and efficiently. Information about route and bus exchanges is shown when it is scheduled and due to the efficency in the system, the time spent on exchanges between the bus drivers is minimised and the break time is maximised. Information that is of high importance to keep track of concerns passenger related functions, such as when the stop button is being pressed and doors during off and on loading beeing opend. This is clearly shown in the cluster when the situation requires it.

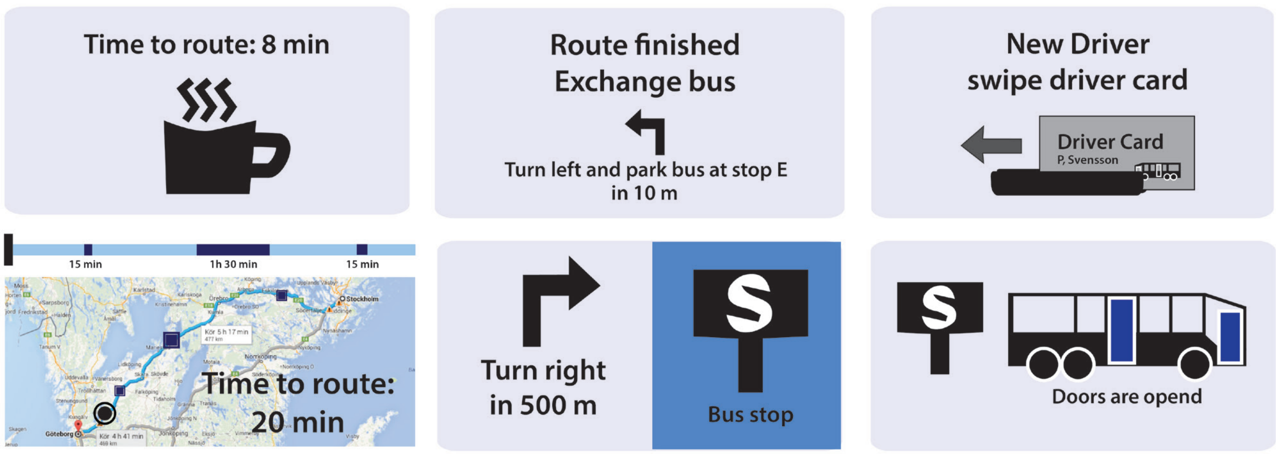


Figure 50: The functions shown in the availability area that supports effective planning and efficiency.

When driving longer distances with low mental workload or when driving without passengers from and to the depot, the driver need to begiven information to keep alert in order to maximise safety. The functions that support alertness are shown in figure 51 and concerns interactive maps with route schedule and route directions to support easy navigation, eco levels to support ecological driving and used entertainment, such as connections with mobile music devices. This functions should be available to be activated when needed and automatically shown when the situation requires it.

Figure 51: Functions in the availability area that keep the driver informed and alert.

The availability area also presents information about errors and warnings found by sensors or other system communications, see figure 52. The warnings could be in a wide range of severity, from the need to stop the bus right away (the stop error) to information that the driver just need to be informed of (the obs error). The warning information concerns errors detected in the vehicle as well as detection of road blocks ahead. The system also detects unplanned route changes due to construction or accidents and presents new navigation plans as well as directs the driver to imortant resting stops.

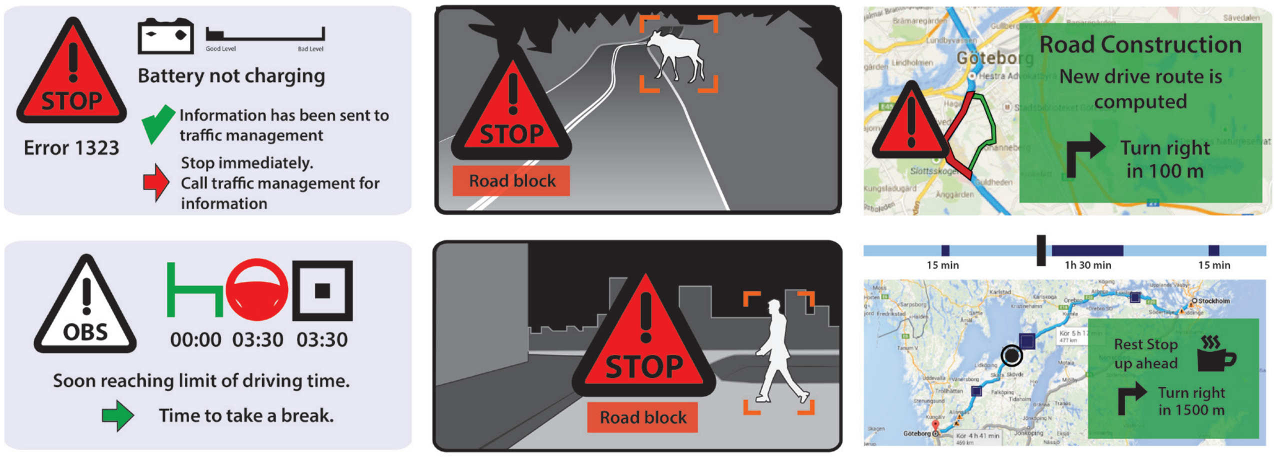


Figure 52: Functions in the availability area in form of warnings that supports safety.

10.2.3 Functions on secondary information displays

Additional information needed to the driver is given by the secondary information displays due to the small space provided on the instrument cluster. The system is easier percieved if the information on the instrument cluster is not always changing. Instead additional information is shown and perceived by displays placed in the bus area, either by the instrument panel or in other places that is not disrupting the perceivement of environment outside or instrument used in the bus. This information concerns for example detailed route schedule with bus stops and time inbetween them needed by the city drivers, visualised in figure 53, as well as camera feeds from in and around the bus and additional functions needed when driving that the cluster has no room for.

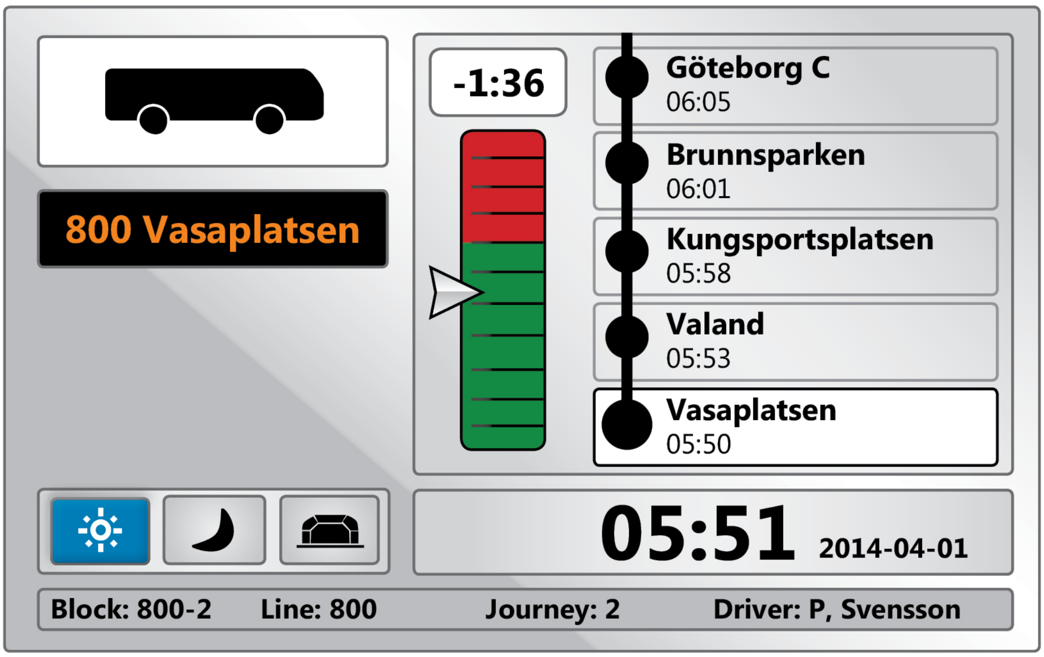


Figure 53: Bus stop and time visualisation

10.3 Concept Use Cases

The concept visualisation and information handling can best be described through visualising the concepts on predefined use cases which describes scenarios and tasks the three driver types are exposed of. The start-up of a bus often includes checking it for errors and current state levels. This is done in the same way for all drivers since they all start the bus in the same way and expect the same start-up result. The concepts for the start-up have a separate screen which differs from the standard instrument cluster used when driving due to that the driver does not need to show other information when starting up the bus. The start-up information therefore take up the whole cluster screen and show driver confirmation after he has logged in into the system with the individual prefered settings changed in accordance to saved information on the card. The start-up screen also visualises an overall system over-look of the instruments included in the bus and their state, in order for the driver to get important knowledge of the bus state before driving away, see figure 54.

When driving, the standard cluster looks in different ways depending on driver and situation, figure 54. The scenarios for driving concerns driving from depot to route start without passengers, driving in city traffic with passengers and driving longer distances with passengers. All driver types drive from the depot to start of route without passengers. During this case, the information displayed in the availability area is focused on supporting driver alertness since this situation has a low mental workload and due to this being the time of the work day with most accidents. When driving in city traffic, there is a much higher mental workload, therefore the instrument cluster only shows information necessary to the driver at the time. Warnings detected by the system is always informed to the driver to support safety and is especially important in hectic environments such as city traffic. During drives on longer distances with passengers , the driver has a lower mental workload than in city traffic and could benefit from information about the bus state as well as planning supporting information, e.g. maps and route navigation, and eco levels.

For the city drivers it often occurs that drivers need to exchange bus in the middle of the work day and this is supported in the system. It recognises the time of the exchange and directs the driver and the bus into the right stopping position. When the new driver enters the bus, the system asks him to log in with his driver card and therefy activates the bus and the system just as it does on the start-up of a bus. When driver has logged in, the start-up screen and information will therefore be presented just as in the start-up case.

There is always risks about errors happening during driving and when it does, the driver need to be alerted in a clear and easy percepted manner. This is done through the error screen which is a screen placed in the area of availabilities that presents the error type and state. It is also percepted through the screen that information has been sent to the function it concerns. It is also clearly stated what action the driver needs to take in order to fix it. In this way problem handling has been eased by the system from a driver point of view.

The different use cases can be seen in figure 54-55 as examples of how information is presented in the final concepts of the instrument cluster. For more detailed described use cases in illustrations and text see 9.3 Use Cases Refinement (figure 37-47) in Chapter 9.

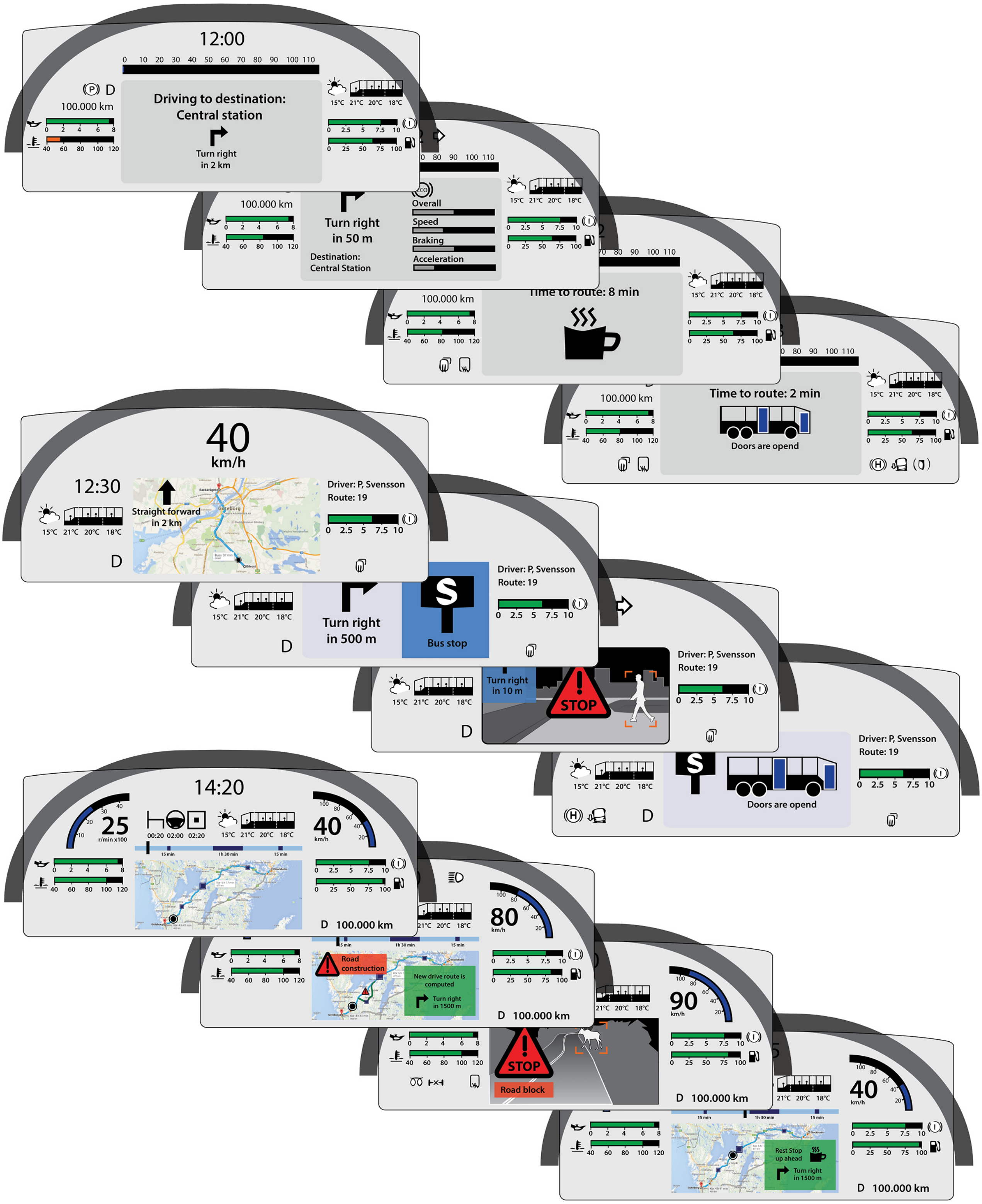


Figure 54: The concepts for the three types of drivers shown in the use cases that concerns driving: driving from the depot to start of route illustrated with the intercity concept (top), city concept driving in city traffic (middle) and the tourist concept with information that concerns driving longer distances on conutry roads (bottom).

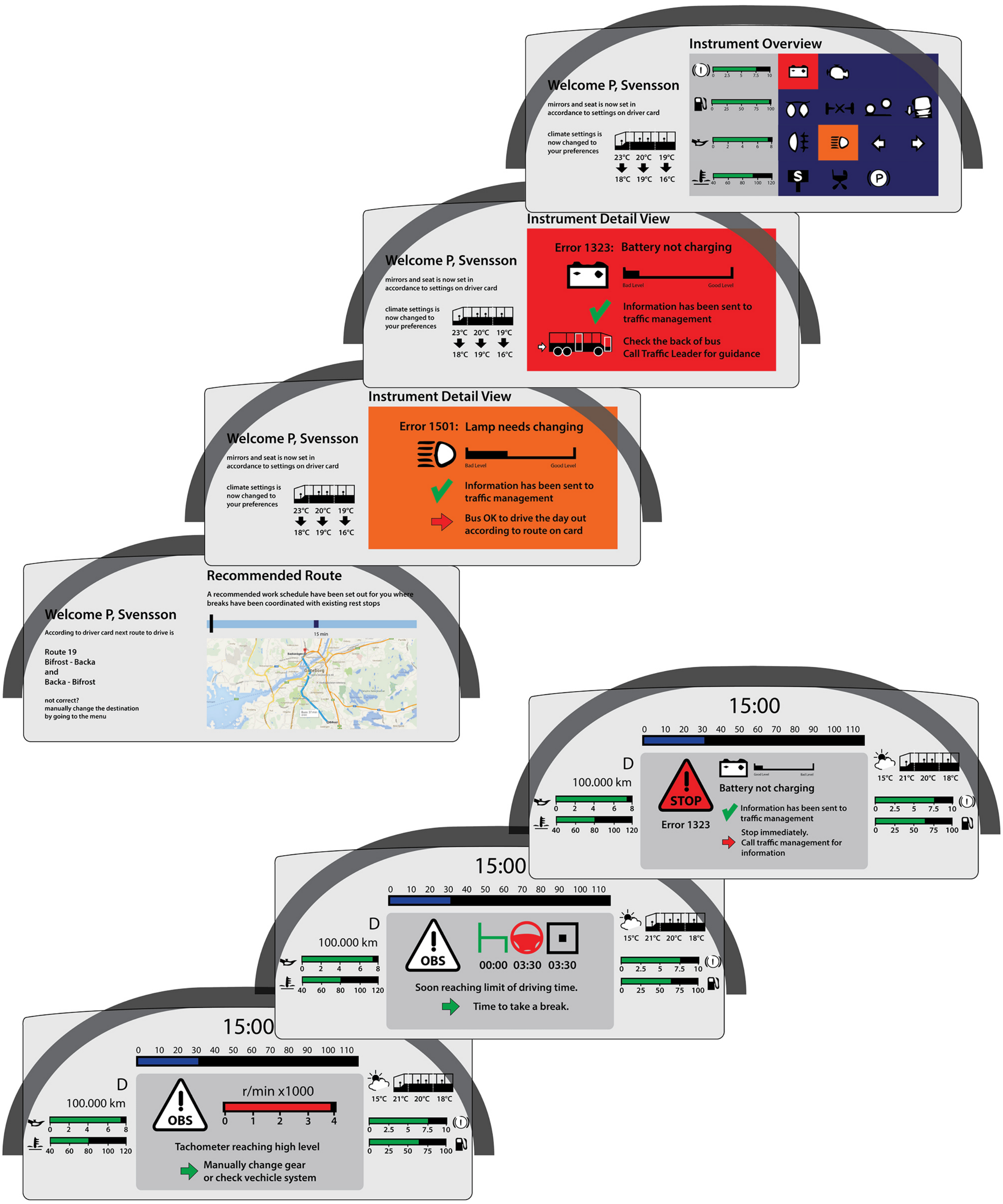


Figure 55: The concepts for easing technical problems. At the top: the start- and check-up screens which will appear in the start-up of a buss or during an exchange of drivers when the new driver logs in with the driver card (illustrated with a city driver's route information in the end). The bottom: error handling through the intercity concept including two different warnings, "stop" for severe warnings that concerns the immediate safety and "observe" for other warnings, including manual shift of gear or restrictions about driving time.

11. DISCUSSION

Decisions made and processes performed in the project are here discussed and questioned.

11.1 SCOPE AND AREA SELECTED

To choose usability and cognitive ergonomics as a focus for the project has both positive and negative consequences. To have a more technical focus and look deeper into technologies and creating an instrument cluster with aspects to material and manufacturability could have been beneficial if the results were to be used more directly as new product ideas for Volvo Bus Corporation. Although, these aspects were chosen not to be covered. The scope of conducting user studies and specifying the system from the user's point of view was pretty extensive already for a master thesis. The choice of focus could in many ways been seen as positive for Volvo Bus Corporation, while user studies and usability are often neglected and not given as much resources as the technical and manufacturing aspects. In that sense the project brought forth information that was unknown and that would not have been found by internal product development work at the company. One of the advantages of the study was that it focused on the collaboration between different instances in the organisation and sub-optimisation of the bus-driver system that creates negative organisational effects could be avoided.

11.2 THEORY DISCUSSION

The theories presented in the report are quite relevant to the areas covered during the product development process. Although, some more basic theories of the human mind might not be directly connected to areas discussed. But depending on type of reader of the report this information could be useful and was chosen to be kept in the theory chapter.

Extra useful for the concept generation and evaluation was the design guidelines and rules presented in the theory. They were directly applicable to the problems and very useful in the process.

11.3 METHOD DISCUSSION

Most methods used in the project supported the product develop process with information and knowledge. A lot of methods were also used with purpose of being representative. Methods were chosen only if they were considered to be valuable for the process or vital in conveying information to the reader. There are several other methods within the area of usability and cognitive ergonomics which could bring information of value to the project. Some of them are very time consuming and was not prioritised.

The methods used might not cover areas like risk handling and prevention and detailed evaluation of the current system. Although for this type of futuristic and new-thinking project this methods might evaluate too much in detail and take focus away from the main features and problems with the system. Therefore the methods can be considered to have been used in a satisfactory way which gave acceptable results.

11.4 Process discussion

The overall process and way of work in the project can be seen as a funnel, collection information in one end and then producing an outcome and result. It is not necessary to collect information in order to design a suggestion for the new product. Although, if merely design work would have been performed without proper investigation, important aspects would have been hidden. That the process was iterative was essential for this project. Findings needs to be discussed and evaluated, especially in a qualitative study like this, to make sure the user thought was actually reflective and understood in the intended way. Through the whole process, there were many small iterations, building up more and more knowledge and narrowing down to identify the main issues and factors. There were several informal iterations from evaluating and re-writing questions for the interviews continuously, re-drawing system pictures and other visualisations after discussion, to generating, evaluating and redesigning the concepts. This way of working, where the process moves forward but at the same time looks back and tries to improve to make the best of the finding put forth, was successful in the project to make sure the result became useful and thought through properly. The overall process has suited the project quite well and created focus in the right order to make the work run smooth and effective.

The different phases in the process and the results from these are discussed further under each phase.

11.4.1 Need identification

The user studies gave a lot of information to the project and were performed in a time effective way that elicited a lot of requirements and demands. The broad focus on questions and areas covered in the interviews was important not only for the results but also for the understanding when developing concepts. To understand the total work environment of the bus drivers was beneficial to see the larger system changes that could be needed. Although focusing on the whole took time and resources from getting more deep information about the current instrument cluster and how the driver perceived all the different type of current functionality.

11.4.2 Function & task formation

The iterations in the function and task formation phase were performed informally through discussion and redesign of models, visualisations schemes and sketches. This way of working had benefits, but maybe the process could have been performed with more structure and defined iteration steps.

11.4.3 Concept design 1

To have a holistic approach and merely evaluation and design the system on a higher level both has benefits and drawbacks. During feedback sessions examples of the functions were visualised and might have given the impression of being a suggestion for a final detailed design. These symbols of the function might have taken too much attention and made the concept seem to have more information displayed at the same time than it actually would have in use.

Evaluation of the early concepts could have been done even more extensively and with simulation tools. Maybe more elaborate ways of evaluation and simulation would have brought forth more knowledge and made the feedback sessions more realistic for the users. Although, as the designs are more about grouping and overall design, detailed and elaborate simulations are hard to perform and might have been even more confusing for the user.

11.4.4 Concept design 2

The information and results from the feedback of concepts in the earlier phases gave the second concept design phase focus. The changes needed to be performed in the system were clear. That the drivers evaluated several different concepts and gave rich feedback information, made the process in the second design phase pretty straight forward. Since the concepts have been created with the guidelines in the theory and specified requirements in mind, the heuristic evaluation merely verified that the concepts suited these and the concepts from the Concept Design 2 phase was kept as the final concepts.

11.4 FUTURE IMPLEMENTATION IN VOLVO BUS CORPORATION

The work completed through this report could help Volvo Bus Corporation reach further beyond their competition in the industry. Since it hard for the organisation to get to the actual users (i.e. bus drivers) which uses their products (i.e. the buses and the incorporated system), the information gathered in this report could help the company understand the driver needs in a better way and from that need recognition, improve their products to be more fitted the customer.

We believe that the final instrument cluster designs presented in this report would, despite their conceptual level of design, improve the ease of perception for the drivers as well as the handling and understanding of the vehicle. If the system design was improved according to the suggestions in this report, the bus company as well as other organisations involved, would save a lot of time that is today wasted on verbal (manual) communication between people. Miscommunications would be minimised due to the identification numbers added to the information shown to the drivers and the error handling in general would be more efficient, which takes away delays and improve both driver and passenger comfort. In the end, the clients to Volvo Bus Corporation would be more happy with the service they were given and would perhaps prefer their service above others in the future.

11.5 LESSONS LEARNED

This project have given immense experience about user-centred product development in its totality. Collecting data was a big part of the project and through that phase, manu valuable lessons were learned for getting the most out of the subjects. The meetings were well planned and questions were in beforehand chosen in order to ease the communication, but through the phase it was learned that one needed to stay analysed at all times and don't just follow a questionnaite strictly. All interviewees had different experience and knew different things, it was therefore learnt that when a questionnaire is sometimes good to have as a base, it is always best to have a discussion with follow-up questions and not moving on to the next question before the first has been interely gone through. It was also imperitive to analyse the subject interviewed and always observe the tone, the movements and understand the meanings between the lines. These meanings were sometimes more important than the actual statements of the subject.

The importance of presentation was also something learnt through the project. In order to understand the concepts and the placed information, a visualisation of the concept with an included story of how it would change was not enough. The evaluators needed the concepts to change in visualisation in order to understand them fully and thereby evaluate them if they are indeed easy perceptable etc. It was due to this realisation the evaluation in concept design 2 was more thoroughly visualised in the scenarios with the screen changing in accordans to the situations. Additonally, how the concepts were presented and what questions were asked during the evalutions was of importance. It was always best to encourage the evaluators to say what they were thinking rather than spelling out specific questions about the concepts.

It has been a very stimulating project which have given a lot of useful experiences in varied categories. If given the chance, we would have chosen to do the project all over again.

12. FURTHER RECOMMENDATIONS

The result from the project could be seen as inspiration for coming development projects at Volvo Bus Corporation. Because the development was based on user needs and findings from the real environment, the suggestions and results from the project should be reflective and a good mediating tool for further development.

The concepts are not evaluated or changed in design on a detailed level. Possibly some of the symbols used to communicate information are not optimal and could need evaluation and redesign. The design and final look of the instrument cluster should be further discussed with additional idea generations and evaluations with users in order to make sure the design fits both in function and form language. It should also be designed as a recognised Volvo branded design in order to be placed in its portfolio. The ability to change the interface for different customers and adaptability is positive from a sustainable environmental perspective. To achieve sustainable benefits, the instrument cluster needs to be designed in a way that updates of technology is possible. Additionally, the visual impression needs to be timeless enough to not look unmodern throughout the lifecycle of the bus.

On a detailed level, there needs to be more work with implementing colours in the instrument cluster for easier perception. With help of guidelines stated in the theory chapter of the report, the colours, fonts and texts needs to be further developed. Also, levels of contrast needs to be taken into consideration and usability tests should be performed with realistic detailed design suggestions and functional prototypes.

Additionally, there is possibilities of extending the instrument cluster to cover larger areas of the dashboard and driver interface. With a larger area for the instrument cluster, more additional information could be integrated in a better way and reduce the need of several secondary information displays. This work has to be performed carefully, as is seems like the drivers currently prefer to have these areas separated. This has to be balanced with the fact that the current system with a lot of secondary information displays sometimes creates physical-ergonomic problems, with strained necks and back problems. If buttons and other parts of the interface where positioned differently, closer to the driver's seat, there would be more space for displays. The further development and decisions of the future instrument cluster needs to be holistic and take into consideration to all of the drivers place, the user and the bus company organisation.

13. CONCLUSIONS

Through the data collected and analysed during the project, conclusions concerning the bus driver system and the environment around could be drawn. With the questions from the project introduction (Chapter 1) as a base, here the main conclusions will be stated.

HOW DOES THE NEED OF INFORMATION VARY FOR DIFFERENT DRIVERS, BUS MODELS AND CONTEXT?

Different traffic conditions put different demands on the drivers and there are differences in the drivers work. Driver types were identified as city traffic drivers, intercity drivers and tourist drivers. There is a lot of information that is common between the groups and that information could preferably be presented in a similar way. Additionally, there are functions and prioritisations of information that differ between the drivers. Thus it could be beneficial to adapt the instrument cluster to the needs of the driver or the organisation.

An adaptable digital instrument cluster can make it easier to customise the system for the specific bus organisation and driver. The level of service required in the driver work and passenger interaction also affects levels of mental workload and need of different functions. Although secondary information screens, ticket systems and passenger information might solve these issues better than implementing additional functions in the instrument cluster.

WHAT INFORMATION DOES THE BUS DRIVER NEED AND WHAT COULD BE DELEGATED TO OTHER PARTS OF THE ORGANISATION? HOW SHOULD THAT COLLABORATION WORK?

The instrument cluster can preferably be designed to support better information delegation within the organisation. The bus driver often communicates with the help functions within the organisation, aspecially the traffic managers, when it comes to error messages and traffic information. To identify error messages with identification numbers and use real-time updates and telematics information transfer for traffic information, the communication will be improved and time wasted during technical errors in the bus or traffic cues etc. will be reduced. Removing waste of time in communications between the help functions in the organisation and the driver is vital. Therefore, the cluster should be designed to inform the driver of the information the driver needs in order to do his work smoothly. Other informaton that concern the help functions in the organisation should be automatically sent to them, to support an efficient communication in the organisation and ease the driver work.

WHAT INFORMATION SHOULD BE PRESENTED TO THE DRIVER? HOW SHOULD INFORMATION BE PRESENTED TO THE DRIVER IN A GOOD WAY?

The information that is needed for the different driver types were concluded and grouped on the cluster in order to be placed in a natural way for easy perception. The different information groups were visualised in different manners depending on need and prioritisation, which helps the driver differ between them more easily. However, the information can be presented to the driver in endless combinations and manners.

The information groups in the final concepts were generated from user experiences and evaluated by bus drivers, which supports the user-friendliness of the concepts. Though, there has been no detail study of the final visualisations of the information, since this project did not dwelve in the design on a detailed level. Hence, the question of how the information should be presented to the driver, in the most optimal way, partly remains.

WHEN SHOULD THE INFORMATION BE PRESENTED?

When it comes to the time and place the information should be presented, it differs depending on the information and driver need. Some information can preferably be constantly displayed to make the bus drivers understand the bus and the factors influencing it. This information is important in order to recognise deviations and enable the driver to act in a way to prevent errors. Though, some information could instead be filtered away to reduce mental workload and only be presented when relevant. There can preferable be a combination of constantly showing some information and only presenting other information when it is relevant.

WHERE SHOULD THE INFORMATION BE PRESENTED?

The drivers found that secondary information displays can be used for a lot of the additional functionality information discussed in the report. It is concluded to be better to show only the functional information needed to drive in the instrument cluster to make sure the information there can be easy percepted, and have additional functions that ease the driver work on additional displays or other places in the driver area. This is however based on the placement of the system information displays of today, where the instrument cluster have the same placement and size of today. If the driver area would be changed with an extended cluster, the information placement need to be investigated more thorougly. The important conclusion drawn concerning the placement of information is however, that the users rather have different placements for the information instead of having one place that vary with shown information.

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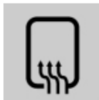
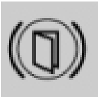
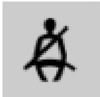
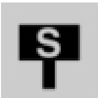
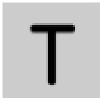
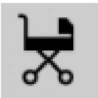
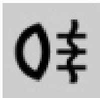
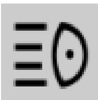
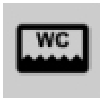
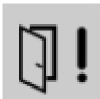
APPENDIX 1:
INSTRUMENT CLUSTER SYMBOLS AND MEANINGS

Here are some of the symbols that appear in a bus shown with their respective meanings. For further information see Driver Handbook 9700, Volvo Bus Corporation.

Sym-bol	Meaning	Sym-bol	Meaning
	Left indicator on		Service personnel
	Right indicator on		Screen / mirrors heating activated
	If there is a problem with the bus you must stop.		Battery not charging
	Information message		The switch for increasing load on the drive axle (bogie lift) of the bogie is on
	Check		Pre-heating on

	Door brake activated		Safety belt reminder
	Curtsy activated (for easier access)		Parking brake applied
	Differential lock activated		OBD – On-Board Diagnostics [1]
	Stop at the next lay-by		Check the tachograph
	Entering or exiting the bus with a pram		Rear fog lights are on
	Main beam		WC engaged
	ABS not functioning		WC tank full
			Fault in the door

[1] Only relates to buses meeting exhaust emission standards to Euro 4 or later.

APPENDIX 2: INTERVIEW GUIDE

Personliga chaufförfrågor

- Hur länge har du varit busschaufför?
- Hur fick du din utbildning, har du gått ytterligare utbildning efter det?

Uppgiftsanalys

- Kan du dela upp att köra buss i 3-6 delar/arbetsuppgifter? Gruppera dem, i vilken ordning?
- Vad är det svåraste, där du behöver tänka till extra? Svårt att bedöma situationen? Där du behöver lösa problem?
- Vad för kunskap behöver du för dessa arbetsuppgifter?

Prioritering bussuppgifter / bussavdelningar

- När man kör buss, vad är de viktigaste att tänka på, i stora drag?
- Vad försöker du ha koll på när du kör? (Syn, hörsel, känsel)
- - Vilka saker är du uppmärksam på?
- Vad är extra viktigt att tänka på i stadstrafik?
- Kan du beskriva vilka skärmar, fönster och speglar du ser på under körning?
- Vad kollar du mest på? Vilket kollar du mer sällan på?
- Hur länge kan du vända blicken mot en annan skärm innan du vill titta framåt igen?

Problemhantering

- Hur vet du om allt står rätt till eller om du måste rätta till något?
- Vad gör du om det blir ett problem, finns support eller försöker du fixa det själv?
- När kan det vara svårt att hantera bussen, krånglar det ibland, vad händer då?
- Hur ofta krånglar bussen och kan du ge exempel på olika problem? Hur hanterade du det då? Var hittade du information, så du visste vad du skulle göra?
- Finns det speciella körsituationer som du är ovan vid?
- Kan passagerarna störa dig på något sätt? Hur ser det ut då?
- Hur ofta är bussen full/tom, är det skillnad att köra då?
- Kan du ge exempel på något som var svårt när du började köra? Har du lärt dig några tricks för att göra det lättare? Varför är det enklare nu?
- När kan det vara riktigt svårt att köra? Kommer du ihåg något tillfälle det kändes jobbigt/svårt?
- Vad gjorde du då? Vad var viktigt att tänka på och vad kan hända om man gör fel?
- Hur påverkar väder körningen? När är det svårt?
- Hur påverkar tid på dygnet körningen? När är det svårt?
- Hur påverkar typ av trafik och omgivning?

Användar-influens

- Hur mycket kan du som busschaufför påverka vid valet av bussar? Äger företaget bussarna själva?
- Hur mycket flexibilitet har du som busschaufför när du kör, i förhållande till exempel tidtabell? Måste den hållas till varje pris?

Säkerhet

- Skapar interaktion med passagerare problem på något sätt? Känner du dig trygg när du kör, tex i Göteborg på kvällen?

Körningen

- Har du åsikter om instrumentklustret och några erfarenheter av att den nuvarande utformningen kan ställa till problem? Några idéer eller tankar?

Automatik

- Finns det situationer när du känner att du inte räcker till, där du önskar att bussen kunde hjälpa dig på något sätt?
- Vill du har mer information från bussen eller hur känns det om bussen skulle gripa in automatiskt?
- Vad anser du om bussar som reglerar maxhastighet av sig själv, i olika zoner?
- Vad anser du om guidning för mer miljövänligt och säkert körsätt, Information el ingripande?
- Vilka uppgifter skulle du helst slippa och låta bussen göra av sig själv?
- Ser du några risker med automatik i bussen?

Körscenarion

- Kan körsituationer variera mycket? Hur? Blir det någon skillnad att köra?
- Ge exempel på några scenarion.

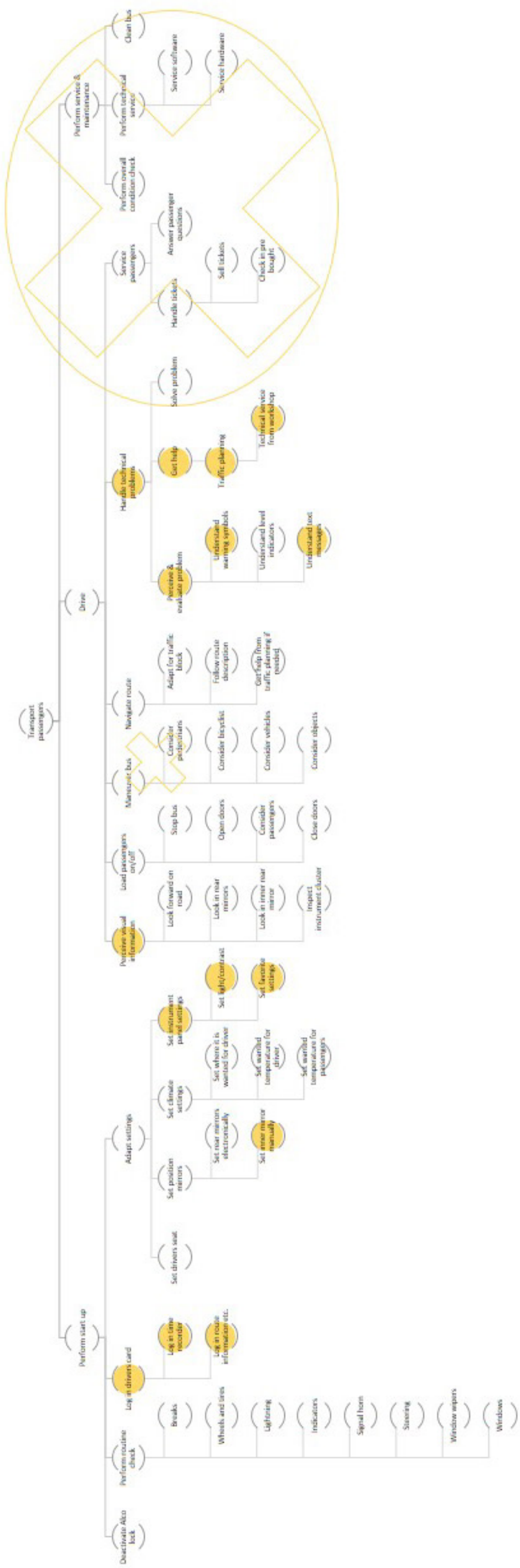
Scenarios

Vi vill att du väljer en situation som du anser vara ett jobbigt scenario för dig när du kör. Kan du först beskriva det här scenariot och sedan ha det i åtanke när du besvarar dessa frågorna (ge ut papper)

- Morgon rusningstrafik i Göteborg, du kör i en av de mest trafikerade delarna av stan. Du har blivit 5 min sen, pga stopp i trafiken. Bussen är absolut fullpackad.
- Landsväg natt, slutet av turen, långa raka sträckor med dålig synlighet och få stopp
- Nattkörning, oroligt område, få passagerare
- Kväll, stadskörning mycket folk ute på stan, bussen stökig

APPENDIX 3: HTA

The tasks completed by the user in the bus system are stated and analysed in the hierarchichal task analyses (HTA) to the right. The areas which the project was focused on solving better are highlighted and the areas that was not included in the scope are crossed over.



APPENDIX 4: USE CASES

The use cases defined that together summarises the drivers' work day.

Use Case 1	Start-up of bus
Summary	The user prepares the bus to leave depot and takes off to start route.
Actor	The bus driver
Goal	To check the state of the bus and prepare it for driving
Precondition	The bus is parked at the depot and connected to external heating/electricity.
Description	1. The driver opens bus, put out electrical heating enters the bus and squeeze in jacket and bags in the driver place.
	2. The driver blows in Alco lock in order to be able to start the bus.
	3. The driver goes through the routine check of the instruments in the cluster
	4. The driver visually perceives information regarding the state of the bus on instrument cluster.
	5. The driver perceives state of air pressure until it is ready to drive.
Alternatives	2.5 The driver goes out around the bus and checks lamps, wheels and the outside of the bus
Post condition	The bus is ready to drive on route

Use Case 2	Driving from depot to start of bus route, without passengers
Summary	The driver starts the work by driving the bus from the bus company depot to the starting point of the route scheme.
Actor	The bus driver
Goal	To transport the bus safely from depot to route start in the planned time.
Precondition	Bus has gone through service checks and cleaning and is ready to be driven. Bus driver has readied himself for work and has checked that the bus is in order. Bus driver sit in a starting position in the bus chair and has started the bus.
Description	1. Driver starts driving of the parking space in the depot.
	2. Driver drives the bus from the depot to the first stop of the bus route.
	3. Driver stops the bus.
	4. Driver opens doors for passengers.
	5. Driver starts the official route work.
Post condition	The driver drives away with passengers

Use Case 3	Driving with passengers in city traffic
Summary	The bus driver transports passengers inside city traffic and have to stop at bus stops very frequently and make sure all passengers is on and off loaded in an efficient and good way.
Actor	The bus driver.
Goal	To transport passengers in city traffic and keep time schedule through efficient on and off loading of people at bus stops.
Precondition	Bus driver has come to bus stop to load off passengers
Description	1. The driver checks the stop button indicator.
	2. The driver manoeuvres the bus slowly through the crowd and checks forward and side rear mirrors.
	3. The driver stops at the first stop. Drives into side of road at bus stop.
	4. The driver checks in the inner rear mirror to see if some passengers that need extra time to offload prams or wheelchairs.
	5. The driver opens the door.
Alternatives	1. When checking stop button indicator that might not be activated and bus driver has to decide if it should not stop at all and looks in the inner rear mirror to make sure no passengers are prepared to get out.
	1. The bus driver miss that a passenger has pushed stop button because of reflections makes it hard to see.
	3. When stopping at bus stop the bus driver might want to lower the side of the bus for better accessibility to passengers.
	5. Doors are opened automatically by sensor signal.
	7. Doors are closed automatically with shutting lock if person in the way.
	7. The driver closes the doors.
Post condition	The bus driver arrives at final bus stop before break.

Use Case 4	Driving with passengers longer distances on country roads
Summary	The driver starts and stops the bus very seldom and drives longer distances on country roads with few intersections of city traffic
Actor	The bus driver
Goal	To follow a route plan and transport passengers long distances without delay. To stay alert during low mental load and drive eco-friendly.
Precondition	Bus has been loading on the first passengers on the route and bus has come out outside the city
Description	1. Driver checks mirrors and turns out on a big country road.
	2. The driver manoeuvres the bus in a safe and comfortable way.
	3. The driver evaluates how smart the driving is, according to a driving coaching screen.
Post condition	The driver has finished the country road driving.

Use Case 5	Exchanging of bus in the middle of work
Summary	The user exchange another bus driver at a bus stop in hectic traffic
Actor	The two bus driver exchanging bus
Goal	To change driver of the bus in as little time as possible and make sure the bus is setup in a correct way for the new driver.
Precondition	Bus is stopped at bus stop in hectic traffic
Description	1. The new bus driver finds the bus and says hello to current driver.
	2. The other driver jumps out and new sit down in chair
	3. The new driver adapts the chair to right position.
	4. The new driver changes the rear inner mirror to right position manually.
	5. Adapts the steering wheel and instrument cluster hardware.
	6. Customise what is displayed on the instrument cluster
	7. Set climate settings and music on the radio
Alternatives	1. The bus is in the wrong place at the bus stop and the new driver cannot find it, traffic planning is called and see the bus on their screens and explain that it is the wrong place
	3. The driver may not have time to adjust seat and drivers away anyway
	4. The driver may not have time to adjust mirrors or tries to adjust them correctly, but fail since some iteration are needed.
	5. The driver forgets or does not have time to adjust it correctly.
	6. The driver might not be able to change settings in instrument cluster, since the organisation has password lock that prevents drivers to adapt it.
	7. The driver does not understand how to change climate in a preferred way
Post condition	The drivers have exchanged each other and the bus heads out to continue the route.

Use Case 6	Error message / warning from bus
Summary	The bus driver perceives a warning, interprets the meaning of the message/symbol and gets help from traffic planner to solve the problem.
Actors	The bus driver, traffic planner and service workers
Goal	To conclude problem and its severeness as fast as possible and the according action the bus driver need to take.
Precondition	The bus is driving in the city and has about 20 minutes' drive left on route. Before the warning there has been no indication of deviations from normal mode.
Description	1. Driver perceives a warning on the instrument cluster
	2. Driver process the meaning of the symbol
	3. Driver calls the traffic planner and tells about the symbol and problem
	4. Traffic planner informs the driver to drive the route to the finish point and then get the bus directly to the workshop
	5. Traffic planner informs service workers of the bus and its problems and when it will arrive to the workshop
	6. Driver acts according to what traffic planner instructed and drive through the route

Use Case 6	Error message / warning from bus
Alternatives	2. The driver misinterprets the meaning of the symbol.
	2. The driver no not understands the meaning of the symbol and ask traffic planner.
	3. The traffic planner and the driver misinterpret each other in terms of what error the driver is explaining about.
	4. Traffic planner informs driver to stop the bus immediately in the most convenient way possible, the bus is not safe to drive.
	4. Traffic planner informs driver to drive the bus to the workshop and let passenger know the problem.
	4. Traffic planner informs driver that the problem is not severe and will be looked into in the next routine check, the driver can drive as planned.
Post condition	The problem is solved and the bus driver can continue the last part of the route.

APPENDIX 5: PROBLEMS FOUND

Problem areas found through need identification are stated in a table. The spread of which they occur in terms of use cases are visualised by colours.

1	2	3	4	5	6	Problems with perception of information
		yellow	orange			On/Off loading time too long
		red	red	red		Stop button not visible enough
yellow	orange	red	red			Driver information too complex
yellow	yellow	orange	orange	orange		Information is not given in a natural manner
yellow	yellow	orange	orange	orange		System is not intuitive to interact with
yellow	orange	red	red			Lights in environments in- and outside the bus disturb information perception of instruments
	orange	red	red			Lights in environments in- and outside the bus disturb the overview of the outside environment
			orange	yellow		Information is perceived by anyone who can visually see the instruments, including passengers, which should not have that information
		red	red			Feedback on passenger wanting to get off at next stop is not visible enough
		orange	orange			Frequently used functions is not prioritised in perception
yellow	yellow	yellow	yellow	yellow		Too many instruments with the same function in the instrument cluster/ panel hinder easy learning and use of system
orange						Misuse of instrument settings occur and should be hindered
		orange	orange	orange		Settings should be able to be changed depending on situation
		orange	orange			Visibility of instruments is not adjustable to environment light
1	**2**	**3**	**4**	**5**	**6**	**Problems with technical handling**
	yellow	red	red	red	red	It is hard to know if the problem can be fixed by the bus driver himself
		red	red	red	red	Communication between driver and bus company people is not efficient and effective
		red	red		red	It takes time to fix problems which hinders bus driver work and passenger schedule and minimise bus company credibility
		red	red		red	It is hard to evaluate problem severeness and communicate the problem to the company
		red	red			It is not clear enough if the bus is drivable or not when error messages or alerting information pops up
					red	*problem occurring often and hindering work*
					orange	*problem occurring in small doses and irritate work*
					yellow	*problem occurring little and gives a negative experience of system*

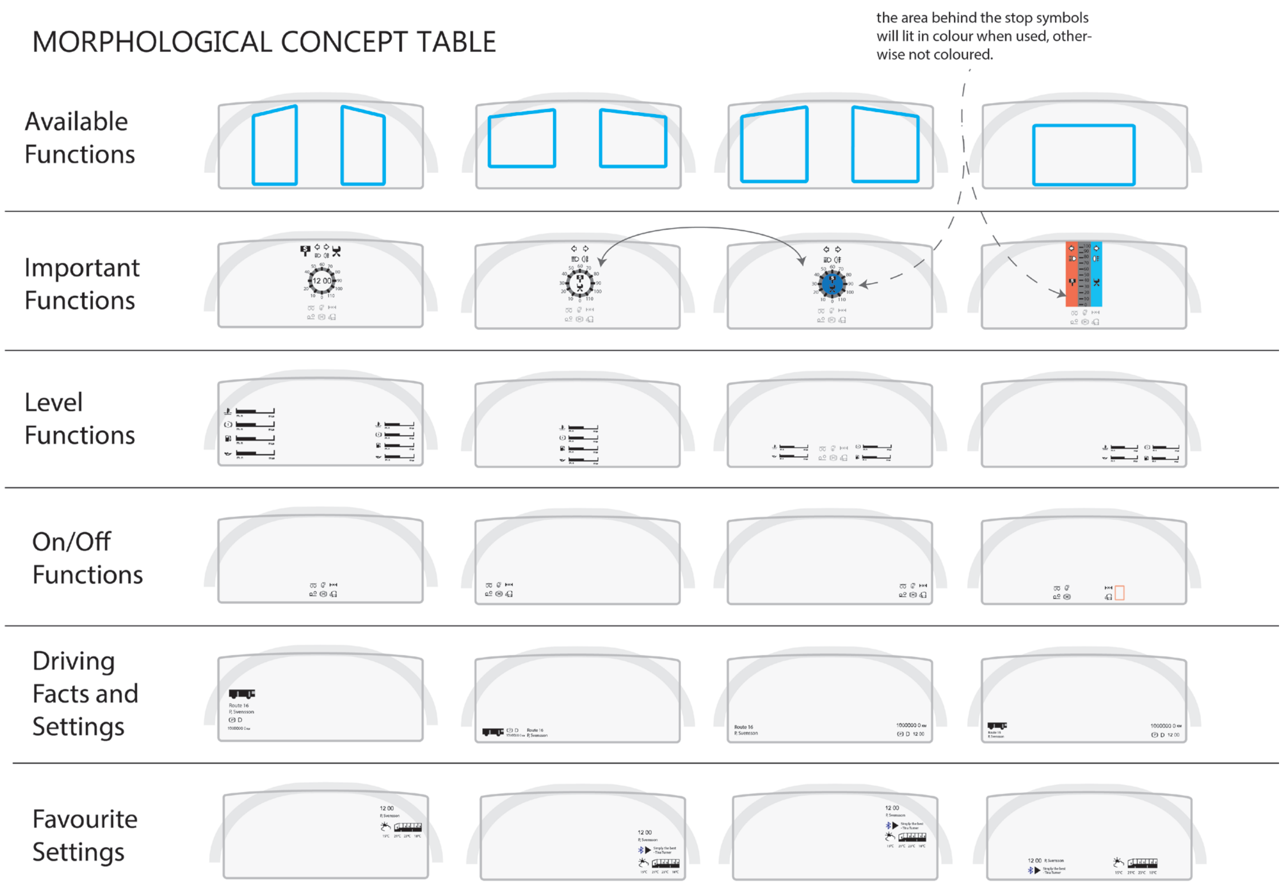
APPENDIX 6: CONCEPT TABLE

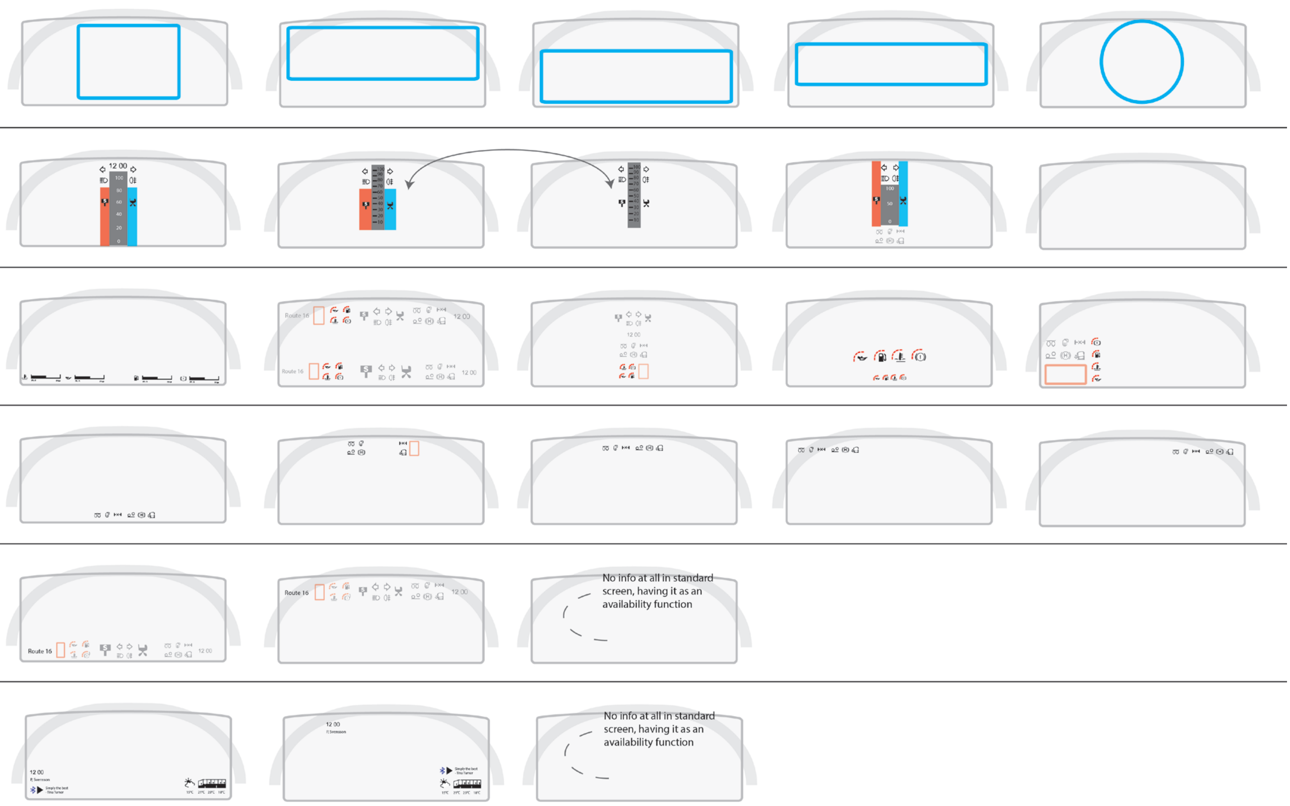
A table containing the concepts and ideas generated for the different areas of questioning concerning the handling of information for drivers in buses.

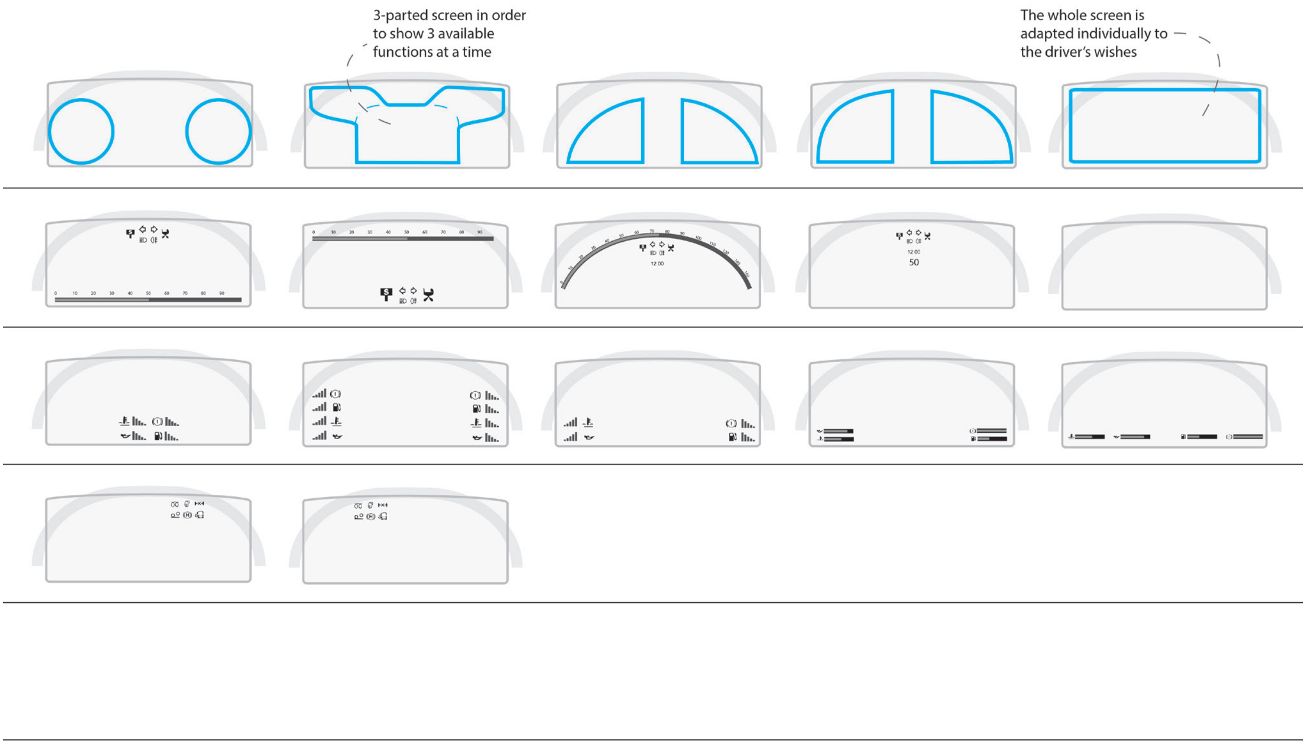
Different functions - What to show?	When can information be displayed?	In what type of situation can information be activated?	How can variation in information be changed?	Different hardware technologies - How to show it	Where could information be visually displayed?	How could information be conveyed by other senses?	Where to send information?	How can information be grouped?	How can information be presented, in what type of shape?	How can information be identified and remembered?
Ordinary instrument cluster, speed, tachometer, fuel state etc.	A combination of continously, and at critical and semi critical state and when function activated by driver	The same regardless of traffic type	Driver perform settings manually by entering the system, but automatically information change at warnings and error messages	Ordinary instrument cluster in front of steering wheel	In front, traditional instrument cluster position	Vibration in seat in some busses	To bus driver	Present scales and state in similar way and binar information messages with symbols lighting up. Separately	With round scales, clocks, symbol lights and text square	By symbols similar to what they are indicating
Camera and screen for visual enhancement during dark conditions, with pedestrian spotting. Infrared detection of pedestrians.	Continously	When driver is driving inside city	Automatically, preprogrammed according to route	Extended digital screen with possibility to adapt parts of interface merely on software, make possible to adapt to all different kinds of companies, needs.	On right side, where dashboard and entertainment buttons and interface are currently placed	Different sounds at warnings	To traffic leaders / traffic planning	Related functions close to each other	With round scales, clocks	By symbols and number combinations
Eco-driving coachning, so driver learns what way of driving is efficient from a fuel and exhaust particle perspective. For example "Sparsam" , "Pilotfish", Volvos I coachning	At critical state - action needed directly	When driver is driving on country roads	Automatically, connected to position and GPS coordinates	Head-up display that shows information directly on window screen in a way that is not too disturbing or only show information at certain times	On the windscreen	Haptical vibration in seat	To technical service people	Information concering technical state and information concering route separately	With long scales, rectangels	By symbols and letter combination or name
Feedback on time and how far behind or early the bus is compared to time table, like Västtrafiks "I Tid"	At semi-critical state - driving can continue for a while whitout severe risk	When stopping at bus stop	By traffic leader, that recieves information about an event, example a traffic accident and can change info for driver from traffic planning office	Loudspeakers that create sound	On steering wheel		To Volvo Action Service (already excisting help available to call all over the world)	Information continuosly needed during driving and information that needs to be available at certain situations	With squares	By graphics over the bus indicating position of error/activity
Bus stop overview and information	When function activated by driver	When starting up bus at garage	The bus company sets major part of settings according to normal need. Bus driver can only manually set a few number of changes.	Electric vibration devices that can be programmed to different patterns of vibration	On the A-Balk		To Technical Chief for statistics		With symbols, similar to function itself	By messages POPing up explaining clearly
Route direction	When driver needs to know information in order to plan for consequenses of the symbolised warning		Automatically, by sensing condition, for example light condition and time of day	External Hardware + software system that is possible to place in for example steering wheel behind a holder. Could be smartphone /pad that is inserted. Could be own by driver itself or company. Wireless charge and bluetooth communication to entertainment system. Also for answering calls.	On the left side		To Volvo Bus Corporation for error statistics		With a grid net	Showing at the same place each time
Visualisation of bus and technical function / errors to support correct mental model for the driver. Similar to graphic already used in Volvo busses for showing opened doors etc.							To external service firm		With round buttons	Showing at different places all the time but with same symbol
Map and bus position overview									With arrows indicating where to go	

APPENDIX 7:
CONCEPT MORPHOLOGICAL TABLE

The morphological matrix of graphically displayed concept possibilities, structured by information groups. The visualisations and placements of each information group can be combined into concept designs.




12 00
Route 16
No info at all in standard screen, having it as an availability function
No info at all in standard screen, having it as an availability function

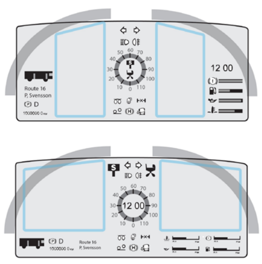

3-parted screen in order to show 3 available functions at a time
The whole screen is adapted individually to the driver's wishes

APPENDIX 8:
PUGH SELECTION MATRIX

Pugh Matrix									
Standard driving screen concepts 1st iteration	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Ease of perception	0	-	+	0	0	0	0	+	+
Grouping of related functions	0	0	0	0	0	0	0	0	0
Color function suitable to sterotypical meaning	0	0	0	+	0	-	-	-	-
Customisation possibilities	0	0	0	0	+	+	+	+	-
Enable settings to change depending on situation	0	0	0	0	0	0	0	0	0
Provide good mental model of system	0	0	0	0	0	0	0	0	-
Adaptability for future vechicle technologies	0	0	0	0	0	0	0	0	0
Low need of supervision of instrument cluster	0	0	0	0	0	0	0	0	0
Support driver alertness	0	0	0	0	0	0	0	0	0
Encourage environmentally friendly driving	0	0	0	0	0	0	0	0	0
Enable efficient handling of technichal bus problems	0	0	0	0	+	+	+	+	0
Provide information of passengers jumping off at next	0	0	-	+	-	-	-	-	-
Sum +'s	0	0	1	2	2	2	2	3	1
Sum 0's	12	11	10	10	9	8	8	7	7
Sum -'s	0	1	1	0	1	2	2	2	4
Net Score	0	-1	0	2	1	0	0	1	-3
Rank	3	4	3	1	2	3	3	2	5
Continue?	no	no	no	yes*	yes	yes	yes	yes*	no
* part of concepts will be combined, through discussion about which parts of the concepts are good,									
and which parts that should be removed/exchanged									

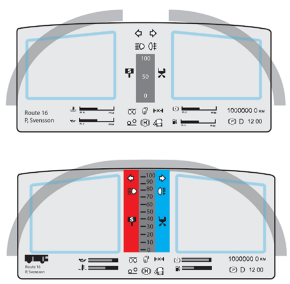
Concepts compared

Concepts 1 & 2



Two concepts with the most important information in the centre as a line with different placement of stop signals and time visualisation. Available information will be shown on the sides of the screen, making it available of showing two other information groups instead of one big one.

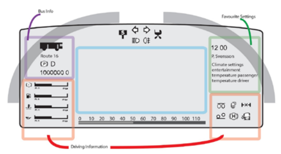
Concepts 3 & 4



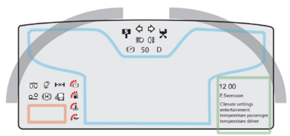
Available information on two sides with different visualisation of stop signals and speed. The idea is that the whole sides of the centre area will lit up with a red and blue colour if the stop buttons are used.

Visualisation of the bus could be taken away to make room for bigger visualisation of available information.

Concepts 5 & 6

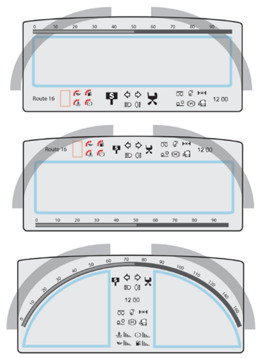


A centered space for available information groups and other information on the sides



A more down-scaled screen where some information could be easy accessible instead of stay visible at all times with a bigger visualisation of the available information needed at the time.

Concepts 7,8 & 9



A standard screen with the speed prioritised and additional information taken away to make room for available individualised information and create a clean look with only the driving information needed visualised.

APPENDIX 9:
HEURISTIC EVALUATION

C = City				Fulfilling guideline
I = Intercity				No significant changes
T = Tourist				Fulfilment less than current system
	C	I	T	Realised through
Towards theory from Endsley et al, 2008				
Principle 1: Organize information around goals and not from the technology				New grouping
Principle 2: Present Level 2 information directly and help comprehension.				Clearer scales/numbers
Principle 3: Provide assistance for Level 3 SA projections.				Maps, route support
Principle 4: Support global SA.				Support info
Principle 5: Support trade-offs between goal-driven and data-driven processing.				Distractions, like red lights, flashing symbols etc. not active unless critical
Principle 6: Make critical cues for schema activation salient				Colour coding, displayed over whole cluster etc.
Principle 7: Take advantage of parallel processing capabilities				Not worked that much with sounds and the senses yet
Principle 8: Use information filtering carefully				Not taking away important info
Towards theory from Nielsen, 1993				
1. Show system status and give feedback at the right time to keep user informed				Interactive cluster, with some continuous feedback and some event driven
2. Similarity between system and reality and use words and phrases familiar to the users'				Keeping word use
3. Give user control and freedom, to exit from functions accessed by mistake.				Keeping stalk for changing inside bus
4. Conform to standards and do not use different words that means the same thing				Keeping word use
5. Hinder errors from occurring				Information conveyed more efficient
6. The user should not have to remember information				Error Symbols not showing without text
7. Be flexible and effective so that experienced users can adapt the system				Customisable
8. Have aesthetic and minimalistic design				Unnecessary info removed
9. Help the user to recognise, diagnose and recover from errors				The new error handling
10. The system should enable use without documentation				Clear descriptions of actions to perform

APPENDIX 10:
USER STUDY CONCLUSIONS SUMMARY

BUS DRIVERS

Education & mental model

The bus drivers have special bus driver's licence, they obtain after education.

Important technical knowledge to remember is:

- The airflow in the bus, which is essential for the breaks, doors and dampening in driver seat.
- Start cables and how to use them.
- Checking and refilling water level.
- Checking and refilling the cooling liquid system.

The bus drivers have further education and courses at least every 5th year about.

-Bus drivers often get a short introduction and driving lesson when driving a new buss model for the first time. This is a bit different in different organisations.

-The bus driver needs not only handle the bus, but also other systems implemented by the organisation.

-The busses are becoming increasingly electronic and often the driver cannot identify or fix the problem by their own.

-The driver only wants more information about problems they can solve themselves, live low water level and lack of cooling liquid. If they do not have the equipment to fix the problem with them, the information will go to service instead.

-The drivers knows that many problems can be solved by restarting the bus completely. Turning it off, wait for some minutes and then try again, that solves a lot of electronically errors.

-The drivers knows that the workshop plug-in the bus to a computer and then fix the problem, they think it is impossible to solve these issues when driving.

-Some drivers, driving city traffic, does not have access to perform all types of changes on the cluster, but tampers with the system in different ways and disables functions. This is a big problems in some organisation.

-The education the bus drivers takes involves a lot of different training, including heart and lung rescue and Fire rescue education, eco driving etc.

-Fire rescue education: The problem is that if a tourist or long distance bus gets punctured in one of the wheels in the back of the bus, the other one will soon be afire and in that situation the driver would need that kind of education.

-The driver has to be careful to have an iron stick to tap on the wheels from time to time if not sure there is air in it. Important.

Work conditions

-When driving chartered busses and there is long distance cues on the highway, for example on Autobahn in Germany, the drivers can get delayed a lot and the company and the driver get expensive fines. It is not possible to take breaks because the passengers needs to go to the hotel. This is perceived as really stressful and the driver has no control of the situation. The drivers use cards to check into the bus to track their works hours, authorities can check them one year back. In city traffic, the drivers do not need to keep track of these hours. There are always situations that cannot be planned for.

-It is possible for the driver to not work if feeling tired or sick, but they want to help out and also when asked several times if they can work more than 8 hours they can feel a pressure of accepting that some of the times.

-The benefits of being a bus driver and what some of the drivers see as the thing they like the most with work is the independency when driving. They know their task and can manage almost everything themselves. It is nice to not have a manager supervising all of your job.

-One driver who had been driving city buses before states it took 2-4 weeks to get used the work on a shuttle bus.

-Driving buses is totally different from driving cars, the thinking is different and bigger.

-Drivers are paid differently, one driver with 30 years of experience in city traffic is a retiree but still works and get paid by the hour

-The highest percent of the employees are permanently employed in city traffic

Work Days

-Drivers often gets different driving schedules and work both mornings and late nights. This flipping of hours of the day is hard and make it even harder to work on evenings and late nights.

-Some drivers are only employed by hours and also works for different companies.

-Driving in city traffic means longer work hours, short breaks and irregular work hours.

-2,5 h bus driving. That's maximum driving in a row without break. Then the driver gets 10 min break on end destination in order to be able to drive 2,5 h more.

-Either the driver drive a lot in one row or the driver get one longer break in-between the driving sessions.

-The day is often divided into 2 or 3 parts each divided by breaks.

-If the day only has 2 parts it usually is a bit shorter.

-The people becoming drivers should have a "stomach of steel". They cannot go to the bathroom when they want and they cannot eat whenever they want.

-Three different groups of work hours in city traffic:

1: drives mornings and end around 15-16 and if divided the drivers ends at latest 18.00

2: in-between shifts, start at 7-8 and end at 19-20

3: latest; starts at 15-16-17 and drives all the night out, stops at 5 in the mornings

-example of work hours: 3.46-9.04, 14-17-xx.xx & 5.54-18.18

-One of the most important factors for driving time efficient is to let people in and out in a good way.

-Often there is no room for breaks at the end stop before return. If late arrival there, the driver directly has to drive again.

-If passengers are waiting outside, the bus driver often lets them in to wait, but then also have to sell tickets or answer questions and it is not really a break then.

Driver Tasks

-The different busses have different systems where the user has to perform additional tasks than driving.

-Most drivers have to perform safety checks before leaving the garage, these includes:

- Breaks
- Wheels and tires
- Lightning
- Indicators
- Signal horn
- Steering
- Window wipers
- Rear mirrors
- Windows

To fix and check these areas are often left to cleaning or maintenance, but the bus driver also have to check at start up.

-All bus drivers should greet each other when meeting in traffic

-Driver is shuttle airport busses need to:

Start-up, control and manage the 7 different screens and systems

Drive empty without passengers a short way to and from central station

Sell tickets, control tickets, control cell phones

Drive in city traffic

Drive on highway

Keep time schedule

Count number of passengers for statistics (often the same time as driving because of time loss otherwise)

Answer questions from the passengers

Handle passengers which are unfamiliar with the route and procedure of tickets

Handle tourists and passengers speaking other languages

Handling worried and stressed passengers

Be service minded and friendly - can be tiresome for some

Call out to remember seat belt

Check for big chunks of garbage and left belongings

Call out bus stops in the microphone - wants automatic message instead

Only remembers the route they drive to and from the airport

Drivers in city traffic need to:

Drive in city traffic

Look out for pedestrians

Keep time schedule

Handle threatening passengers in risk situations

Remember a lot of different routes and learn new routes

-Drivers driving chartered busses and tourist groups need to:

Check the bus before driving so that everything works

Drive in all different kinds of conditions

Keep time schedule of the passengers

Answer questions from the passengers

Handle tourists and passengers speaking other languages

Handling worried and stressed passengers

Be service minded and friendly - can be tiresome for some

Call out to remember seat belt

Check for big chunks of garbage and left belongings

Cleaner task

-The drivers have never themselves filled the bus with water that should have been done before arriving to drive the bus.

-The lamps as well as other things are checked by the cleaners.

-Each driver should go through a checklist and check everything on the bus before they drive it out, but this is not done by drivers anymore since it is already done in the cleaning and the drivers need any minute of their breaks they can get. Now they can take a coffee before going out in those 5 min it would have taken to check everything.

-It has happened that something has gone wrong anyway, but it is only due to the human factor.

-And sometimes the bus brakes while driving.

-The cleaners in city traffic buses check:

breaks, wheels, lightning etc.

-They do not check the horn any longer since they cannot be so loud all the time.

Driver Task Opinions

-Saturday traffic is very calm to drive on as a shuttle bus driver

-Friday afternoon is the hardest as a shuttle bus driver

-All user tasks get too much when having too many passengers and traffic to keep track of

-In these days the drivers feels the burden of some user tasks that they feel could be taken away by automation: selling tickets, counting passengers for statistics

-Passengers in general are very egoistic and doesn't think of anything else but themselves and their own bag

-Passengers do not stack their bag in the proper way to save space for others, which means the driver need to correct them or correct it themselves, the space is always needed.

Bus types and changing

-Drivers do not feel secure and comfortable driving a bus they have not been driving for a time or have taken a course in

-Changing a bus in the middle of a route is the worst due to the stress of getting the bus on the route again as well as the heaviness of not being familiar with that vehicle

-The buses are different in set-up and instrument placement which harden the work for the drivers.

FUTURISTIC

Future Trends

-The public regional transport organisations like SL and Västtrafik request longer busses to accommodate for increasing amount of passengers.

-Offloading time becomes increasingly important to minimise traveling time and increase number of transports with the same resources.

-Double-decker busses are requested more often, but have poor offloading time and should therefore be used for transportation with few stops.

-Longer busses seems to be preferred by passengers in comparison to double-deckers. Although longer busses is harder to manoeuvre.

-The bus companies find it harder to meet up to the increasing request from the public regional transport organisations.

-In the future the needed information might be very different because of different technologies and traffic environment.

-Electrically driven busses are predicted to be used more frequently in the future. Then a lot of information in the instrument cluster is unnecessary.

-Devices to help manoeuvring, like mirrors and screens at bus terminals might increase.

-Bus drivers work will be more industrialised to optimise resources. Bus drivers might have to change routes more frequently and when the company get fines from the public transport organisations when driving wrong or getting late it is increasingly important that the drivers can drive right even the first time on a new route.

Head up display

-The drivers find that head up displays are an interesting possibility

-There is a concern that head up display can feel almost like a reflection in the window and be very disturbing when trying to see the road.

-Pop-up that just come up when there is something really important would probably feel less disturbing.

-For tourist busses there could also be a pop-up navigation system, so the driver does not need to look down and search for a road.

-Not positive in city traffic to have something like the speed in the window all the time. Unnecessary since you have to drive below speed limits anyway.

Integration possibilities

-There is different opinions on whether it is nice for the driver to adapt the instrument cluster or not.

-All the different ad on systems in the busses today could be integrated in the instrument cluster and make up an extended instrument cluster.

-Door camera and back camera displays could be integrated in the instrument cluster.

-Back camera would help a lot because some driver explain they often do not dare to back at all.

-The instrument cluster could be a touch screen, already now it is possible to interact with and change settings with the lever on the steering wheel. It might be hard to access the screen in a good way with touch control if it is behind the steering wheel.

-Even when standing still is have to be possible to access the instrument cluster in a good way if it is a touch screen.

-To have a touch screen for the secondary display to the left with comfort settings have already been discussed and could also be a possibility.

BUS AND INSTRUMENTS

Mental Workload

-Drivers in general think the systems in the busses are too complex to use while driving.

-Drivers driving long distances, exclaimed that it is hard to switch between drivers in one bus, there are too many things to set up before the next driver is good to go.

-The systems should not need as many as 8 different actions for a driver to complete something they want to do.

Feeling of being neglected

-The drivers feel neglected. They think that the technicians who develop the buses and the drivers' place does not have the needed experience and thoughts of a driver.

-The bus companies who develop the buses do not talk to drivers about these problems, they should. The bus goes around 20h a day and needs to be useable for everyone's sake.

-Everything is too complicated. The safety that has overtaken the driver functions.

- "they twist the back of themselves"

Enhancement of Perception

-The information and warnings needed should not only be concentrated to visible signals on the screen, instead they should be placed and perceived where they belong and use the sense to perceive them with which is the most natural.

-The visibility of passengers waiting at stops at night is low and if the drivers could be helped with that it would be good.

Warm cameras that shows people at stops as a white light are now developed and used in American bus companies as a solution to that problem.

-An automatic break for people that appears suddenly in front of buses could be useful as well, though the risk of drivers stop looking for people in the way must be taken into consideration.

-But the question is how it could be applied to city traffic in a manner that hinders collision with suddenly appearing pedestrians but still allowing the bus to move forward in a highly intense traffic area with people everywhere.

-An incident: While there were heavy rain and with her umbrella in the way and the focus on that an older lady ran into a bus standing still and accused the driver to have run into her.

-The automatic brake needs to have a marginal of some sort so the bus can pass in city traffic without constant stop appearing.

-Back sensors are tricky to introduce while people often stand really close behind the bus. In order to make them move you almost have to start backing really slowly. You do not want warnings then.

-If there is something like another bus or an obstacle that cannot move behind it might be better with back sensors. But the best is probably to have a camera so that it is possible to see exactly what is behind the bus and where.

-Vibration in seats is a good way to perceive urgent information as for example the beginning of driving off road or not having the blinkers on. This solution is now used in certain cars and buses.

-Vibration in buses must be developed in a way that distinguish them from the ordinary vibration constantly appearing on the worn out routes in city traffic.

-The information should only be able to be perceived by the people who are concerned by it. In that way the drivers do not need to think about worried passengers. Worried passengers most often occurs on coach buses and longer tours.

Perception & Senses

-Sight is most important - visual perception essential

-Hearing can be of value and they listen for cues as well, although sound like sirens from police cars do not enter the busses due to isolation and sound from the radio or TV/Film showed on tourist busses block out sounds from the traffic.

-Using the haptic sense to perceive signals is a good idea too. Vibration in seat for example would be good to implement in all buses in order to prevent unexplained accidents.

Buttons & Levers

-From the driver seat, they had before 60 cm to all buttons and instruments over the driver place. In that way the driver could reach all instruments needed while sitting on the chair. Nowadays it is different. Drivers with experience over 30 years misses the old time and are critical to the new buses and the engineers developing them.

-The buses before included the buttons on the sides when they were bought, nowadays the buses include the wheel instead.

-Scania has used men from the flying business when developing the buttons and instrument cluster in the buses which has made the buses better. In these buses the buttons are better grouped together.

Cluster

-There are too many lamps and signals blipping in the bus and too many error signals that is nothing to care about that the drivers stop caring about all lamps altogether after a while. It is too much to handle, too much to keep track of.

-If a red lamp is glowing, the driver have to reach out to the workshop and call it in. It could also be possible that the workshop can have it all registered when a red lamp is glowing and contact the driver instead. That could be good as well.

-The buttons are needed to be put in the same place on all buses! Lightning buttons can be spread all over the place, not grouped. Technicians interested in different things than the drivers.

Important in cluster to keep

-Important things in cluster: Air, oil, but drivers are not interested in actual value of the instruments, they just want to know if it is okay to drive or not. The workshop can see actual value when plugging in bus to computer.

-Engine temperature & Too low water in engine

Needed symbols

-The drivers want 2 big stop signals that can be placed anywhere, but should be visible to the driver. (2 because if 1 breaks).

-Now when the passengers press on the handicap button, only that signal shows, it does not show stop signal as well, which it should.

-Either if the passenger press stop or the handicap button – the stop signal should be visible.

-The stopping signal

-Handicap and baby stroller signal – these don't need to be kept apart, but they could be kept both – the drivers want all stop-signals to light at the same time

Visual perception pattern

-The instrument in mostly inspected during start up and then only gazed at occasionally during driving.

-The driver cannot take a lot time from looking forward or in the rear mirrors. Driving on the highway or outside the city some driver explain they check it more often.

-When driving in hectic city traffic the drivers find hard to have time to check the cluster at all.

-When starting up the bus a starting sequence give information to the driver and that is also the time where the bus drivers gives most focus on the instrument cluster.

-The instrument cluster should not need to be supervised, other information should indicate if the driver needs to closely inspect something important.

Speed meter

-Some drivers mean that speed is only interesting to monitor when the driver goes to fast and that should get notified with a red warning then. The speed could be displayed with a clear number somewhere.

-The speedometer is good to have according to city traffic drivers.

-There are too many lines on the speedometer, it is not very clearly to read right now. It could only be a number as long as it is easy to see.

-The speedometer is important in walking areas, when driving up and down a hill.

-If driving over 30 km/h outside schools, the drivers go directly to prosecution. It is really important to check.

-Cruise controller has been taken away from the buses according to city traffic drivers.

-In city traffic the average speed is under 15 km/h. Drivers never comes up above 60 km/h. Outside the city, the drivers can come up to perhaps 50 km/h.

Continuous feedback and situational awareness

-The drivers want to check to see that nothing is wrong well in advance to prevent the bus from breaking down.

-Oil seems to be inspected from time to time to make sure it is in a good state and the driver wants to plan where to stop and refill it.

-Liquids that need refilling, such as oil, cooling liquid, windscreen washer liquid can preferable have scales according to some of the drivers (chartered busses). It makes it harder to plan if you would only get warning when they need to be refilled.

-Battery status - Check more in the winter

-Air pressure - Extra important during winter

-Motor temperature - If temperature is not rising in the bus, have to change bus before leaving the garage.

-Climate/Temperature inside the bus is checked at times to make sure passengers are comfortable.

-Even though the drivers do not look at the instrument cluster a lot they explain the position of it makes them perceive changes anyway.

-Comparing Volvo's instrument cluster to Neoplan's, Volvo's is perceived as easier to overview and adjust. Neoplan is more limited and there is information missing.

Differences depending on outside light

-A lot of bus drivers do not know how to change the screen between day and night modes and find it blinding at night. Even bus driver that have been driving for 2-3 years do not know they can change the light. One explanation is that the buttons for that is too far away, not on the panel itself.

-When the main current in the bus has been put on, the light in the bus should automatically start. During dark times (evenings, autumn, winter) it will be hard to find anything otherwise. It should at least be clearly visible by a glowing light: the button for the inner lightning. This should start glowing when the main current has been put on.

-One driver explained he turns off most of the tell-tales with the night mode and only see the speedometer and tachometer when empty driving without passengers. He prefers this, but his colleague did not know about this function.

-Brightness when driving at sunny conditions is frustrating, it is hard to keep track of traffic and it requires more focus to see what is displayed on the screens. Even though a curtain could be pulled down to hinder the light, you do not because the passengers want to see out.

Tachometer

-The tachometer is regarded as useless by most driver, since they use automatic gear shifting. Although in some tourist busses they might use manual.

-One driver explains how he uses the tachometer to indicate if the wheels are spinning at start on slippery roads in the winter. He says he cannot hear how hard the engine is working, since it is so far back and therefore looks at the tachometer to make sure the engine is not overloaded.

-The tachometer is good to have for the workshop part of the work, but not for the drivers only driving the bus.

-Since the automatic gear came, the tachometer is not needed.

Fuel meter

-Driver prefer to have a scale displaying the fuel level, since they do not trust lamps as much to be correct.

Air pressure

-The actual value of the air pressure is not that interesting, the driver look more that it is in the green area and is in a good interval.

-Button on the wheel for air is not needed.

Motor temperature

-The actual value of the temperature is not that interesting. The drivers look that it is in the green interval which could be 90 or 100 degrees. The temperature depends on outside temperature and normally varies a bit.

Error messages & information

-False error messages disturbs the drivers. Some error messages comes frequently and the driver know that it is probably not correct. They cannot do anything about it sometimes, even after checking that there is no problem they cannot take the sound and message away. Then it steals attention from driving.

-There are a lot of warnings, control, diagnose etc. The driver do not know some of them and put them away with button. Sometimes they come back and it is annoying.

-Often error messages that says hatches and doors are not shut, but they are shut but just sit loosely because of vibration and the driver cannot fix that and repeated error messages and sounds appear.

-Most errors in the busses are electronic nowadays and the mechanical parts are seen as more reliable

-Eventually the bus needs to be changed because of the faulty error messages, they just continue to appear frequently.

-The motor lamp often have a lot of different errors, but they get use to disregarding that.

-Warning messages are easy to misinterpret.

-Critical errors where the bus have to stop immediately can have a big red stop triangle that pops up on the windscreen. Then you understand the seriousness and that you have to stop.

-The warning for too low water in engine often cause false alarms, because when the bus have been driving a bit, the water gets warm in the engine and then the level gets normal.

Unnecessary warnings

-Worn brake linings are also information given to the driver, which he don't need since all buses are checked in intervals, where this is looked over. This, the driver does not care about. He can report it to the workshop but he will always get the answer to drive like nothing.

Personalisation of instrument cluster

-Even though the current instrument cluster is adaptable to a certain degree bus drivers are not always allowed to change that much. Settings are often set by service people and the driver can for example change light contrast depending on day to night.

-The knowledge of how to set favourite settings and change the instrument cluster is varied among the drivers. The same things apply to entering manuals and checking error messages.

Cluster and Service

-The busses drive 20h a day

-The standard stop signal need to be changed from time to time because it breaks easily. You need 9 star screw and 2 M10 to change a little lamp. It should be much easier, now it is idiotic.

-The first time it took 1h to change, now he has trained so it just takes 20 min.

-The filters sit too long inside the engine. They should sit on a row to easily change

-Need to be easier to serve a bus

-Electronics need to work more properly and better

-If the workshop work hard: they can do 2 busses a day. But if there are 4 buses need to get served.

-The buses are used in traffic and is not done for anything else

-The Company Västtrafik shall serve the drivers. And the drivers shall serve the customers. That's the idea which must be pushed forward.

-Identified users for instrument cluster

1st user: drivers

2nd users: service work people

Stop Buttons & Indication

-Most bus drivers sometimes miss to perceive that the stop button has been pressed.

-Missing a stop cause problems in traffic due to passengers' need to get off even if it is in a place in between the stops which are not suited for a bus to stop at

-The stop lamp is sometimes not clearly visible due to the wheel coming in the way depending on the position the driver sit in

-The stop signal is used around 600 times a day in city traffic

A bus goes 20 h a day

Every other minute the stop lamps is used

Which means the lamp is used 30 times an hour x 20 = 600 times a day

The busses could also go for 25-26 h a day – which means the signal is often used >600 times a day!

The drivers therefore think it needs to be prioritised in the bus in the future

Lightness

The stop lamp should be able to be visible in any day of the year, whether it is summer, winter, light or dark. Now that is not the truth.

The stop button lamp can be hard to see when it is light outside and can be too strong and be blinding when it is dark outside.

-Problems with stop lamp:

During day light, bright summer light etc. the driver see no difference whether the lamp is glowing or not.

During darkness, nights and winter etc. the stop lamp glows too brightly and distracts the driver in an uncomfortable way while driving

-Needs:

Adjustment of strength in brightness on visible signal

Protection against sun light / brightness and direction of signal towards the driver

Clear visibility for signals whether you are tall or short as a driver, should not be blocked in any way whoever is driving

Ideas of Solutions

the drivers think there should be some kind of protection against light around it so a shadow is created over the lamp – then it could be seen in daylight too

in old buss models the lamp could be dimmed mechanically with a plastic cover and that was a good solution according to the drivers.

Some drivers put paper and other things over the stop light to stop the blinding effect, which has made the lamped started to burn in some cases.

A dimmer would be sufficient for adjusting the lamps brightness and darkness depending on the situation of the day.

These solutions that the old buses used should be able to be transformed and developed digitally now

-The drivers' wishes for a tube that blocks the light from the surroundings to be developed for the stopping signal which should be directed towards the driver, but adjustable in different directions to suit different drivers. This tube would distinguish the light from the lamp better during daylight.

Stop button visualisation

When the stop button indication is just a tell-tale among other symbols it is hard to see

In the new busses that is being produced the stop button has got an own colour, more central placement and is a bit bigger.

When passengers push the stop button that can be visible for the passengers, but the bus driver only needs to get the stop information when arriving at the bus stop and it could be included in some kind of navigation system.

When having fewer bus stops on the route some drivers find it easy to remember to check the stop signal.

No distinction between handicap stop button and the ordinary

-Ordinary passengers push the special stop buttons for prams and disabled persons. Then in the older busses you cannot close the door before resetting an extra button. When stressed and wanting to close the door fast it is annoying when it does not shut and there will take some extra time remembering that the lock is on and has to be reset. Some suggestions is to reduce number of special buttons, place them only where the wheelchair is and to remove it since they check what persons are jumping off and they will see if there is prams or wheelchairs anyway and give them more time.

-The ramp warning signal on Volvo busses are very quiet compared to example MAN. This makes the driver unsure if it works and also can miss the warning and start driving with the ramp out.

-Having a black silhouette for the signal/button for disabled people/baby strollers needing to stop in the screen in the instrument cluster is not enough for it to be visible for drivers in city traffic.

-The drivers driving city traffic does not have time to check the instrument cluster unless a warning/signal is showed, and the silhouette for disabled people/baby strollers does not draw enough of the driver's attention when driving

Colour codes

-Bus driver think red means 100 % wrong = needs to stop and too late to fix it and plan around.

-Orange = semi critical, can still plan or change something to make it work

-Yellow = could be used instead of orange, are perceived in similar way

NAVIGATION, GPS –ROUTE ASSISTANCE

Planning & current situation

-Planning when driving is essential and it is important to have a lot of information fast to plan the route in a good way.

-City traffic has descriptions of bus stops on paper guides when driving. These only include a small amount of information and assume the driver already knows the way and can improvise if accidents or road blocks occur.

-Driver can find it confusing when changing buss and route in the middle of the work day and then remembering which route you are driving at the same time as handling the traffic and the passengers.

-Passenger often assumes city traffic bus drivers to have GPS and can get irritated and offensive when the bus drivers take the wrong way or cannot plan a good alternative route when needed.

-Some other passengers are helpful and can help the bus drivers find new alternative routes, although the bus driver cannot be sure of how suitable the route is to drive for a bus.

-It is easy to accidently take the wrong way as a beginner, but the drivers quickly learn how to avoid those situations while driving wrong is so embarrassing, it is avoided.

Geofencing - Automatic driving regulation

-Some busses have driving coaching screens where the drivers gets colour coded warnings when driving. When driving over 92 km/h the driver gets a warning, but that is only for warning because they should not drive more than 90 km/h. It can feel annoying for example when driving less than 95 km/ in order to overtake a truck. It is conflicting because you have to overtake the truck but it does not feel good to get a red warning. But the driver knows they are doing right and have a reasonable speed.

-Some busses are restricted to 95-100 km/h and cannot driver faster.

-Some drivers see that it is positive, because you cannot drive too fast, even is the situation or passengers pushed you to do so. Takes away some stress.

-Driver think 50 km/h warnings or restrictions in the city is not necessary while the speed they can actually drive is mostly is way below the limits.

-If there were automatic zone speed limits, these have to take in consideration speeding up before a hill and taking in consideration getting through the traffic lights before red. A little marginal above allowed speeds needs to be available.

-The gears shift also needs to take that in consideration, shifting down before a hill, could be automatic.

-The drivers might think they do not need to adjust speed at all, which is risky if the traffic is extra critical during certain conditions not accounted for in the zone speed.

-Bus drivers want to stay in control of the bus and also claims that a bus cannot perform the types of considerations and decision making that a driver has to perform. If for example the speed would be adjusted depending on if there is risk of slippery roads. The bus only looks at the temperature, while the bus driver can understand the situation better.

-If driver is in control and has responsibilities the performance can be better than if removing responsibility with automatic function according to some drivers.

Driving alerts

-Drivers think it is nice to have some kind of alert if they would fall asleep. Even though they claim the risk of falling asleep is so small, you know you just cannot fall asleep.

-If there are warnings it is nice if they are intermediate to the driver in a way that the passengers do not notice it, by vibration for example.

-Drivers prefer to not let the bus overtake their control and are a bit sceptic to auto break.

-Some driver would like alerts when the side or front of the bus is coming too close to something.

Other automatic functions

-Call outs for bus stops is sometimes pre-recorded and in other cases the driver has to shout it out. Some drivers think they should not have to call out.

Automatic doors

-Doors are sometimes automatic in city traffic, and have photo sensors by the doors, activated only when standing still on a bus stop.

-Some drivers do not find automatic doors nice, while they are not as fast as regulating it manually. The on and offloading gets less efficient than if looking yourself and force shutting the doors. Some drivers only use manual regulation, but those buttons are less accessible and that is a problem.

-For security reasons it is important to have fast access to forced shut of the doors and availability to lock auto function. In city traffic the bus driver is trying to avoid getting dangerous persons on the bus. If they see someone is heavily drugged and threatening, they want to block it from entering. Those buttons now is too far away.

Quality issues

-The majority of bus drivers find that the quality of the busses are far too low in comparison to price. They find that all of the different brands (Volvo, MAN, Neoplan) lack in quality in different ways. Still, most of them perceive Volvo busses as the most qualitative of them.

Add on equipment

-Different busses, organisations and public transportation organisation has different systems for displaying the routes and other additional information. It is a problem and could be solved by providing a platform to adapt all solutions to. It would be simpler to have the information in one place. Make it easier to use.

-Sometimes the different systems overlap and displays same information

-Some busses had an extra display just for temperature, which is already possible to have in the cluster.

-The more screens and ad on there are, the more things can break. And they often have errors.

-Extra screens put in the buses:

Payment screen for selling tickets

Timetable screen

Additional help screen

-Some drivers like different screens for different purposes and some thinks they could be integrated in the cluster.

-The most important is that the additional screens do not take up sight area.

-Some of the add-on screens have touch function and some have buttons instead. It is confusing when the interaction is so different between the screens.

-The screens should sit in the best optimal way, should be able to be angled in the best way and as low to be visible.

-Västtrafiks payment machine was in the beginning placed too high beside the driver cockpit, there was no way it was usable so it had to be lowered afterwards, after it was bought.

-The payment machine for credit cards was placed beyond the payment machine for Västtrafik cards which made it close to impossible for drivers to reach if necessary.

-In the timetable screen there exist information as pop-up messages that:

the bus has low battery level. Start up the engine again,

tells the temperature in the bus, how cold or hot it is.

-"Through the timetable screen "they" see exactly where we are and how fast we are driving. "

Additional Bus Equipment

-Rain sensor seems hard to understand and set and when spooling the wiped wipe so many times that it gets almost dirtier than before. Also some drivers do not know how change the intervals. An automatic solution that really works and feels how much it rains might be better.

-The shift gear has been replaced by buttons in today's buses which the driver are fine with, though the glowing of the buttons disturb the drivers during both day and night driving.

-On the doors: there are rubber splines and design tape that takes space around the door which is unnecessary and unwished for since it takes space which is very much needed when bringing in baby strollers inside the bus.

-Drivers in city traffic needs function before design and think everything that is not needed should be taken away.

-A bus driver system called Retarded: oil breaks the bus instead of using normal breaks. Less worn-out brakes. Good! The drivers should always use the "help-break" first and then the normal one, that's the last resort. If the breaks get to warm they can't be used, therefor they exist in electrical buses.

Seat belt

-Drivers often skip to wear seat belt. It feels restraining and is not as comfortable as in a car.

-For drivers that has to turn to the passengers and for example sell tickets the seat belt cuts into chest and shoulder when turning. When that happens a lot of time each work day it hurts the driver.

-Some drivers modify the belt (fasten bread bag clips) to make the belt less tight.

Driver's seat

-A lot of drivers no not find the drivers chair comfortable enough.

-Drivers tend to think the chairs were more comfortable long time ago. They think they sit well in the old chairs and can twist around in a good way. When changing bus in the company, they sometimes keeps the chair and put in the new bus.

-A lot of drivers have back problems they think is caused from sitting in the chair, not using armrests as they should for example.

-The drivers chair has to be really fast to adapt your settings when changing between different busses, they do not always have time to set it correct.

-Even though the drivers chair is adjustable to a certain degree very tall and short people cannot change it as much as they would like.

-Hard to adjust chair in good relation to the steering wheel, the wheel is adjustable, but not far enough for people with long legs. Only a few centimetres more adjustability would solve the problem.

-Sometimes the chairs are unstable, and then it feels hard to drive.

-The driver's seats often lose their comfort after one year or so.

-When turning the steering wheel pole is often in the way and the driver keeps hitting the knee in it.

-For tall and big drivers in coach busses with more cramped passenger entrance the luggage of the passengers almost hit the driver. Especially in the airport shuttle where passengers have really big suitcases with them inside.

-Needs to be easier to clean, while it is often dirty.

-If driver is very short, so the shoulders not get above the extra padding that is supposed to be under the shoulders, the shoulders are forces forward and together in an uncomfortable position.

-The back of the seat is too broad for small shouldered persons. If the seat could be adjustable for all types of body sizes that would be preferred.

-There are too many buttons to adjust the chair. They are hard to understand and manoeuvre.

-The rotation moment of the chair is important even to city traffic drivers so they can turn themselves towards the passengers while still sitting ergonomically. The need for customer service is declining in city buses though since the drivers no longer are responsible for tickets.

Storage room

-The drivers would like more room for storage so they can keep some things close at hand if needed when driving. To be able to reach at a bus stop or similar.

-Drivers think the space for them is too cramped. Just a big bigger with room for their jacket and a bag would be nice.

-In chartered busses and tourist busses the space for guides and room for bags and papers is not enough.

-Drivers driving in city traffic have a space need for a bag and a jacket as well as a reachable coffee mug that needs to be put in a place clearly visible without needing to look too much away from the road.

Mirrors

Outer rear mirrors

-The drivers say the mirrors are extremely important. It is with the rear mirrors the drivers have control over the bus.

-The rear mirror on the double-decker bus does not hang down as much as the other ones.

-The outer rear mirrors point out a lot and it would be nice to be able to change them from inside the bus.

-The mirrors often hit branches and poles when driving. They point out so much that they hit different obstacles.

-The left mirror seems less important than the right mirror. When overtaking it is hard to see on the left side, but the right mirror is better.

-The left mirror can be placed very high or very low depending on the bus type used. Not good if the mirror is too low due to the driver sitting too close to the window/mirror and there is too much space behind.

-When driving into a bus stop people that does not know about that the mirrors are pointing out do not realise they will be hit. If the right mirror was hanging down as much the risk of hitting people is bigger.

-Some think the mirrors too close to the A-pole and they can miss persons outside in the dead angle when entering a crossing.

-The dead angle between the front door and a little behind the front wheel is dangerous, there can be a car driving up along and also bikes and other objects are hard to see.

-The dead angle causes the driver to have to shift in their seats all the time in order to check if everything is cleared before moving the bus anywhere.

-It is worse on the left side; mirrors are better put on the right side.

-If bus turning left or right, the bike the same, then the bus driver cannot see the bike, leads to accidents.

-The bus driver cannot see in dead angle bus drive out slowly and hope for the best.

-Some drivers buy own small mirrors from Biltema, solves a little of the problem. But they would like a mirror that covers a bigger area.

Inner rear mirror

-The inner rear mirror for seeing passengers should also be able to change from seated position, because the different drivers have different heights and often it is first when already driving that you notice the mirror is not placed right for you. Now you have to stop, stand up and change it and that takes time.

Additional mirrors

-Some bus drivers suggest one extra small mirror to make it possible to see the front of the bus. Then they can see how much forward they can drive, because even if the front is flat it would be nice to have more control to drive close to the vehicle before in cues.

-When driving around corners, it is not possible to see if not driving too much forward. If it is not possible to turn then the bus have to back, which is really hard with traffic behind. Mirrors placed in the environment in tricky intersections is a suggestion from a driver.

CLIMATE AND TEMPERATURE

Climate systems

-Different busses and organisations have different heating systems installed.

-Some have system with warm water, others electricity and at night time especially in the winter the busses are connected to an external heating system at the garage when not in use. These system prevent the bus from freezing. But in some organisations only a small percentage actually work and then the hands of the bus driver gets really cold when starting to drive. The heating in the bus itself is also often not functioning in some way when the outside temperature is very low.

-Drivers appreciate heating on the legs, which some busses have, since they get cold otherwise.

-Some drivers find that the heat is hard so set to get good dispersion of heat on different places, for example they do not want heating in face but on the legs instead.

-Some drivers use finger gloves.

-The heating system for some city traffic drivers sits at the top of their heads in Scania buses, where they don't need it. The drivers need heat on their feet. The older one gets, the more heat is needed in the feet and lower body.

-The fans need to have a little lesser effect than they have today in the Scania buses, now if they are turned on they are loud and stormy. The driver really just needs a little blow to keep them awake and it should be very quiet. Everything should be calm and quiet.

Passengers and Heating

-A bus can be defined as "many people in a very small space". This makes it important to keep track of the heat in the bus.

-The most common complaint from passengers riding long distances in buses are from the temperature in the bus, either it is too cold or too hot.

-The passengers in the bus often wants different temperature where they sit. It is a difficult situation for the drivers to maintain a central position of temperature that most passengers are happy with.

-One driver states that he adjusts the temperature to be optimal with passengers sitting with the jacket on, usually under 20 degrees. If it is set higher, the passengers could get sweaty which could create a smell in the bus. The driver actually likes it colder, it keeps him awake and the smell away.

-The climate system in the bus (KLIMA) is very sensitive and often stops working, even though it is an expensive system to develop and use.

The drivers wishes for an easier system to adjust the temperature in the bus, though they don't think an individual temperature could be used for the different passengers in the bus. It would just not be able to be contained from seat to seat.

-When the heating system is down, it is hard for the drivers to work.

Standardising of Buses and Instruments

-According to some drivers with more than 30 years of experience, bus companies tried to standardise the instruments on all buses in the beginning of the 21st century. But the ideas were never followed up and completed.

-There have been a number of different tries for a standardised bus project called Norrm-bus/standard bus/EU-bus or something similar over the years, though it has never come through in the end.

-A standardisation of the instruments in the buses is of common interest to all the drivers. Driving different buses is hard due to the difference in instrument placement. The companies wanting an own design should not go before driver usability.

-For example, Scania and MAN has the opening of the door on different sides of the bus

TRAFFIC

Important Factors during Driving

-Planning the driving.

-Keep track of traffic (ahead, behind and on the sides).

-During turns and going around corners, the rear-view mirrors are very important.

-Not to get stressed up. Important to keep focus and be careful to not get in trouble.

Problems while driving

-If the doors won't close, the bus can't drive away from the bus stop. That is a problem today.

-Before, in older buses, the drivers could deactivate the doors and get out from the bus stop, now they cannot override the system.

-There are override techniques to avoid the system, but that the driver are not learned (only workshop knows) because if the driver knew, they could be driving with open doors, and that wouldn't be good either.

-They can be standing a little all over the place. With the doors wide open because the computer operating the doors won't work properly. Cues behind with cars can be building. Not good for anyone.

-The thing the drivers need to do: shut off the whole buss and wait some time until the computer has been restarted and can work properly again. It solves almost all problems except for puncturing.

-It can be hard to trust the system when it only stops working.

-The system need to be taken care of.

Traffic accidents and cues

-When the route is blocked the driver has to decide if it is worth trying getting out of the cue or if the traffic jam is soon resolved. For drivers in city traffic these questions can be asked to the traffic control with cameras overviewing the city and more information to help the driver decide. On tourist busses the driver have less help and would prefer automatic assistance somehow.

-When driving tourist busses the drivers does not have a lot of local knowledge about the roads and cannot plan alternative routes in a good way in traffic jams. When eventually realising the scale of the cues the driver might take a smaller alternative route but then find the that the bus gets stuck again, while local traffic were faster to react and get out before.

-Drivers driving shuttle busses does not find GPS or maps like something important. They drive the same route all the time. There is also an alternative route they know about. But they rarely uses that either.

-If navigation system would be updated by the traffic control office or by some support system the system would give better information to the drivers, because it is especially when accidents block the route navigation help is needed.

-Some city drivers think that the instrument cluster could be a big map that shows the driver where to go. The map might not be placed behind the front wheel, because the driver have to look down to see it and could instead be projected on the window with Head-Up technology.

-Traffic leader monitor traffic information in route description in the screen driver knows exactly where to go. All the driver needs to think about is stick to the description. GPS position of the bus is constantly sent to traffic control.

-Stockholm have problems with road work and rebuilding of streets, to get information about that quickly to the driver to enable re-planning the route is essential.

Navigation system concerns

-Navigation system might be useful when starting to drive a new route, but the drivers remembers the routes quite fast.

-Even if the driver has different routes it is easy to learn, at least according to drivers driving in and outside Gothenburg.

-There are concerns about that GPS can take too much of the focus and make the driver less aware of the traffic and not remembering the route. The drivers think focus on rear mirrors might be decreased.

-Good if GPS do not take up to much focus from driving.

-Navigation systems will only help driving on an unfamiliar route and should not be used as a normal mode. Navigation should be an option the driver can choose or not.

-The driver might be less alert when using navigation system.

-There is a joy of learning new routes and finding your way by yourself, the navigation system should not take away that learning process and make driving too boring.

Fleet management & traffic control

-The bus traffic is believed to be increasingly centrally controlled.

-One example from Stockholm is that a traffic leader at traffic control might have 85 busses to keep track off.

-Might be around 10 different traffic areas in Gothenburg and 10 traffic control centres.

-In Stockholm there were 4 different traffic control centres but now there is 1 for all 4 areas.

-Centralisation trend to make sure the traffic leaders are skilled and professional and can perform their tasks well, instead of as before using staff managers without proper knowledge of traffic leading. The more complex traffic environment and system bus traffic leaders needs to be as skilled as air traffic controllers.

-Call between driver and traffic leader might take 20 seconds and includes what the driver should do in a specific situation.

-Technical issues might take 4-5min. Call should be directed from traffic leader to technical which has can handle time consuming issues and has more knowledge about that area.

-With fleet management the technician on support can access the bus history and check for old problems and figure out what the new problem is.

-The drivers needs clear information about when they should call traffic control and when they do not have to.

-The traffic leader needs to make judgements on how to make issues affect the passengers least. Even if the bus have an orange - semi critical fault the bus might have to be driven a bit more. Traffic control needs clear and correct information to take decisions.

-To have communication between traffic leader and bus driver through the phone is probably good, since there is someone trustworthy overlooking the bus and answers the driver what to do. The drivers feels more comfortable then.

Accident Factors

-Most of the interviewees confirmed that the most frequent accidents buses are involved in happens while idle running, meaning the buses are more often involved in accidents from, to and on the depot than on the actual bus route.

-The accidents on idle running happens as often from the depot as it happens to and on the depot, there is no difference in frequency on idle running accidents.

-The most common accidents on idle running is caused by tiredness, resulting in driving off-road.

-The most common accidents on the bus route is caused by a miscalculation and results in hitting minor obstacles on the road, for example signs, poles etc.

-There are many accidents that are unanswered though and an important thing to rule out as a cause is interaction with mobile phones.

Tiredness, relaxation and alertness

-Tiredness exists very seldom on the bus route according to most interviewees due to the alertness the driver gets while driving/working.

-During the idle driving however the driver is not as focused due to that the work hasn't started yet and with no customers on board the driver gets relaxed, which might be the cause of the accidents

-Especially after the end of a work period the drivers get instantly tired and relaxed. The focus and sharpness from before ends in an instant.

-Drivers are used to the work so tiredness doesn't affect them.

-One driver claimed that the tiredness in mornings are easier to get used to than the boring and tiresome events of the evenings.

-Though other drivers are not morning persons and rather drives in the evening, so it differs between personalities.

-During evenings the driver need to be more attentive to people popping up in the surroundings, which makes the driver more tired, though while the focus and alertness is on the driver does not feel it that much.

-Tiredness does not worry drivers, they adjust to it easily by staying calm and perhaps not communicate unnecessarily with passengers on board.

-When drivers feels tired, the driver prioritise the driving and traffic ahead while the service towards passengers and the selling of tickets come in second hand.

-It is the constant surveillance of the road that causes the tiredness in the long run. It comes creeping at you.

-One driver states that he stopped working as a driver due to the tiredness that hits the driver after each working day. He felt dumb and tiered to his bones. Now he works at the workshop and starts every day at 6.30 and is much happier with his life. He didn't feel like he had any energy and strength left for after the work when driving.

-One driver thinks it would be interesting to see which day the drivers collides the most.

-The drivers usually work 4 days in a row and are free the 5th day. The driver is pretty sure that most accidents happen on the 4th day in the afternoon.

-The drivers usually work 4 days, 1 free, 4 days, and then probably have 2 days free.

-Inside the bus there are insurance that covers possible accidents, but outside is worse.

-In order to hinder tiredness to cause accidents, the visibility and perception of the outside need to be heightened and prioritised.

Accident example:

-a man who doesn't remember anything from the accident drove off road and got stuck in the bus with his mobile phone in his pocket, unable to reach it

-the accident cause is unknown: it could have been tiredness, blacking out, non-watch of the road

-interaction with mobile phone could be ruled out due to the fact that it was stuck in the pocket

Road & Traffic Conditions

-The roads are often worn out, resulting in bumpy rides which makes the work entirely different than having the things not moving. The information in the cluster gets harder to check while the springs in the seat moves up and down to ease up the bumps.

-City traffic involves certain stop areas which are harder to go through than others, for example Korsvägen in Gothenburg. These areas are handled with care and knowledge that there are lots of people, traffic and obstacles that could come in the way.

Weather Conditions

-Sun causes problems to the driver in terms of visibility, both visibility of the road and visibility of the signal in the instrument cluster.

-The difference in traffic environment and weather conditions when driving long distances makes it hard to enable a system that helps the driver to turn in the right manner. It might be hard to programme the system to incorporate the weather conditions the situation is affected by.

-When passengers put on their reading lamp or if ceiling lamp is on it causes reflections in the window screen.

Cues

-Traffic accidents or road construction causes cues on the road which harden the driver's task to keep to the time table. Being late causes stress and frustration among both drivers and passengers.

-Alternative routes needs to be taken in the right time when cues appear.

-Standing still in cues causes tiredness among drivers, especially the ones doing long distance driving who has a time schedule for both himself and the passengers on board for the day of the driving and the next.

-the drivers work hours are in jeopardy when driver gets late

-the passengers time schedule on the different hotels, restaurants, sights minimises when unplanned cues appear

Day vs. Night Driving

-Driving in city traffic often means it is more people out on the day, both as passengers and pedestrians as well as driving cars and bicycles, than there is on the night.

-The drivers often prefer to have more traffic and passengers to consider, than have close to none, because the lesser to consider the more comfortable the driver feels, resulting in lowered focus.

-But when the things to keep track of get too much, too intense, the drivers feel stressed and a bit out of control. The drivers likes to be in control of things.

-The hardest work day from one driver's point of view is the one where they get to work both morning and afternoon, instead of having an earlier morning period or a late night.

-After 19.00 the congestion tax no longer applies in Gothenburg, resulting in an increase of car traffic influencing the buses working long distance periods.

Lightning

-The biggest difference in day and night driving is the light from outside resulting in different driving scenarios where drivers need different views of the information.

-The bus own inner lightning needs adjustment between day and night. The ordinary day lamp cannot be used during the night due to the brightness blinding the drivers and causing bigger reflexes in the window shield.

-During night shifts the bus drivers uses the "cosiness lamp" which allows better visibility on the road but also lowers the brightness and visibility inside the bus, for both the passengers and the drivers.

-Older buses used to have a screen that could be turned around the driver seat and minimise the light from the passenger area to cause reflexes in the driver's windshield.

-Dividing the inner lightning in the bus would be a preferred solution, having the back and front passenger seats divided into two sections which could have different lights. Then the reflexes and the blindness of the driver would be minimised. [There are buses with these options]

-There is an option on the display that could be reached through the menu called "night panel", which causes everything on the instrument cluster to be taken away, this could be put on and off at any time, lowering the brightness that could distract the driver in the night.

-In front of the back door, the lightning should not be on.

-The lightning in front of the back door should only be switched on when the front door is opening. Automatically.

-In air traffic control towers the windows are angled to avoid as many reflections as possible. That is however not the case in buses.

Reflections in windshield

-Due to too much lightning inside the bus, the window turns into a mirror.

-Drivers state that reflections in the window is a big disturbance while driving, both during day and night, though night and especially autumn/winter are much more troublesome than during the day and spring/summer periods.

-The problem with reflections is directly related to the light inside and in the surroundings on the bus

-The light inside is only turned on for passengers in the night, if necessary. The drivers would rather have everything turned off.

-Sometimes drivers can be fooled by something inside the bus causing reflections in the windows that makes the drivers think there are something inside the bus when it is just a reflection.

-Lights from cars and confronting traffic blinds the bus drivers momentarily.

-The lights on the bus are much weaker than the lights on cars and taxis according to some of the bus drivers. The lights on the bus are more similar to bicycle lights and views only at maximum 10 m forward.

Problems:

-Can't see outside

-Can't distinguish difference with inside and outside.

-With cars on both sides meeting and driving away from you, it is hard to know which cars seen in the windows that are the actual ones and which ones that are just reflections!

-Miss passengers standing at stops in the night, too dark to see them outside and too light inside that blinds the driver.

-Buses with extra doors for protection – creates another reflection to keep track of.

Traffic Thoughts

-Drivers with more than 30 years of experience driving tourist and long distance buses state that it has become harder and harder to drive busses over the years due to the increase in intensity in traffic.

-One driver driving shuttle buses states that driving only occurs in the right lane with the exception of overtaking of trucks.

-Drivers adjust the driving to the traffic and the environment in which he is driving.

-On worn-out roads the driving gets bumpy very easily so the driver drives slowly to make it more comfortable to go through.

-On unstable bridges (that has not been able to be fixed due to constant traffic) the drivers have gotten direction to drive extra slow.

-Snow does not affect the drivers since the roads are shuffled very good, the hard part about winter weather is the cars that drives very slow which causes traffic cues.

-One driver states he thinks more about driving when encountering a bus rather than a tram. The tram has a certain line it follows, buses and other vehicles can be more unpredictable.

-Keeping track of other traffic includes other buses and since a driver know how hard it is to back up a bus, he should give space to buses around him when they have their white light on (symbolising backing up). Not all drivers do that even though they should.

-Bus drivers feels they can't keep control of things when backing.

-Walking street and bus street collides into the same – how can that be allowed?

-It is really hard to keep the 7 km/h=walking speed.

-People at the universities walk right out without looking however high the education is they are studying is

-People might be taking advantages of the drivers that uses all their powers not to hit someone, but themselves don't care and walk without looking.

Priority: Safety & Smoothness & Environment-friendliness

-For tourist bus drivers, the priority lies within driving smooth since these passengers stay on a bus for a longer period of time and priorities comfort. Driving environment-friendly is not prioritised, even though driving smooth and comfortable often coincide with driving environmentally friendly.

-The tourist bus drivers think it could always be good to get a reminder of how environment-friendly the driver drives, no matter the experience.

-The drivers take courses which often involves the environment, the drivers could be reminded of this new information through for example Volvo's iCoaching, in order to keep the newest knowledge intact.

-During observations, other systems for coaching the driving was found, such as Pilotfish and Sparsam, sometimes connected to a small salary bonus for the drivers. It seems like the different bus companies have used a lot of different systems. Sometimes some functions in the coaching system and the bus is the same, and they do not show the same values.

-The drivers always take safety before environmental-friendly driving. Sometimes there are too much of other things to consider in traffic that hinders environmental-friendly driving.

-As a beginner, the drivers do not care about driving environmentally-friendly, they have enough to keep track off already.

-Drivers with experience have learned to always try to drive environmentally-friendly, both at work in buses and in their own cars. It comes often naturally.

-Driving environmentally-friendly often coincide with driving smoothly and planning the driving, which is both critical parts of driving tasks.

-When going up a hill the driver needs to plan the way he is driving. The driver needs to increase the speed before entering the uphill road, though when the driver has reached the hill he lets go off the gas altogether and drives on air, which is good for the environment.

-One driver states it is important to get up to the maximum speed (90 km/h in this situation) as fast as possible and then let go off the speed. In that way there are less particles released in the air which is environmentally good. Though he does not think all drivers think like that.

-The system Pilotfish help the drivers take the environment into consideration when driving. The action of the driver is summarised and scored through the Pilotfish System, visible on an external screen. The goal is to have under 1,0.

-When driving on air, the pilotfish gives 0,5-1, which is a good number.

-The drivers gets reports on how they have been driving and if they have been driving on green under 1, they get 500 SEK extra on their celery.

-Driving uphill, over the maximum speed, the Pilotfish gives the driver a warning, but the driver does that in order to drive environmentally-friendly on a longer row later.

-During harder breaks, the Pilotfish shows red, but those breaks are often a necessity to avoid accidents due to the driving of the other traffic.

-The Pilotfish system only gets annoying when it shows red on situations that the driver could not himself control and had to break hard and get red due to other traffic around.

-Eco driving is really good. But that should be not only for bus drivers to think about, all should have the same conditions and concerns. If not the car in front drives eco, the bus cannot do it.

Anxiety during driving

-Newly-built roads are harder to drive on because of the uncertainness that the road is wide enough for buses.

-Drivers driving through city traffic in Gothenburg drive on tram tracks in order to not hinder the traffic flow.

-When doing so, one driver driving shuffle buses states he feels comfortable because he does not have to think about vehicles around him.

-The narrowness of the street does not bother him due to experience, though it might be harder for other drivers.

-Road construction causes the drivers to pay extra attention to the road and traffic. The drivers need to be careful when driving through roads with construction not to hit anything due to the small spaces of passage leading the traffic forward.

-In an environment where there are people everywhere and additional obstacles blocking the drivers view, the driver feels worried he might miss persons that might appear behind the obstacle.

-Even though cyclists have red in a traffic signal when buses have green, one driver states he is always on his watch for cyclists, even though he shouldn't have to worry about that.

-One driver states that the only thing hard about driving shuttle buses are that taxi cars drives wrongly and often stands in the way.

-The driver always have to think big, take big turns etc. to avoid accidents.

Looking at Screen

-One driver driving shuttle buses claims he does not look at the digital screen much at all, only to check that everything is ok once or twice.

Stress at Work

-Stressful situations include

days with many passengers delaying the on-board time

lots of traffic delaying time table

other buses blocking the path of the driving bus on bus stops

passengers needing to refill payment card before buying a ticket

the feel of not having the time to check all passengers tickets

passengers getting disturbed of the non-service when driver puts efficiency in front of politeness, not giving them the 5 min they would like to be greeted on

the feel of blocking other buses path, empathy for colleagues

disturbing passengers who does not follow the rules of the driver

no food or drink, especially no alcohol

no bathroom breaks

putting the bags in shuttle buses in a non-space saving manner

lazy passengers taking their time and not following the effectiveness and speed needed for fast on-boarding

Stress and effectiveness

-Bus drivers can get annoyed at each other if another bus is blocking the way by standing still on a stop destination to get all passengers on, due to this, drivers often feel stressed to drive away, with passengers still not having paid for a ticket.

-Due to the limited time the driver has on each stop destination (and that delaying means no break) the driver often tries to be effective.

-One observation included a driver driving on the tram track while still selling tickets to three persons by entering information on a touchscreen as well as checking rear mirrors and changing lane.

-Another observation included a driver selling tickets to passengers through the touch screen while telling passengers with prepaid tickets to go through at the same time. In this way the driver got 4 passengers with prepaid tickets on board while selling 1 ticket to a new passenger.

-One driver states that when stressed, the driver follows a certain system in order to focus and get all tasks done in proper time. Effectiveness and speed are the key terms in the system.

-Passengers needing to refill payment card before buying a ticket lower the effect and heighten the stress on the driver. It takes 1 min to refill the card and getting 10 of these passengers means 10 min late on the time schedule, which is the drivers break at the end station.

Drivers having the task to check all passenger tickets as well as the statistics of how many passengers board the bus, often get stressed over the amount of task needed to be done on top of the traffic to keep track of and the timetable to keep.

The drivers feel that some of these tasks should not be the driver's responsibility. Perhaps automation could be a solution.

-One driver states that when blocking the path of another bus the feel of stress is heavier than when passengers disturbs.

Manoeuvring Problems

-The back of the bus always turn a lot more than expected when turning since the bus is too long to know exactly how it will turn in different situations.

-Buses are often involved in smaller accidents due to miscalculations of situations where the buses hit something it didn't expect to. The traffic environment is often too small for a bus.

-The most common damage is back on the right side when turning left with a bus. The right rear end glides often out more than expected.

-Solving the problem is hard because if there were to be warnings that helped the driver how to manoeuvre a left turn, these warnings and indications would be needed in advance of the curve, before the driver even has told the bus it will turn in a moment.

-If a warning comes up when the bus already have been placed in a situation before turning, the damage will already be done because the bus can't back up and do a better turn when there are other vehicles in the traffic everywhere, which there often is.

-Dead angles causes the drivers to sometimes not be able to see that a hitting of an obstacle has happened. It is about 24 m between the driver and the back and the mirror don't help him much to see if something has happened due the backs additional turn.

-Accident example: one bus that was turning out at an end destination brought with it the side of another bus that stood too close to the bus which was turning. The driver didn't notice what happened.

-Experience and carefulness often hinders accidents to happen, but when the drivers get stressed or disturbed of reflections or other visualisation problems, it is easy to drive into small obstacles on the roads.

-Often small accidents leave their mark on the buses backs in form of scratches.

Pedestrians (people outside the bus in traffic)

-People walking in traffic environments have a tendency to walk right in front of a bus without looking anywhere, often having the ears blocked by headsets, preventing any traffic sounds to alert them.

-The drivers try to take contact with pedestrians in order to understand their next movement and be able to plan their driving to avoid collisions, but the pedestrians themselves often don't care to communicate with anything else than their walking.

-Some drivers try to educate pedestrians to be more attentive by not stopping the bus for people walking over streets where they have no right to. These drivers let the bus roll slowly but constantly forward, indicating a forward driving in a manner that stops the pedestrians to try to get in the way and think about what they are doing.

-Other drivers slow down anyhow, whether the pedestrians have precedence or not, in order to not end up in a bad situation.

-On pedestrian crossings, people walk right in front of traffic whether they have green light to do so or not.

-Pedestrians on crossings can also be too attentive and wait for the bus to reach the point, taking contact with the driver, and not before then trying to walkover. This results in an irritating driver who has to break harder for pedestrians who wait too long with walking over, resulting in an unnecessary stop of the bus.

-The worst kind of pedestrians are the ones running after a bus they want to get on. They run in the bus lanes, blocking the next buses driving and do not look at any traffic around them.

-The constant concentration on traffic and people walking in the bus surroundings takes its toll on the drivers, especially during the start of the day.

-The driver has to analyse the situations all the time, keeping track of all visible people and try to understand their patterns in order to plan the driving in a good manner to prevent collisions and accidents.

-Scania have good horns that the drivers use on pedestrians that does not watch out for them, blocking their vision with a hood and their hearing with headsets.

-The law says that pedestrians need to have an eye connection with the driver, but that is not the reality.

Pedestrians/Passengers (people on bus stops)

-The driver has to look out for people running out from behind other buses, since they are blocked from the drivers view and appears only when they are just in front of the bus.

-By experience, a driver can distinguish people standing at bus stops that wants to get on the bus from those who waits for other buses/bus lines. It is visible by the way the people gaze at the bus.

-In the dark, passengers at bus stops are harder to spot as well as pedestrians on crossings. The driver need to be more attentive in the dark towards people in the traffic that might pop up from anywhere.

Bus stops

-At bus stops, the construction is nice-looking, but hard to manoeuvre. It is hard for the driver to get the bus all the way up close to the bus stop where the passengers enter and still keep it straight so it is possible for them to drive away from it without unnecessary reverse.

-If the bus stop is constructed straight, the bus stop needs to be extra-long and not just a short pocket for them to fit into. Otherwise they won't be either straight or up close to the passengers.

-Need space before the stop in order to get the bus straight and close and away from the traffic lines

-If the bus stop is constructed as an angled bus stop, it needs to be angled and big enough for the bus to get up close and still be able to drive away

-The problem now: the front need to drive over the line in order for the back to get close enough to get the bus straight.

-If the bus stop is constructed too short, the bus needs to use the next drive file, which they do not want to do.

-This is hard to help with automatics. The mirrors are enough as helpers, the drivers know how to drive to manoeuvre it correctly, and it is just the construction that needs to be better.

TRAFFIC SITUATIONS / BUS TYPES

City vs. Tourist buses

-Driving tourist buses means the driver is in charge of the whole bus and "owns" the responsibility for whatever happens to it and the passengers inside.

-The tourist bus drivers are therefore interested in all instruments showing the performance and state of the bus

-The drivers driving city traffic buses only need to know three things; if the bus (1) is okay to drive, (2) not okay to drive or (3) needs to get to workshop, but is okay to drive it there.

-The drivers function in city traffic: to simply move the bus from one place to another. (Driving to destinations according to work plan and then get back to the depot).

-Tourist bus drivers needs to check that everything works before, during and after the drive of a bus. Therefor these drivers need and want to have information on more of the instruments in the bus than a city bus driver.

-City bus drivers can let go of their bus and their responsibilities after their shift, the tourist buses have further responsibilities to look after the bus afterwards.

-The city traffic is more stressful than traffic outside the city.

-When buses have the opportunity to drive at tram tracks or bus lanes the drivers do not feel the city traffic to be as stressful as it normally is, then the traffic is as normal and not stressful as the traffic outside the city, due to the non-interaction with other vehicles.

-City buses have a more complex traffic situation to handle.

-It is hard to manoeuvre the bus correctly in the narrow traffic environments and there are a lot of traffic, pedestrians, passengers as well as the time schedule to keep track of.

-Stressed people tend to be unpleasant and unpredictable.

-Passengers tend to hinder the driver task by for example standing too close to a door that it won't close or blocking the view of a rear view mirror by standing next to the driver.

-The drivers always have to be alert for accidents in order to plan alternative routes.

-Passengers on bus stops can be inconsiderate towards the speed of the bus and the rear view mirrors outside of the bus is an obstacle that the driver need to consider when driving up-close to a bus stop, since the drivers do not know if the passengers are aware of the mirror coming in full speed towards them.

-Passengers at bus stops tend to not care to give signals towards the driver in order for the driver to know if the passenger have seen the forthcoming of the bus or not, so the driver always need to perceive and process information around the environment themselves, and be careful.

-The sight and perception of the outside is very important to city bus drivers since their traffic environment is so complex.

-The drivers need to be able to see through window properly and use the mirrors in the right way without any blocking.

-The same problems applying to city traffic also applies to driving in the suburbs, except not in the same amount.

-In city traffic it is hard to concentrate on anything else than the traffic ahead of you, the drivers don't have time to always look and check the instruments for signs of a stop

Bus Driver Profession

-The bus driver profession has been industrialised and been split into pieces and the responsibilities distributed. There is one person who readies the bus for the drive (cleaners), another person drives it (driver) and a third person takes care of it afterwards (workshop).

-The traditional bus driver work was an ownership, where all responsibilities was put on the driver.

Passenger Differences

-The passengers on tourist buses are different from the ones on city buses.

-In tourist buses, the passengers drives with the driver and bus for a longer period of time and have time and the visibility to watch the driver and the instrument warnings more than a passenger on a city bus.

-The tourist passengers tend to be more worried of visible warning signals and traffic situations than city bus passengers.

-One driver states that this is partly because it feels normal to passengers for city buses to have a lot of warnings and signals showing on the instrument cluster since the traffic situations are more intense, and partly because tourist passengers have a better view of the driver in long distance buses and have more time to worry for problems.

City vs. Suburb traffic

-In the city you roll the buss in 30 km/h. The drivers do not need much of the instruments in the cluster at all. Though the speedometer is wanted

-The suburb traffic uses higher speeds – more use of the speedometer

-The tachometer is never needed.

-The gear is often mostly automatic, but can be both automatic and manually selected as well.

PASSENGERS

Interaction with Passengers

-The passengers riding busses does not form a certain pattern. They are different in age, gender and nationality.

-Passengers are often the ones complicating the drivers work.

-Some of the drivers do not want to be responsible for the passengers' bags and some feels obligated to. Either way, the bags of the passengers are often in the way or put wrongly in places by the passengers themselves, which complicates things for the long distance drivers.

-Passengers themselves are often standing in front when there are seat in the back.

-In buses where seat belt is obligatory, passengers do often not care about wearing seat belt and the drivers task are sometimes to tell them to do so, though they do not feel it is their responsibility, it is the passenger's own.

-Even though the passengers can complicate the driver's work, the drivers themselves think the work gets easier when there's more people on the bus than if there is little.

-The bus driver service (in city traffic) to help older passengers out of the bus is included in the bus driver profession, though if the timetable is pressured and the driver is stressed, they rarely get up from their seats. The time is priority.

-If a handicapped person in a wheelchair need to get out the driver need to get up and take out the ramp for them.

-Scania has electrical ramps that often get broken due to too much use.

Checking passengers

-When sitting in the driver seat, the inner mirrors are used to check the passengers.

-The inner mirror does not show a good visualisation of the passengers by the back doors. They have become better and better but are still not good enough.

-Children sitting in the stairs can be seen all the time, which is not good

-The inner mirror should be much bigger so it is possible to see the whole bus at one glance.

-The passengers in the back are hard to see.

-They have cameras put in front of each doors.

Passengers and Bus stops

-When the drivers have stopped at a bus stop the passengers can themselves push at a stop button to get the doors opened. That is a problem, because they can be standing at a stop for a long time.

-The responsibility of opening the doors should be lying with the driver, not with the passengers.

-"Emergency openers" should exist much higher than they do know (just 1m up).

Communication with passengers

-The communication between drivers and passengers differ depending on the distance and the type of transportation the bus goes.

-The communication frequency differ also in work days, during weekends the passengers riding are often more chatty than on weekdays.

-The drivers in city traffic do not need to talk to them if they don't want to. Sometimes it is better to keep quiet.

-In buses without a payment management system, the communication with passengers are a must since the drivers need to tend to the passengers tickets themselves. These kind of drivers always greet their passengers when boarding to start a connection.

-During longer transportation passengers can sometimes get too friendly with drivers and ask questions that the driver cannot answer, for example if he is tired or not.

-At airport shuttle busses, who drives both city and long distance driving, the passengers are often nice and can ask questions from time to time, though not in a negative and disturbing manner.

-The questions asked often concern the timetable, possible delays and bus stops.

-In buses driving long distance, the passengers do not seem to understand they need to press the stop-button in order for the bus to stop at a stopping point. They think the buses stop at all the destinations anyhow, which might be true for city traffic buses, but not for long distance ones.

-When airport shuttle busses do get complaints from passengers they are stressed themselves due to them being late and ask the drivers to stress through their work to get to the end destination earlier. In those cases the driver says they will try to do so, but in reality does not change their driving behaviour and drive normally.

-In the airport shuttle busses the bus drivers remembers their passenger between the stops and adapts the language they use in speakers and information after that.

Disturbing Passengers

-The shift with most disturbing passengers are the ones on Saturday nights where passengers often influenced by alcohol (or worse) drinks in the buss without the permission to, need to stop for bathroom breaks even though the driver warned there will be none and gets sick inside the bus.

-Passengers can ask questions during the drive without meaning to disturb, though the driver might feel disturb due to the concentration the driver needs to have on the road. Then the driver asks the passenger to wait until the next stop, which is often no problem.

-Passengers talking to a mobile phone load can be disturbing

Passengers and Entertainment Systems

-During long distance driving, the drivers are in charge of entertainment in terms of Wi-Fi, DVD, radio and computer plug-ins. There is no easy system in today's buses that allows the drivers to switch on these while driving on the road.

-The drivers do not often know how to use the entertainment systems in the bus if they have not been driving it recently. Hence the system is learned mostly by experience and could be a problem for beginners.

-The drivers wishes for a simpler set-up for the entertainment systems. The most optimal set-up would be the one only needing one moment of action to switch from TV to DVD to computer plug-in, a button for these on the instrument panel (like the ones on today's TV systems) would be sufficient.

-Due to passengers not asking to switch on these entertainment systems before starting the route, the driver must always stop the bus somewhere in order to put the system on, which makes it hard to plan the route.

-Common passengers asking for the entertainment systems are sport teams and conference guests.

Passengers and Security

-In longer distances, drivers need to keep track of the passengers, especially the louder ones, in order to make sure no one stands in the way of bus functions (mirrors etc.) which could jeopardise the safety of everyone in the bus.

-During longer distance with a big and loud crowd as passengers, some passengers want to use the speakers in front of the bus to sing a song for the rest of the group. But due to there not being any safety measures towards a passenger standing in the front aisle without seat belt, the drivers need to ask the passenger to not use the speaker while driving.

-Not having cash on the bus anymore is a relief to many of the drivers, it feels much safer to drive without cash. Even though their own personal wallet could be at stake if a robbery were to happen during work.

-To this one driver states a solution by having two wallets, one fake with just little cash and some cards that is okay to give up and one real.

-Outsourced buses and drivers are forced to request legit tickets from passengers, which is one cause to attacks of drivers.

-After one driver got attacked twice, the bus company took away the requirement of passengers showing tickets, which one driver states as a bad choice since that did not do anything to protect the driver. Adding of security guards would have been a better solution.

-When arriving at an end destination in the middle of the night and turning to go back on the same line, the driver feels the most unsafe. The driver need to let all passengers on board, though do not like driving alone with un-trustworthy passengers that might be influenced by something.

Protection Screen

-Driving shuttle buses without protecting screen door, which often is included in city buses, feels alright. They need the connection with the passengers anyway due to their work tasks.

-A protection screen lessen the volume of the driver which might disturb passengers that can't hear what is saying.

-A protection screen is good to have since it gives the driver time to alarm that they need help if something were to begin to happen.

-Though there have been reports on attacks where the screen have been smashed and have not been able to protect the driver, hence as one driver states, the screen might not be that useful after all.

Passengers and Tickets

-One driver with experience both in city traffic and long distance confirms that after 1 year of driving experience, a driver can tell if someone is lying about having a ticket.

-In buses without a payment management system, it is the driver's task to sell tickets to the passengers. Tickets can be bought in beforehand at shops like Pressbyrån or by smartphone application which saves the driver's on-loading time and is cheaper for the passenger. It is also better since the drivers on a busy day often let the passengers with already bought ticket go before the ones with no tickets.

-Even so, these buses and their drivers have not been able to train their passengers to behave the way they are supposed to, since the passengers still buys more tickets on the bus.

ORGANISATIONAL

Bus company responsibility and requirement from public traffic

-For example SL requires the bus companies driving their routes to check all buses so they are not having loud annoying sounds, like rattling.

-SL requires busses to have cameras inside the bus in front of each door. The driver is also required to look at them before closing the doors to make sure there is no passengers in the way. Because it is very common that a passenger can fall in front of the door and get squeezed otherwise.

-In commercial traffic the routes are planned differently and shut down if too low on passengers. Statistics on passengers are important in commercial traffic.

-There are routes which have too much passengers and the companies are pushed to offer higher capacity of transferring passengers.

-The busses needs a very high availability, in between reparation, of 95 %. And the availability to perform bus routes can be 99,98 %. So the route needs higher reliability and the bus can have, that causes a lot of extra planning.

-Passengers and public traffic has not tolerance if the bus is not working, the bus company is responsible for fixing the situation so that the passengers gets transported.

Delegation of information in the organisation

-If the error messages were explained more clearly the communication between the driver-traffic control-service would have less misunderstandings.

-In city traffic where traffic control ask the drivers about the state of the bus, the driver might not have the technical knowledge enough to understand the seriousness of the error and say that it is not that bad.

-Traffic control might not have as good understanding about the technical problem as people in service and if problem underestimated, service will not get the information until it is too late and a big problem has occurred.

-Positive to introduce values or colour code to explain the seriousness to the driver and give both Driver, Traffic-control and Service the same information that cannot be misinterpreted.

-Many of the warning messages are about errors that is electronic and impossible for the driver to fix. If the driver cannot do anything about it and it is not dangerous, that information could be saved and sent to service directly.

-Service messages can be collected somewhere where they are easy to overview if wanted.

-The driver might be better off not receiving messages that increase mental load without possibilities to fix it or change driving behaviour.

-Example of universal language in organisation, bus should be able to provide this, no need for interpretation by the bus driver:

- Green - Driver can continue driving
- Orange - Driver needs to act and get the bus to workshop
- Red - Driver need to stop the bus right now and let service come fix it

-The drivers often cannot influence what type of bus they are driving. Some of them can influence through workers unions and influence when ordering busses.

Communication Driver - Traffic planning – Service

-The bus drivers often has a jour telephone to call for help. With communication between bus driver and traffic leader the seriousness of the problem is decided.

-The drivers wants to talk to a person about the problem, and feel they are leaving over the responsibility for it.

-When driving city traffic there are possibilities of calling in another bus. The traffic leaders arrange this.

-The driver find it hard to explain symbols they do not know - for example, the symbol that looks like a helicopter, or the symbols that looks like two loops. This can be misinterpreted by traffic leaders which then takes wrong decision.

-The process of fixing technical problems might be easier and faster is service people could get the information from the bus directly.

-When a bus gets stranded, people from workshop goes to bus, but sometimes have wrong information about what the problem is and have to go back and get other tools when they realise what is the actual error.

-Right tools and parts for reparation could be prepared if workshop got correct information before. That would decrease cost and time for reparation for the bus companies, a good selling point probably.

-With workshop having more correct info from bus, they could also decide if an extra bus have to be called in.