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Improved Driver Support in Smart Cities to Reduce the Environmental Impact of Trucks

Designing a concept for 2030

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Abstract

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Alida Walfridsson

The transport industry is a key contributor to carbon dioxide emissions and climate change and heavy-duty vehicles are responsible for a quarter of the emissions from road transport in the EU. One way of reducing the energy consumption of a truck is improving driving skills by minimizing breaking for example. When cities become smarter using information and communication technologies more data is available regarding the traffic situation. This can be used to give the driver more information to make better driving decisions. The aim of the study is to identify and formulate how a Scania truck will guide a driver in a smart city with the goal to reduce the environmental impact.

The method used was the double diamond design process model with the four phases discover, define, develop and deliver. Discovering was done through interviewing personnel from the Swedish Transport Administration and Stockholm municipality which set the technological possibilities for the smart city Stockholm in 2030. In the define phase drivers were interviewed and three functions were chosen to proceed with further for a concept: traffic lights, intersections and bus lanes. Both drivers and experts were consulted in the develop phase before completing the final concept in the deliver phase.

The results show that the smart city Stockholm in 2030 will have a more dynamic traffic situation that the driver will have to adapt to. Experienced drivers will not be able to choose the best route and optimize speed without using the new information shared by the city. The result is a concept with the new information presented using a Head-Up Display (HUD) which puts the information in the drivers view range. Information shared in the HUD includes, time to green for traffic lights, warning for approaching vehicles from out of sight streets in intersections, access to bus lanes and recommended speed for intersections and traffic lights to avoid unnecessary stops.

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Populärvetenskaplig sammanfattning

Transportsektorn är en nyckelspelare inom koldioxidutsläpp och klimatförändringar och tunga fordon orsakar en fjärdedel av utsläppen från vägtransporter inom EU. I och med den allt mer globaliserade handeln ökar även frakt av varor hela tiden vilket ökar utsläppen. Eftersom att energikonsumtionen även är en stor del av ett åkeris utgifter finns det ekonomiska incitament för att minska bränsleförbrukningen i lastbilar. Ett sätt att minska energikonsumtionen från en lastbil är att förbättra förarnas körning genom att till exempel minimera inbromsningar. En förändrad körteknik i stadsmiljö kan spara upp till fem procent bränsle. När städer blir mer smarta genom att använda sig av informationsteknologier kan mer trafikdata bli tillgängligt vilket kan användas till att ge föraren mer information för att ta bättre beslut i sin körning. Syftet med denna studie är att identifiera och formulera hur en Scanialastbil kommer guida en förare i en smart stad med målet att minska dess miljöpåverkan.

Metoden som har använts för denna studie är den dubbla diamantprocessmodellen med de fyra faserna upptäck, definiera, utveckla och leverera. Upptäcktsfasen inkluderade intervjuer med anställda från Trafikverket och Stockholms stad vilket resulterade i en framtidsvision för de teknologiska möjligheterna i Stockholm för 2030. I definieringsfasen intervjuades förare från Scania med många års erfarenhet av att både köra lastbil och utvärdera nya funktioner. Tre funktioner från intervjuerna valdes ut för att titta vidare på ett koncept: trafikljus, korsningar och bussfiler. Både förarna och experter från Scania tillfrågades i utvecklingsfasen för att skapa och förbättra de första koncepten innan det slutgiltiga konceptet togs fram till den sista levereringsfasen.

Resultaten visar att Stockholm som en smart stad 2030 kommer att ha en mer dynamisk trafiksituation som förare kommer behöva anpassa sig till. Erfarna förare kommer inte på samma sätt som idag kunna välja den bästa rutten och optimera hastigheten på lastbilen. Med den nya trafikinformationen kommer inte erfarenhet att räcka till för att köra optimalt utan förare kommer behöva ta del av denna nya information som inte är tillgänglig genom vindrutan. Resultatet är ett koncept med den nya informationen presenterad för föraren genom en Head-Up Display (HUD) vilket projicerar information i förarens synfält i vindrutan utan att störa övrig information från omvärlden. Information som delas i HUD:en inkluderar: tid till grönt för trafikljus, varning för fordon som kommer från sidogator i korsningar, access till bussfiler och rekommenderad hastighet för korsningar och trafikljus. Alla dessa funktioner ska hjälpa föraren att köra med en mer jämn hastighet och undvika så många stopp som möjligt för att minska bränsleförbrukningen och med det även minska miljöpåverkan.

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Sincerely,

Alida Walfridsson

Abbreviations

ADAS – Advanced Driver Assistance System

AEB – Advanced Emergency Braking

AI – Artificial Intelligence

AR – Augmented Reality

BSW – Blind Spot Warning

EAS – Electrical Assisted Steering

GLOSA – Green Light Optimal Speed Advisory

HUD- Head-Up Display

ICL – Instrument Cluster

ICT – Information and Communication Technology

ITS -Intelligent Transport System

IoT – Internet of Things

LDW – Lane Departure Warning

NVDB – The Swedish national road database

TTG – Time To Green

VRUCW – Vulnerable Road User Collision Warning

V2X – Vehicle-to-Everything

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1. Introduction

Transport is of large relevance for the global energy sector accounting for more than half of the world's oil consumption, which means that the transport sector is a key contributor to carbon dioxide emissions and climate change (IEA, 2017). Heavy-duty vehicles are responsible for 25% of the emissions from road transport in the EU and 6% of total EU emissions (EU, n.d.). Therefore, from an environmental point of view, it is important to minimize the fuel consumption of trucks. Development of fuel-saving technology is one way of minimizing fuel consumption and emission, changing the way to drive the truck is another (Zavalko, 2018). IEA (2017) finds route planning to be one of the most obvious ways of saving fuel, optimizing the route of deliveries, but also see potential in driver training and feedback systems rewarding fuel-efficient driving. In long-haulage fuel use and emissions can be cut by 9% and in urban operations up to 5% can be cut by improving driving skills (IEA, 2017).

Smart cities use information and communication technology (ICT) to serve a purpose for the people in the city, improving economy, environment, governance, living and mobility. Global investments in ICT are increasing and most of the investments go towards intelligent connected transport and sustainable mobility (Lozano Domínguez & Mateo Sanguino, 2019). Three layers working together to complete the smart city is the technological base that includes networks of connected devices and sensors, applications using data-analyzation and the usage by the city, companies and public leading for change of behavior (Woetzel et al., 2018). Internet of things (IoT) has the potential to fundamentally change the transport equation by using technical and business trends of mobility, automation and data analytics (Alcatel-Lucent, 2020). IoT units creates a network where information in real time is collected and transmitted through the network. Data gathered can be analyzed to for example reduce congestion and energy use by adapting the traffic system to fit the changing traffic patterns (Alcatel-Lucent, 2020).

The truck manufacturer Scania was the first large manufacturer of heavy-duty vehicles to have environmental goals officially approved by Science Based Target initiative. Since 90% of the emissions take place after the vehicle has left the factory Scania works together with the customers to decrease the environmental impact in the whole life cycle of the vehicles. Until 2025 the goal is to half the emissions from the production compared to 2015 and decrease the emission from the vehicles with 20% (Scania, 2020c). With the new information available when cities are getting smarter and the amount of IoT units are increasing, Scania wants to know how they can use this information to guide the driver of the truck in a better way to drive more energy efficient.

1.1 Aim and Research Questions

The aim is to identify and formulate how a Scania truck will guide a driver in a smart city with the goal to reduce the environmental impact of trucks.

- In what ways will the city change that affects a truck driver?
- What information will the smart city provide usable to assist the driver?
- What is the best way of communicating the information to the driver?

1.2 Delimitations

The study takes a future perspective and is delimited to Stockholm, Sweden, in 2030. This makes it possible to be innovative but still be realistic since it is in the near future. Because of the city perspective the focus is on distribution trucks and urban driving. Buses are not considered in this study.

The study is also delimited to manual driving. The SAE International standard J3016_202104 for levels of driving automation defines six levels of driving automation were level 0-2 require an active driver at all times and at level 3-5 the vehicle can drive itself. Today the Scania truck is a level 2 and in five years the goal is to have autonomous vehicles driving in motorway traffic but it will take even longer before autonomous driving in urban environments are a reality (Scania, 2021a).

An assumption made is that the Scania truck will be connected and able to receive live information from the city. In this study, only information shared between the public city infrastructure and the vehicle is considered, the potential of sharing information between vehicles directly and with other private IoT products are not considered.

1.3 Thesis Outline

Following this introduction (Section 1) is the background where Scania is presented as well as information regarding technical possibilities and environmental impact of trucks (Section 2). Following is the method of how the study was implemented and how the analysis was done (Section 3). Thereafter, the results are presented starting with the Stockholm 2030 context and continuing with the results from users and experts contributing to the first draft. Feedback from users are then presented before the final concept (Section 4). The discussion is presented in Section 5 and lastly, a conclusion wraps up the thesis (Section 6).

2. Background

This section provides the background information needed to understand the context of the thesis. Including descriptions of relevant technologies in the automotive industry and smart cities as well as an introduction of Scania and information regarding energy efficiency in trucks. Previous studies in the subject is also presented in this section.

2.1 Scania

Scania is a global company with 50 000 employees in over 100 countries with their headquarters in Södertälje, Sweden (Scania, 2021b). Scania is a world leading supplier of transport solutions including both trucks and busses as well as engines, service and financial services. “Scania’s purpose is to drive the shift towards a sustainable transport system, creating a world of mobility that is better for business, society and the environment” (Scania, 2021b). Challenges like climate change, population growth and urbanization all impact the transport business and Scania does not back down to the challenges. Scania has been using alternative fuels for 30 years and are now tackling electrification together with providing energy efficient products. To achieve the most efficient transport solutions for cities innovative technologies for a smart transport, like vehicle connectivity, are also applied (Scania, n.d.b).

2.2 Environmental Impact of Trucks

Trucking have a major negative effect on the environment, contributing to noise and air pollution (EPA, n.d.). As the world gets more globalized international trade increases and the supply chains of goods become more complex. The estimated growth of shipments in the U.S. is 45% by 2040 (EPA, n.d.). The transport sector accounts for 25% of the total energy usage in developed countries which is a major source of environmental pollutants that can lead to human health problems and global warming (EU, n.d.). Transport companies have an incitement to reduce fuel consumption since that also reduce their fuel expenses which is a large cost for the companies since they consume much more fuel than regular cars (Zavalko, 2018). Fuel account for over 29 % of the life cycle costs for a heavy-duty truck (Borek et al., 2020).

Zavalko suggests to minimize accelerations of an excessive intensity and to eliminate unnecessary acceleration or reduction, the speed should be kept consistent. Breaking should also be minimized according to Zavalko, emergency or service breaking should only be used to ensure traffic safety. Complete stops should be avoided since it requires more fuel to get up to speed again. Lastly excessive vehicle speed should be reduced to lower fuel consumption (Zavalko, 2018). Borek et al. (2020) also recognize reducing breaking as the greatest fuel saving technique and shows that fuel economy can be improved most in situations with more traffic where more opportunities to avoid breaking occurs, up to 10% fuel can be saved according to simulations in these scenarios.

2.3 Advanced Driver Assistance Systems

Advanced driver assistance systems (ADAS) is described by Piao and McDonald to support drivers by providing warnings about potential risks and automating tasks to relieve the driver (2008). The world has seen a rapid growth of ADAS because of improvements in communicating, sensing and computing technologies. ADAS replaces some of the human decisions and actions with precise machine tasks which is helpful to reduce the human errors leading to accidents and to control the vehicle with increased capacity for environmental benefits (Piao & McDonald, 2008).

Autonomous ADAS systems use ranging sensors and computer vision to read the surrounding environment. This means that the system does not depend on outer systems and can be used with any infrastructure. On the opposite, in cooperative ADAS systems individual vehicles relate to the environment by communication with infrastructure or other vehicles. When Intelligent Transport Systems (ITS) arrived in the 1980s the concept of cooperative driving started but it was not until the 2000s research and development were scaled up. Road-vehicle communication is a cooperative system that makes it possible for operators to provide dynamic information to drivers, regarding traffic and weather conditions for example. The communication can be one way or two way depending on the purpose. (Piao & McDonald, 2008)

When driving a vehicle perception, cognition, action selection and action implementation is necessary in the process (Inagaki & Itoh, 2013). ADAS includes functions such as perception enhancements and help the driver to pay attention to possible risks which is a way to help the driver to understand the situation. Functions also help the driver by issuing warnings to encourage the driver to take a specific action and even takes control when the driver does not act after being warned (Inagaki & Itoh, 2013).

2.3.1 Scania's ADAS

Scania has many autonomous ADAS functions integrated in their trucks. The ADAS function Advanced Emergency Braking (AEB) helps the driver to break when a risk for collision is detected (Scania, n.d.a). Other functions are the side detection systems Vulnerable Road User Collision Warning (VRUCW) and Blind Spot Warning (BSW). These systems warn the driver of "hidden" cars when switching lanes and cyclists or pedestrians in the truck's blind spot (Scania, 2020a). Another function is the Electrical Assisted Steering (EAS) which is used in three functions adding either comfort or increased safety to the truck. Lane Keep Assist (LKA) keeps the vehicle centered in the lane by utilizing EAS. Lane Departure Warning with Active Steering (LDW AS) is an extension to the standard LDW system and intervenes when there is a potential lane department by steering the vehicle back into the lane. Lane Change Collision Prevention (LCP) is working to avoid lane change incidents and works together with BSW to detect other vehicles. If necessary, LCP not only warns for it but can use EAS to also stop the lane change (Scania, 2020b).

Scania Cruise Control with Active Prediction (CCAP) uses topographical map data and GPS technology to select gear and speed strategies for the lowest possible fuel consumption. The system determines the characteristics of the road three kilometers ahead and the algorithm is continuously developed to be able to avoid unnecessary breaking (Scania, 2018a). With the function Adaptive Cruise Control (ACC) a minimal distance can be set to a vehicle in front of the truck. Meaning that the cruising speed will be kept until catching up with a slower vehicle and then match that vehicles speed (Scania, n.d.c).

2.4 Vehicle-to-Everything

The main goal of Vehicle-to-Everything (V2X) technologies is to have vehicles, people and things fully connected (Storck & Duarte-Figueiredo, 2020). The technological development of IoT is guiding the evolution of V2X. The possibility of combining human abilities and vehicle intelligence with multi-level collaboration systems by sensors and mobile devices creates a global network which enables several services. Through the interaction between vehicle and environment using the internet both can consume and provide services. V2X communication enables exchange of information which provides the vehicle with accurate knowledge about the environment that can be used to improve traffic flow, reducing pollution and accident rates (Storck & Duarte-Figueiredo, 2020).

The 5G technology, already available in several countries, has the potential to increase the possibilities with IoT products and the industry is adapting fast to develop 5G compatible devices (Induo, 2021). The communication speed and stability between units are two important factors for scaling the usage of IoT products. Another important part is the low latency which is reduced from 20-50ms with 4G to 1ms with 5G which improves real time information (Induo, 2021). During 2020 the 5G network was launched in Stockholm (Ericsson, 2020).

2.5 The Swedish National Road Database

The Swedish national road database (NVDB) has been created on behalf of the government and contains all of Sweden´s roads, streets, bicycle lanes and some basic information regarding the road network. The data in NVDB is stored in accordance with Swedish standards which enables to combine the data with other road data. The NVDB describes how the road network is connected and the properties and rules that are associated with each road, for example width of the road and speed restrictions. If more specific information is required for a service NVDB can be used as a base where more information is added. NVDB is used in systems for guiding and planning of transport, analyze accident data, systems for guiding or control of traffic etc. (Swedish Transport Administration, 2018)

2.6 Zone Management

Zone management or geofencing is a digital geographical zone where connected vehicles can be controlled in different ways. Geofencing can also be used to limit a vehicle's access to zones. A geofencing solution can lead to more effective transport, reduction of greenhouse gases, less noise, improved air quality and improved safety. (Swedish Transport Administration, 2020a)

2.6.1 Scania Zone

Scania Zone is a position-based service for automatic adaptation to predefined zones. The service makes it possible for the client to put up geofence-zones with restrictions regarding speed and emission and start functions like warning lights on a garbage truck when driving over a schoolyard. When a truck enters a zone with restricted speed the truck automatically adjusts the speed to the rule and when arriving in a low-emission zone hybrid trucks switch to driving electric. A zone can be a large area or just a part of a road, can be tied to specific times and zones can overlap with each other. When using this technology, the truck also registers the degree of succession of following the zone rules and report it back to the employer. (Scania, 2018b)

2.7 Human Machine Interface

Human machine interface (HMI) is a part of a system where machine and human work together (Boy, 2011). The HMI provides system feedback and mediates user intention and is the way humans communicate with machines. Vehicles getting more and more computerized has led to many onboard systems that increase the workload on the driver. The goal has been to improve safety, performance and comfort but these systems now induce new types of accidents which should be considered when designing new HMIs (Boy, 2011).

For in-vehicle HMI the primary requirement is to deliver the information with minimal distraction to the driver (Yang, Ahmed & Subedi, 2020). Particularly during high workload situations like driving a heavy truck or driving in heavy rain an overload of information in the HMI can be a distraction. Therefore, it is important that the communication is easily recognized, processed and interpreted (Yang, Ahmed & Subedi, 2020).

Usability is something many products have and many more lacks according to Rubin and Chisnell (2008). At first glance it can seem hard to determine what makes a product usable but when absent there is an issue. When a product is usable the user can use it without hesitation, questions or hindrance. To be usable Rubin and Chisnell mean that the product also needs to be useful, efficient, effective, satisfying, learnable and accessible to the user. Reasons for a product to not be usable can depend on too much focus of development on the machine or system or that design and implementation do not always match (Rubin & Chisnell, 2008).

2.8 Related Work

More countries are starting the journey to construct smart cities which is an important strategy to solve problems regarding rapid urbanization. Guo, Tang and Guo (2020) have examined whether smart city innovations can improve traffic congestion. A smart city relies on information technologies like IoT, big data, cloud computing and artificial intelligence (AI) but Guo, Tang and Guo found that adaptation of the public was an important factor to strengthen the effect of improving transportation. A public with a better education and technological literacy will faster adapt to changes and integrate new technology in their lifestyle, like optimization of navigation. Human capital will therefore support the construction of the smart city. The results show that the quality of urban traffic is improved and traffic congestion is reduced in a smart city and the results accelerates over time (Guo, Tang & Guo, 2020).

An HMI is used to display visual and audible warnings from technology used in connected vehicles that can be found in a smart city. Ahmed, Yang and Gaweesh (2020) have designed three driving simulation scenarios where drivers tested if they preferred having the HMI or if it was a distraction. The application included forward collision warning, distress notification, situational awareness, work zone warnings and spot weather impact warning. The participants in this test liked that visual warnings had a priority level where the highest priority warnings were displayed closest to the driver and that audible warnings were only beeps and no voice. Most useful were the HMI during poor-visibility driving conditions and the favorite feature of the participants were the forward collision warning (Ahmed, Yang & Gaweesh, 2020).

A qualitative study made by Vaezipour et al. (2017) examined driver acceptability of in-vehicle HMIs for eco-driving and the drivers' opinions of various designs and functionality. The exploratory study was done with a user centered research approach using focus groups. The participants approved of the eco-driving monitoring and thought that the HMI have potential to improve their own driving. A number of participants argued that beginners specifically could benefit from the HMI to educate themselves of how to eco-drive. Some participants expressed concerns regarding more experienced drivers that might not accept feedback from an eco-driving HMI system, especially if it contradicts their own knowledge. This reflects an unwillingness to receive objective feedback. One participant suggested that this type of HMI could be beneficial in business vehicle fleets. Vaezipour et al. found that monetary savings for fuel and maintenance is the perceived usefulness of an eco-driving HMI.

Previous studies have looked at attitudes on receiving information to improve driving using HMI and for which scenarios an HMI is helpful for a driver as well as the possibilities for public organizations to utilize the data from smart cities. Lacking is how the smart city data can be used by private companies and how such information in an effective way can be used in an HMI to help drivers reduce energy consumption of the vehicle.

3. Research Design and Methods

This section presents the research design and the methods used for the thesis. The double diamond design process model has been used to structure the thesis. In-house research at the Design Council in 2005 resulted in the double diamond diagram that in 2007 was used in an in-depth study of eleven global brands. The method was produced as “a simple graphical way of describing the design process.”. The method is divided into four phases which maps the divergent and convergent stages of the design process, shown in Figure 1. The first diamond represents the process of exploring an issue more widely or deeply (divergent thinking) and the second is focused on action (convergent thinking). The four stages of the double diamond are: discover, define, develop and deliver.

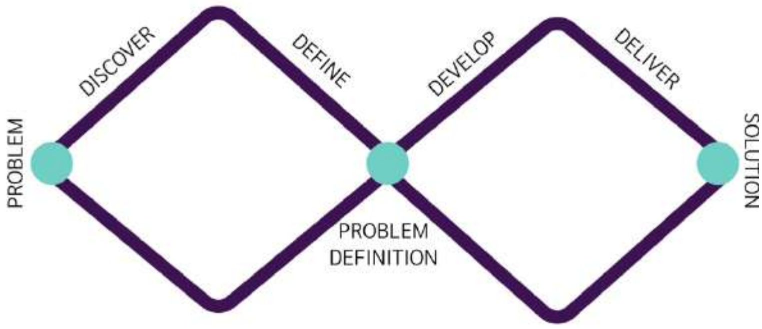


Figure 1. The double diamond design process model.

3.1 Discover

In the Discover phase the perspectives are kept wide to allow for a broad range of influences and ideas. Market research is one part of the discovery phase that can lead to development of new products and services. Analysis of future trends can be used to see new modes of communication and find new services that can emerge on the basis of for example environmental changes. Another part of the Discover stage is user research which is used to identify how products and services are used currently, find areas for innovation or improvement and identify potential products and services that address user needs. (Design Council, 2005)

3.1.1 Interviews

During the discover stage two interviews were held with the intention of gaining knowledge of plans regarding the technological development in the city of Stockholm until 2030. The first interview was conducted over the phone on the 29th of January with Olof Johansson, program manager for digitalization of the transport system at the Swedish Transport Administration (Trafikverket). The second interview was held on Zoom the 15th of February together with Robin Billsjö, strategist within urban development and sustainable transport at Stockholm municipality. Before conducting the interviews, protocol questions were made to serve as a path for the respondent to take in accordance with Dilley (2010). The questions were structured in a way that lead the conversation towards the larger research question of the study but was not limited to the predefined questions (Dilley, 2010). The two interviews were held in Swedish, the native language of both interviewer and respondents, and were recorded and transcribed afterwards. Quotes from Johansson and Billsjö have been translated when used further on.

Complementary to the results from the interviews official documents published by Stockholm municipality and the Swedish Transport Administration has been used to complete the picture of the plans regarding technological development in the transport sector in Stockholm, which are presented in Section 4.1.

3.1.2 Thematic Analysis

A thematical analysis of the future trends of Stockholm was made. Examining perspectives of different research participants, thematic analysis is a useful method according to Nowell et al. (2017). The flexible approach of thematic analysis can be modified for many studies to receive rich, detailed and complex data. The first phase includes familiarizing yourself with your data which when collected through interactions the researcher will have knowledge about the data. When starting to process the data in the second phase initial codes are generated which is a process of reflection to simplify and focus on specific characteristics of the data. In the third phase the codes are sorted into themes which link substantial portions of the data together. To remember is that the themes should not directly link to the research questions. The fourth phase focus on reviewing of the themes. Themes can now be added, removed or split into two themes if necessary to accurately describe the initial data. Defining and naming the themes should be done next to give the reader a sense of what the themes are about. In the final phase the report is produced. The thematical analysis should provide a logical, concise, coherent and interesting account of the data and the final analysis should tell a story about what the themes reveal about the topic (Nowell et al., 2017).

3.2 Define

The Define stage is the filter where ideas are reviewed, selected and discarded. The findings from the Discover phase are now analyzed and defined as problems with actionable tasks. During the Define stage the wider context of the problem or opportunity, both within the company and outside, is researched further. In this stage communication with experts is important as well as understanding the technological or production capabilities of the company. Lastly the ideas must be in line with the corporate brand: vision, mission, values and guidelines. (Design Council, 2005)

3.2.1 Initial Interviews with Drivers

In the define stage five male drivers employed by Scania were interviewed. The drivers are anonymized upon agreement. Three of the drivers are in the age span 40 to 50 and had 20 to 30 years of experience driving trucks. The other two drivers are 60-75 years old and have 40-50 years of experience. The interviews lasted about 45 minutes and were held on Microsoft Teams using a semi structured approach. The goal of using a semi-structured interview is to gather information regarding a set of central topics and at the same time have room for new topics or issues to emerge (Wilson, 2014). According to Wilson semi-structured interviews are used when details still are needed and the topic is still under investigation. Semi-structured interviews are also good to understand user goals and to gather facts attitudes and opinions (Wilson, 2014). The interviews were voice recorded and the recordings were used to take notes afterwards.

In the second part of the interview the drivers got to be part of creating a user journey map. Four of the interviews with the drivers included this part. Endmann and Keßner (2016) describes the user journey mapping as being focused on identifying areas with need for user research by learning about user processes. The process's associated activities are written down as a first step, in this study the activities are associated with the results from de define phase. To gather the users understanding of the process and tasks in smaller projects interviews with users is one way to approach the method (Endmann & Keßner, 2016). During the interviews pain points were written down and the emotions relating to each action were tested on a three-point scale to get an understanding of where improvement can be made. Presented in Appendix A is the user journey map with the four drivers emotion ratings for each action and a summary of pain points and possible solutions.

3.3 Develop

During the Develop stage one or more concepts that addresses the problems identified are refined. Design methods used in this stage include brainstorming, visualization, prototyping and testing. The principle of the Development stage is to iterate the concept to get it as close to the final product as possible. Feedback is taken through formal and informal communication with the team and stakeholders. Testing of the concepts is a major part of the Develop stage and rely heavily on traditional market research through tests with users. (Design Council, 2005)

3.3.1 Workshop

A workshop was held in the beginning of the develop phase together with seven employees at Scania from the User Interaction and Ergonomics team. It was held using Microsoft Teams and started with an introduction to the subject which followed by a brainwriting session for an hour. Brainwriting is a group of people writing their ideas in silence, in contrast to brainstorming where ideas are shared orally (VanGundy, 1984). The nominal group technique was used for the workshop where the participants generate ideas silently in writing and then time is provided to make clarifications of the ideas verbally and time for questions to clarify meaning and importance of logic of the idea (VanGundy, 1984). According to VanGundy there are disadvantages with brainstorming that can be overcome with brainwriting. For example, brainwriting improves equality of participation and minimizes status differences in the group. During the brainwriting session the tool Microsoft Whiteboard was used for the participants to share notes and drawings.

3.3.2 Second Interview with Drivers

An exploratory test was made with the same five drivers previously interviewed. The exploratory test is a way of testing early versions of an interface in the development stage

(Rubin & Chrisnell, 2008). A mock-up with static screen representation made in Figma was used to represent the layout. On suggestion of Rubin and Chrisnell (2008) the participants were asked to review the prototype and answer questions about the layout. The informal process was a collaboration between the participant and the moderator. The thought process of the participant is of importance at this stage and the moderator should encourage the participant to "think aloud" (Rubin & Chrisnell, 2008). The participants were also asked to suggest how to improve areas confusing to them (Rubin & Chrisnell, 2008). The exploratory interviews with the drivers were held using Microsoft Teams and lasted about 45 minutes each. The concepts were presented using PowerPoint and the order of the concepts and the order of questions regarding them were different for each participant to be able to compare the concepts in a better way. Since the interviews were held in Swedish, quotes from the drivers presented in the results have been translated, but the quotes can also be found in Swedish in Appendix B.

3.4 Deliver

The deliver stage of the process is when final testing is done and the concept is finalized. The result is a product that successfully handles the identified problem from the Discover stage. Lastly feedback is reported back on the success of the project (Design Council, 2005). The final product for this study is a concept, based on the empirical information gathered, that can be further developed.

3.5 Method Discussion

Qualitative research is sometimes criticized of being too subjective according to Bryman (2012). The researchers view about what is significant and important determines the findings and thereby the results. In qualitative research the investigator is the one to gather the data and what is observed and heard depends on the person. Therefore, a qualitative study is not easy to replicate (Bryman, 2012).

It is also often suggested that the findings of a qualitative research are hard to generalize. When interviews are done with a small group of people in a certain organization it can be hard to argue that these persons are a representation for a larger group. However, some argue that when looking at a group of people with a specific feature, like a truckdriver, generalizations can be made within that feature but they will be limited. (Bryman, 2012)

4. Results

The results are presented in the order of the phases they were conducted. Starting with the results from the discovery phase where Stockholm 2030 is mapped out. Continuing with the define stage where a user study with drivers were conducted. Following is the define phase where experts contributed to the first draft that the drivers gave feedback on. Lastly the final concept is presented which is a product of all of the phases.

4.1 Stockholm 2030

Stockholm municipality's vision for 2040 is to be the world's smartest city. Achieved through innovative solutions, openness and connectivity to become environmental, economic and socially sustainable (Stockholm municipality, 2017, p.2). Digitalization and technical development are leading to new possibilities regarding usage of data and information and the amount of data and information gathered increases rapidly (Stockholm municipality, 2017, p.8). The impact of technical innovations is affected by people's and organizations' ability to take advantage of the technology rather than the possibilities of the technology (Palm et al., 2019, p.19).

Traffic planning is currently most focused on work commuting but leisure travel is an increasing part of the traffic which is harder to plan for (Billsjö, 2021). Trends like urbanization, globalization and increasing life span creates new needs in the city (Stockholm municipality, 2017, p.5). When the city grows the competition of the land usage gets tougher. Optimizing locally is needed to meet the requirements of different freight to avoid unnecessary transport and promote smart solutions (Stockholm municipality, n.d., p.18).

The freight traffic work of Stockholm municipality is found in a regional and national context. The Swedish Transport Administration is responsible for the long-term infrastructure planning of state roads. The Swedish Transport Administration's mission also includes developing policy instruments and to stimulate innovation in the transport sector. (Stockholm municipality, n.d., p.9)

In Stockholm, digitalization and new technology is used to simplify the possibilities to be environmentally friendly for the people in the city. Stockholm's energy consumption is reduced through smart digital and technical solutions and provides sustainable solutions for a modern transport system (Stockholm municipality, 2017, p.16). For transport, connected units means decreased fuel consumption and optimization of routes (Palm et al., 2019, p.23).

4.1.1 Smart Traffic Sensors

Stockholm municipality is looking into what ways they can use smart multi-sensors in the future and connected traffic lights will be one of the first smart sensors implemented in the city. Stockholm municipality will "use the traffic lights to control the traffic in a smart way. The traffic lights can be used to adjust the speed in a way so that queues are placed where they make the least harm." (Billsjö, 2021). This is made possible by using AI together with the data collected by the sensors. Keeping the traffic flowing at places where air quality is an issue will have a positive effect without reducing the number of cars. (Billsjö, 2021)

Stockholm municipality also want to start by using the sensors to gather more data about traffic flows and traffic types that today is done in a more primitive way and not as frequent as sensors are able to achieve (Billsjö, 2021). The usage of loading-points is one place where Billsjö wants to collect more data since it is an important part of the city. In the dense city mostly curb side loading-points are used for delivery of goods and collection of waste but the municipality have poor knowledge of how they are used. Sensors placed in the area can collect data that can tell how often, when and for how long trucks are located at the loading-points. This data can then be used to improve the loading-points accordingly. This data can also be shared openly to enable private initiatives. More shared data through more sensors gives information of current and historical traffic conditions regarding for example loading-points. This can be used by trucks to plan their route in an optimal way (Billsjö, 2021).

Putting up sensors is not unproblematic; the Swedish Authority for Privacy Protection needs to approve of the sensors and its location to make sure that privacy is not violated. The first tests have been approved for and the first smart multi-sensors have been put up during 2020 on Kungsholmen in Stockholm (Billsjö, 2021). An evaluation made by the Swedish Transport Administration show that the challenges for the intelligent transport system (ITS) are access to data, electrification, laws and procurements. (Swedish Transport Administration, 2020b)

4.1.2 Geofencing

A technology increasing in popularity is geofencing. Stockholm municipality has been working with geofencing since 2017 and sees three major areas of application: speed, electric drive and access. Access refers to getting access to certain areas that the vehicle usually does not have access to because of for example limited bearing capacity, vibrations or size of the vehicle (Billsjö, 2021). Geofence access can be used to give out an exemption permit to a truck in a better way than the permit on paper used today. This would also give the Swedish Transport Administration and Stockholm municipality the opportunity to follow up the degree of succession. Being able to grant access with specific time restrictions and speeds for some transport can decrease the impact of the freight and with the right restrictions not degrade the road either (Billsjö, 2021; Johansson, 2021).

Freight traffic could also be prioritized for better accessibility on arterial roads by the use of geofencing (Stockholm municipality, n.d., p.20). Bus lanes can when not used fully by buses be accessed by connected vehicles through geofencing. For this to be reality, legislation needs to be updated. By using the capacity better, the traffic flow in the system would be improved. When developing geofencing it has to be in collaboration between municipalities and the Swedish Transport Administration (Johansson, 2021).

In new projects geofencing is used as a tool for deliveries at night. Using speed limitation and electric drive requirements combined the noise requirements in the city can be met which enables this kind of project (Billsjö, 2021). "I think that we have a huge potential with this type of functionality. […] We can control how, in other words what and which times vehicles are moving. For example, we can drive freight during the night." (Johansson, 2021). Both Stockholm municipality and the Swedish Transport Administration see potential in delivering during night using the geofencing tool and exemptions of this kind will become more common as the city becomes more dynamic (Billsjö, 2021; Johansson, 2021).

4.1.3 Platform and Database

To enable the vision of the worlds smartest city some basic conditions needs to be established. A communal digital platform and open standards needs to be used together with ensuring security and integrity of the shared data (Stockholm municipality, 2017, p.3). Cooperation in the region and nationwide is required for a long-term solution to provide uniform services to residents and visitors. International cooperation will also be needed to obtain digital sustainability. Cooperation with ISO organizations in their standardization work and with EU to promote standardization and interoperability (Stockholm municipality, 2017, pp.12-13).

Stockholm municipality is working on a centralized platform where all kinds of data can be shared in a safe way regarding not only traffic. Through this platform IoT units like sensors will be purchased and the sensors can then be used by several different organizations within the municipality (Billsjö, 2021). Before purchasing new IoT units the opportunity to use an existing unit should be explored (Stockholm municipality, n.d., p.23). Sensors near a loading-point could also be used to check for cracks in the nearby facades for example (Billsjö, 2021).

The Swedish Transport Administration is evaluating the quality of the current information in the NVDB and there is room for improvement (Johansson, 2021). To be able to increase the usage of geofencing more data than what is currently shared through NVDB is needed and the data needs to be much more updated and secured. The accuracy of the current data is not sufficient to use for regulating vehicles. The data needs to portray the traffic rules in the same way as the physical signs and to be able to get that precision connected vehicles will have to be a part of the solution, reporting deviations between physical traffic signs and digital rules (Billsjö, 2021). The system for changing information in the database has to be improved to be able to provide correct information even for areas with for example ongoing road work. Data exchange between different parties needs to function in a good way to improve data quality in the database, "as a driver you don't want to need to know of you are driving on a state or municipal road, it should just work." (Johansson, 2021).

To enable the smart city a common IT-infrastructure and digital platforms are required. Exchange of information between systems are shared between integration platforms to secure interoperability and long-term durability. Technical solutions are also based on open standards to enable several suppliers for development and service, and are built modular to be able to reuse in other systems and data is provided as open data to promote data-driven innovation (Stockholm municipality, 2017, p.21). It is important that there is national as well as international collaboration so that vehicles get the same information, not depending on if the road is managed by the Swedish Transport Administration or Stockholm municipality for example (Johansson, 2021).

IT-security is one of the aspects that makes it complex to collect and distribute data which makes the development take time (Billsjö, 2021). There is a risk that for-profit enterprises target specific groups or geographical areas which leads to a more diversified society. To make use of knowledge and not reduce development, cooperation between public and private sector is needed (Palm et al., p.23). "A private service provider is needed in between who build a service based on the data which can predict when it [a loading point] is free and make some route optimization based on that data." (Billsjö, 2021). A private company can use data and work with guiding traffic in an optimal way but the Swedish Transport Administration or other public organizations cannot force vehicles to take a specific route if it has not been an accident or similar (Johansson, 2021).

A working IT-infrastructure is the first step towards having data that is accurate enough to be used to direct autonomous vehicles and with a dynamic city it becomes more important to share traffic regulations with drivers digitally (Billsjö, 2021). That way drivers can be more foreseeing and plan ahead but to operate this change takes long time in Billsjö's experience.

4.1.4 Regulation

The development of laws and regulation is important to increase effectiveness within the transport system. Regulations needs to be adapted when technology and services develop and people's conditions change. A connected traffic system will have high demands on certifications on vehicles and infrastructure and cooperation with EU is required. (Palm et al., p.34)

Geofencing has the potential to work in a regulating way to only give access to certain streets to electrical vehicles or hybrids running on electricity in the area but this is not something that always can be decided by the municipality (Billsjö, 2021). To be able to set up a low-emission zone (LEZ) or a zero-emission zone (ZEZ) there must be a problem with the local air quality (Transportstyrelsen, 2020). Therefore, ZEZ cannot be used as a mean to drive the shift towards fossil fuel free transportation in cities by the municipality. It requires a decision from the government to be able to force electric driving in a larger extent (Billsjö, 2021).

"We have a stiff-legged transport regulation, that is not very innovation supportive." (Billsjö, 2021). To enable for freight transport during the night, when load on the infrastructure is less, guidelines have to be established (Stockholm municipality, n.d., p.16). Today trucks are not allowed to drive in Stockholm municipality between 22:00 and 06:00 all days of the week (Stockholm municipality, 2019). Another area in need of updated regulation is on what grounds lanes can be set for certain vehicles. Today busses can have a lane for themselves but it is not legal to let certain vehicles like trucks, connected vehicles or electric vehicles have a lane of their own. Therefore, it is not possible to grant access to some extra vehicles to drive in the bus lane. An addition to the law is needed and has to be done politically to be able to get a more effective use of the space in the city (Johansson, 2021).

4.1.5 Feedback Data

Data from all kind of vehicles are of interest when developing a smart city. Today the Swedish Transport Administration collects millions of data points but in a very limited area. Data regarding all kinds of information from vehicles and connecting them with other data like cellphone data makes it possible to understand the traffic and its needs better and start new projects using this knowledge. (Johansson, 2021)

Through putting up sensors, feedback can also be given regarding the usage of roads and loading-points for example. What kind of vehicles and cargo are driving where and how are the loading points used. This can then be used to improve the traffic situation by increasing the size of a loading point where there often is double parked trucks for example. (Billsjö, 2021)

Stockholm municipality is working together with companies in the transport business. In some of Taxi Stockholm's cars sensors are gathering information about the road quality which then is used to direct recourses to where it is needed. These kinds of cooperation will make it possible to have a circular flow of information that all users of the roads in the city can benefit from (Billsjö, 2021). Another collaboration with Volvo uses data from the braking system to know where in the city it is slippery or snow on the road. This is used to decide where and when to plow and salt which is economical for the city and improves the roads for the vehicles, "in the same way we could get data about other things from the vehicles" (Johansson, 2021).

The database will be dependent on connected vehicles reporting back deviations between physical signs and the digital data they receive from the database. This is a cost-effective way of reviewing the data in the database and gives the drivers more reliable information. To begin with, Stockholm municipality will require their new vehicles to be able to report back deviations to the system and the compliance of the traffic rules (Billsjö, 2021). The desire is also to receive information regarding what information vehicles has received and understood and which rules has been followed and which has not been complied with. This would be to get a better understanding of the range of the data and how it is used and not to hand out fines. This can be done through a third part to get anonymous feedback. For example, it would be of interest to know if studded tires have been used on restricted areas like Hornsgatan since today that information has to be gathered by manual counting (Billsjö, 2021).

4.1.6 Dynamic City

With a more dynamic regulation of the streets it is possible to close streets during times when the number of people on the streets are larger. "Some streets can be regulated to pedestrians only during certain periods, for example during lunch rush so that it becomes part of a market-place where food trucks are placed instead." (Billsjö, 2021). Digital signs in the physical space together with digital information will inform the road users about the changes. Today streets are closed for months during the summer to allow for more pedestrians which is done by putting up new traffic signs for the period (Billsjö, 2021).

Loading-points can also become more dynamic when data is collected telling the coverage of the loading-points during different parts of the day. A forecast can then be used to dynamically change the size of the loading-points, making more space for parking during the night and more space for loading during the day. This also requires digital signs as well as digital information to make it possible to plan ahead (Billsjö, 2021). Johansson (2021) sees potential in better solutions for cooperative logistic and distribute deliveries over day and night to be able to adapt to the more dynamic city depending on fluctuating speed limitations and access to electrical vehicles.

Johansson suggest to "work with how we use the capacity that exists in a more flexible way […] then I think we can improve the flows in the system and then we could simply spread out the traffic in a better way." (Johansson, 2021). How we are traveling also changes, the trend is that leisure travel is increasing and this type of traveling is harder to predict and is more changeable than the ordinary work travel we are used to (Billsjö, 2021). IoT products will enable vehicles to receive data from the dynamic system and with time become better to predict traffic situations due to machine learning and AI (Palm et al., p.23). In a dynamic city, professional drivers cannot rely on experience and information becomes more important for them to make informed decisions (Billsjö, 2021).

4.2 User Study

Building the foundation of the smart city is one of the main aspects to be able to implement the new technology that is tested today in a larger scale. Regulation as well as standards and functioning databases and platforms are vital to handle the data that only will increase in amount when vehicles get connected and IoT units are put up in the city. In this section the results from the user study, the initial interviews with the drivers, is presented regarding possible driver assistance functions.

During the initial interviews the drivers rated user actions from a user journey map based on information from the discovery phase. The user actions which got rated with bad emotions connected to the action are the ones explored further in this section. The user journey map and the ratings from the drivers are presented in Appendix A.

4.2.1 Traffic Lights

With smart traffic lights and available data, the city can use algorithms to automatically adjust traffic lights to optimize the traffic flow through junctions and data can be analyzed to identify faults in the traffic signals to minimize traffic disruption (GSMA, 2020). This can be used by the city to improve the traffic flow independent of if the vehicles in the area are connected or not. This optimizes the traffic flow as a system in the city. By using the data for status of traffic lights connected vehicles can also improve their individual route and optimize speed. NordicWay 2 is a project that has looked into the communication part of connected traffic signals and how to transfer the information from the device to the connected vehicles (NordicWay, 2020a). The two different ways of using the information from the smart traffic light tested by NordicWay 2 is Time To Green (TTG) and Green Light Optimal Speed Advisory (GLOSA). TTG works with displaying how long time is left on red or green for the driver to plan their journey in a better way when approaching a traffic light. GLOSA instead is an algorithm that calculates the optimal speed to pass the traffic light when it is green, without the vehicle needing to stop (Mellegård & Reichenberg, 2019). Challenges with realizing GLOSA is that it requires standardized communication infrastructure, cellular communication and protocols together with the fact that most traffic lights in urban areas, where GLOSA is expected to be most effective, are dynamic. Until a short time before the lights change dynamic traffic lights can be unpredictable (Mellegård & Reichenberg, 2019). Dynamic traffic lights today are mostly controlled using inductive detectors in the road (Stockholm municipality, 2020) but by using data from the smart multi sensors the traffic lights could plan further ahead which is beneficial for the GLOSA algorithm.

The drivers were in the initial interviews questioned about their opinions on TTG and GLOSA and they were all positive to TTG. The drivers want the time displayed large where they do not need to turn their head to see it and they suggested that the color of the numbers should reflect the color of the traffic signal. The opinions of the implementation of GLOSA differed more between the drivers. One comment was that if you receive speed suggestions too early you might slow down other vehicles but if it is done in a good way considering the traffic as a whole it can be a good thing. Two of the drivers think that TTG is a better option than GLOSA since they can make decisions by themselves easier that way. One of the drivers suggests to use GLOSA to warn the driver that they will have to stop at a traffic light, but not to give specific speed suggestions. Since it requires more energy to start and stop the majority of the drivers see potential in using GLOSA to get speed recommendations, especially when it is red and soon will be green. They point out that TTG is not necessary if GLOSA is used.

The drivers were also asked if they would want the truck to automatically adjust to the advised speed using the same technology as the adaptive cruise control to adjust the speed to surrounding traffic. The drivers did not think that the truck should act on its own, they like to have control over the situation themselves. One driver suggested that by pushing down the gas pedal quickly you could activate the function to let the truck follow the recommended speed by itself. When the truck knows that it will have to stop the drivers were more positive about receiving help with breaking as long as it is not done too early interfering with other traffic.

Pointed out during the initial interviews were also that it cannot be too much information and symbols that the drivers need to take into consideration when driving. It is tiring to get a lot of impressions all the time and that will affect the driving. One of the older drivers believes that younger people who grew up with computers appreciate automated functionality and smart suggestions more than drivers who have been in the industry longer and likes to drive using their experience.

4.2.2 Bus Lanes

The NordicWay 2 initiative also have a project regarding dynamic access control. This project tests requesting access to a bus lane by cellular network communication. When the truck approaches the bus lane a request is sent to the traffic management center who grants or denies the request. The driver then receives the answer in a display in the cab (NordicWay, 2020b). This is one way the city will become more dynamic, but first legislation needs to be updated. The process for access granting will be needed to be scaled up and become automated in a platform that has to be in collaboration between the Swedish Transport Administration and Stockholm municipality. During the NordicWay 2 test the driver had to actively send the request and the request had to be manually approved but when further developed the truck could automatically send the request when entering a specific zone using geofencing. Preliminary access could also be asked for by the route planner to optimize the route.

During the initial interviews with drivers all of them liked the concept of utilizing the bus lane in a better way, especially if they were the ones to get access. All of the drivers pointed out that it is not legal today to drive in the bus lane and they had a hard time accepting that it could be different in the future. Therefore, in the beginning it might be extra important to communicate in a clear way when and where the truck is allowed in bus lanes. The drivers expressed that the function needs to be automated since pushing buttons removes concentration from the driving. There should be minimal interaction needed from the driver and one driver suggested that the screens used today are way too small in the future to fit these kinds of functionality.

The information about access to a bus lane should according to the drivers be communicated through a sound and a symbol in the instrument cluster (ICL). The sound is important to make the driver aware of the new notification. When driving with many vehicles around, as it will be when usage of bus lanes is needed, focus is not on the ICL but on the road and the traffic and only visual notifications are hard to miss. Suggestions on informing the driver visually was to have a green bus symbol when allowed and red bus when not allowed in the bus lane, green and red bus sign or a green arrow pointing to the lane and then a red cross when not allowed any more.

The drivers also thought that it would be beneficial to have information about the access to a bus lane earlier then when arriving. Generally, they want all information they can get, in this case to be able to plan their route in an optimal way, but they did not see a problem with receiving the information about access when arriving. If bus lane access could be booked further ahead it can be used for an optimal route planner.

4.2.3 Intersections

The smart multi-sensor that has been put up for tests in Stockholm to gather data in an intersection can through sharing the real time traffic situation data with nearby vehicles, give drivers information about vehicles entering the intersection from out of sight roads. In intersections without traffic lights where the right rule applies the driver could for example get information about vehicles entering from the right to be able to plan the speed of the vehicle. In theory the driver could receive information about all vehicles in an intersection and be extra informed of the vehicles with priority. Being able to slow down before an intersection to leave way for another vehicle before approaching the intersection can reduce the number of stops over time. An algorithm with the same intention as GLOSA can be used when approaching intersections to suggest a speed to the driver and not only give warnings for vehicles. This can help the driver to reduce the energy consumption of the truck.

All of the drivers were positive about some kind of warning for vehicles entering intersections from other directions. They are also aware of the positive impact of not having to stop a heavy truck both on the environment and the economical part of saving fuel. They highlighted that it would be an appreciated function when driving on narrow streets where vision is limited since a truck has a long breaking distance. A truck would in this scenario also benefit from warnings regarding pedestrians who think they are more visible then they are to a truck driver. The function would also be good to have when driving long haulage according to one driver. When driving in the countryside where the speeds are higher through the intersections, knowing before arriving to the intersection if other vehicles are approaching would be beneficial.

Speed advisory and cruise control connected to intersections got the same response as for traffic lights, meaning that the drivers like to make their own decisions and have control over the vehicle. They recognize that receiving advice can be a good thing as long as it is not disturbing for the driver. Generally, the drivers were more positive about getting recommendations for speed when discussion intersections, probably because it cannot be compared with another function, like TTG in traffic lights.

Suggested by the drivers were to use the yield traffic sign or a warning sign to indicate that there are vehicles in the intersection to consider. One driver suggested a sound followed by a picture of an intersection with a vehicle on the road on the right, and mentions that something like that would be really helpful.

4.2.4 Loading Points

With the more dynamic regulation of the city and sensors gathering information about the usage of loading points drivers could benefit from receiving information about the status of the loading point. Using live feedback and including predictions for when a loading point will be available could also be combined with the live feedback. Private initiatives could use the data to create a service for this purpose.

The initial interviews with the drivers confirmed that loading points are a problematic place where trucks often have to wait for a spot to open up. The possibility to get live information about the status of a loading point is something the drivers want but it is not always possible to make any changes to improve efficiency. Sometimes it would be possible to pick up/drop off something small nearby if a loading point is occupied but when distributing larger orders, the order cannot be changed after loading. In these cases, receiving information about the current status of the loading point would be nice to have but would not change anything for the drivers as they see it. When only picking up things the order is not set in the same way and receiving status updates could mean that the driver can change the order of the stops.

It was pointed out by one of the drivers that it can be a line to the loading points waiting to deliver and by going somewhere else first no time is saved if more trucks have time to place in the line. Suggested by the driver was to have a digital queue for the loading point to solve the problem. Further, a digital que can be used to book a timeslot for delivery dependent on traffic for each truck. When the route is started a timeslot is booked on the loading point and during the trip the time is altered to fit the arrival time of the truck. In this way the system can get optimized to make the least number of trucks wait.

Having a smart loading point booking was more popular by the interviewed drivers. The information about estimated arrival and booked timeslot should be available to the driver but the driver should not be notified of changes since it can be a disturbance to the driver. One driver lifts the problem with not every truck having the technology to book a timeslot digitally for the loading point which could result in a truck being on the loading point when the truck who has the booking arrives. Another driver does not think this will be an issue, and points out that it is a transition period, since the trucks without the necessary technology can have a manual booking as it works on some loading points today. When delivering today the drivers have to communicate on the spot to be efficient so they are used to talking to each other at loading points.

4.2.5 Route Planning

A more dynamic traffic system puts stress on the information in the database. When streets are closed some hours of the day and the speed regulation changes on roads depending on traffic the database needs to be updated in a larger extent than today. Managing information in the database regarding on going road works for example will also be of relevance in the dynamic city where drivers need to trust the route planner to a larger extent. When planning routes today it is based on the fastest and/or shortest way. When the city becomes more dynamic and shares more data, route optimization algorithms will have to be much smarter and consider the smart traffic lights, the changing speed on some streets and both live and historical data regarding traffic flows collected from sensors and other vehicles. With more information about loading points the order of the deliveries should also be optimized in new ways.

With the use of geofencing the route planner can also optimize the route by applying for access to for example bridges or streets which would make the trip shorter but where heavy trucks are not usually allowed. By using Scania Zone, the access restrictions regarding speed or electric drive can be forced and a report can be sent back to prove successfully following the restrictions. For this functionality collaboration between public and private sector is needed in a larger scale than only sharing of data.

The interviewed drivers like to drive based on previous knowledge and do not use a route planner to guide the way. They are positive about receiving information regarding closed streets, events, lower speed limits and other things out of the ordinary. It is also important to not get too much information, if a driver will not be in a certain area the information regarding that area should not be given. How this would work in real life without a route planner is not something the interviewed drivers had a suggestion for.

If the drivers were to use a route planner it is important that it informs the driver of why the particular route has been chosen otherwise the risk is that the driver thinks experience is better than technology and will not drive according to the instructions. By starting a route, it is easier to choose the correct information for the driver and hopefully when the driver is told why, the chosen route will be used to improve the driving. It is important that the information is not a distraction but the interviewed drivers also find this kind of information vital when driving in a dynamic city in an optimal way when experience cannot be trusted in the same way as today.

For the information to be up to date and trustworthy cooperation between public and private actors can be an economical way. Within the transport business there is possibility to, with help from smart digital innovations and increased cooperation through connectivity, strengthen Swedish business competitiveness (CLOSER, n.d.). To make this work, standards are needed and a common way of sharing data within the city, through the nation and in EU. Feedback in the system is something Stockholm's municipality and the Swedish Transport Administration are requesting from connected vehicles when driving in the city. Improving the accuracy of the traffic data can be used to warn drivers about ongoing road works and this kind of information is beneficial for the development of autonomous vehicles. Scania has developed autonomous vehicles for closed areas but they will eventually be seen on public roads as well (Scania, 2020). Using data from the city allows the truck to know the current state of roads not only nearby but of every part covered by the sensors, enabling the autonomous truck to think ahead. Being a part of the feedback loop improving the data in the city is therefore something that Scania should have an interest in.

4.2.6 Take Points

There is a lot to gain from using the smart city data for planning routes in an optimal way depending on the traffic situation and being able to in real time book a slot for loading points. The challenge with these functions is not primarily how to display the information to the drivers but how to make use of the available data in an optimal way to make better decisions than an experienced driver. Therefore, an interface for the two functions route planning and loading points are not further explored in this thesis.

Further the focus is on how to display information regarding TTG and GLOSA from traffic lights, how warnings for vehicles in intersections and recommended speed should be displayed and how to inform a driver about receiving access to a bus lane.

4.3 First Draft

In this section the development phase is presented starting with the results from the workshop with the expert group which combined with the results from the previous two phases set the design goals for the first drafts. The section ends with the feedback results from the drivers.

4.3.1 Expert Opinions

The third phase started with a workshop where interface and functionality were discussed for the three functions: smart traffic lights, intersections and bus lanes. A general thought that came up was that a Head-Up Display (HUD) or Augmented Reality (AR) should be used to display the information of the new functions in the windshield. Pauzie (2015) defines a HUD as "any transparent display that presents data without requiring users to look away from their usual viewpoints." and AR in this context is information displayed on the windshield which is placed to match the scenery of the outside road conditions. When a HUD is mentioned further it refers to a smaller area at the bottom of the windshield in the drivers view range and AR is limited to the size of the windshield.

Traffic lights

AR was a popular topic during the workshop and all of the functions got a suggested strategy on how to display information to the driver. Countdown for traffic lights were suggested to be displayed next to where the driver see the actual traffic light in the windshield. Since the driver is already looking there it would not disturb the viewing pattern of the driver. Hopefully it could be placed in a way to not block other important information for the driver but in reality, it can block pedestrians or other vehicles which could contribute to an accident.

Another suggestion was to display the TTG information by mirroring the traffic light and adding the countdown next to it in a HUD or displaying it in the ICL. Colors should be used to differentiate between green and red but there should also be a way for colorblind people to differentiate. The recommended speed was suggested to be displayed in a HUD and to also be used for a smart traffic cruise control that automatically adjust the speed accordingly. This function should be customizable by the driver. A warning should also be displayed if the driver will not have time to pass the traffic light.

A general thought brought up by one of the participants was to use haptic feedback, using the sense touch to communicate with the user, to make the driver aware of for example that a stop is needed. Specifically, it was suggested to use haptic feedback in the pedals. Birrel, Young and Weldon (2013) found that haptic feedback can be one way of providing a driver with more information without increasing the workload and that it can successfully be used to deliver eco-driving feedback. For traffic lights that could be to indicate in the pedals that acceleration not is needed.

Intersections

When discussing how to give information when approaching an intersection using AR, one suggestion was to highlight the yield sign in the windshield if vehicles are approaching from other directions. Another was to display a warning symbol on or near roads where there are vehicles approaching that are needed to yield for. This warning will come before the actual vehicle is visible for the driver to be able to adjust the speed. When the vehicle is visible it can, like for the traffic sign, get highlighted to remind the driver to give way. The same technology could also be used to highlight other signs that are important for the driver not to miss.

A suggestion to warn for vehicles in intersections not using AR was to show red dots in a digital map to show where vehicles are. Here it is important to not be too specific with the warning, how many vehicles coming from the right for example is not an important information according to the participants in the workshop. Suggested was to also take into consideration if the intersection statistically has many accidents and potentially warn the driver of that.

In the city there are also a lot of pedestrians, cyclists and other smaller transportations that the driver needs to be aware of. They can also be tracked with the sensors in the intersection and it would be good to let the driver know about them too according to the workshop. A large truck is easy to spot for a cyclist but not as easy the other way around. How this warning should be differentiated visually from regular vehicles was not suggested during the workshop.

The information regarding where there are more vehicles and where and when there is a red light in the city should also be used by the route planner to optimize the route with as few stops as possible according to the participants. It is though not quite that simple since vehicles have their own agenda and the color of the traffic lights depend on where vehicles are coming from.

Pointed out in the workshop was also that information regarding connectivity should be displayed to the driver by having a symbol showing internet connection or lack of internet connection. This is important so that the driver does not think that no warning means that there is nothing to worry about. They did not think it was necessary to warn the driver when a traffic light or intersection is not connected and no information will be communicated.

Bus lane

For accessing a bus lane with AR technology two suggestions came up. The first being highlighting the real traffic bus sign with a green color in the windshield to indicate permission and the second being displaying an arrow indicating switching lane displayed looking like it is on the road. The first suggestion does not have a corresponding way to indicate to leave the bus lane, but for the second a similar way can indicate switching lane back with the arrow displayed on the road.

Regarding permission to drive in the bus lane, except for AR, it was suggested to show with an arrow indicating to switch lane, similar to the AR, in the navigation system and in the same way indicating to switch back when not allowed. The other suggestion was to have a green bus sign symbol in the ICL when allowed in the bus lane and then a red sign when not allowed. Both of these suggestions were supplemented with a sound to make the driver aware of the notification.

To complement this, it was suggested in the workshop to use ADAS functions like LDW to warn the driver if switching to a bus lane without permission and even using EAS to make sure it does not happen. Another way suggested to communicate information when the driver starts to make a lane change to a bus lane was to use green/red lights or symbols in or adjacent to the rearview mirror, where the driver is already looking when switching lane, to indicate acceptance or not allowed in the lane.

Recommended speed

During the workshop it was also brought up that the road conditions data like slippery or snowy roads should be implemented in the speed advisory algorithm since breaking a heavy truck is largely affected by such parameters. On the same note it was also suggested that statistics regarding accidents should be used to give advice on lower speed in intersections where accidents happen more frequently. To help the driver to drive accordingly with the instructions nudging could also be used. Nudging is a way to alter behavior without restricting options and help individuals make better decisions (Thaler & Sunstein, 2008).

Improved ADAS

Data gathered from sensors in the city could be used to improve already existing ADAS functions according to the participants in the workshop. Today many ADAS functions are not used in the urban environment. The AEB function that help the driver to break can for example be used if the driver does not slow down when the recommendation is to stop and the distance of stopping is becoming too short and the cruise control function can use the recommended speed to manage the speed of the truck. AEB in this case is a safety function unlike the cruise control which can bring comfort to the driver by helping out to choose the speed. The smart city cruise control can also utilize the ACC to keep a reasonable distance to the vehicle in front. Other ADAS functions that could benefit from sensor data is VRUCW and BSW by utilizing information about moving objects before they are visible to the truck's sensors.

4.3.2 Design Goals

Six design goals have been set for the concept. The goals originate from the information gathered in the workshop and from the initial interviews with the drivers. The design goals are:

- Internet connection information.
- Warning of vehicles before they are visible.
- Inform of access to drive in the bus lane when allowed and discourage when not allowed.
- Not too much visual information distracting the driver.
- Recommended speed to decrease the number of stops.
- Intuitive design.

In the workshop both AR and HUD were discussed. Proceeded with further is the HUD because of probability of implementation for Scania in the time span until 2030. The HUD also fulfill the wish from the drivers to not having to look down on the ICL and also adds an extra screen which was suggested by a driver. Human factors design tries to achieve an efficient cooperation between human and machine and closely linked with driving performance is the visual ability (Pauzie, 2015). When a driver needs to look away from the road to operate the machine the possibility of an accident occurring increases with the time the eyes are off the road. The usage of a HUD decreases the number of times a driver needs to glance down on the ICL. The positive impact of a HUD according to Pauzie is that the driver has more time to view the traffic situation and therefore have a quicker reaction to external events which leads to less stress for drivers. The negative mentioned by Pauzie is that the HUD can be blocking external objects which could be of importance to the driver.

Two concepts using the HUD technology were created to test different ways of displaying the information to the drivers. In Figure 2 the base of the two concepts are shown. The picture symbolizes the view from the windshield and the square at the bottom represents the HUD, the area where information can be displayed. Both concepts have current speed and the ongoing route placed in the middle, this base will not specifically be tested.

Figure 2. The base of the HUD used for both of the concepts.

4.3.3 Concept A

The first concept is built on as few symbols as possible and the majority of the symbols are white, only with some elements of red and green which are not significant to understand the meaning of the symbol, accommodating the needs of color-blind people. In concept A a white speed sign is used which shows the recommended speed at all times, shown in Figure 3. The recommended speed can be the speed limit or a calculated speed to adapt to red traffic lights or other vehicles in intersections to avoid stops. This recommendation symbol can be changed to a stop sign if the driver is recommended to stop, shown in Figure 4. The driver is not notified if there is internet connection in concept A, a symbol is instead shown when the internet connection is lost to warn the driver that no live information will be available which was requested during the workshop.

Figure 3. Concept A: Approaching a red traffic light.

Figure 4. Concept A: Recommendation to stop at an intersection, vehicle from the right.

Concept A: Traffic light

When approaching a traffic light, a traffic light symbol together with a number is shown to tell the driver the time to green or red, shown in Figure 3. During the workshop this was one of the suggestions how to present TTG to the driver and in the initial interviews with the drivers they suggested a simple countdown as well. The symbol marks the state of the traffic light using the current color, the other are transparent to differentiate for a color-blind as well. In Figure 3 when the traffic light is red, the driver is informed that it will be red for five more seconds and is recommended to drive at most 30km/h to avoid stopping. When the traffic light is green the recommended speed is equal to the speed limit if there is time to pass, and otherwise the stop symbol will be shown in the HUD.

Concept A: Intersections

In intersections the driver is warned about vehicles approaching the intersection that is needed to yield for. In Figure 5 vehicles needed to yield for are approaching from both right and left and the driver is given a recommended speed of 5km/h for the vehicles to have time to pass the intersection before the driver arrives. The warning symbols in the navigation is similar to the AR suggestion from the workshop now compressed in the HUD.

If going faster than the recommended speed the driver will have to stop at the intersection. In Figure 4 the stop symbol is shown together with the warning for a vehicle, which means the driver will have to stop for a vehicle from the right. When turning left vehicles from straight ahead are also warned for using the same warning symbol and a recommended speed is given to avoid stopping. When turning right in an intersection with the right rule no vehicles are warned for and similarly when driving on a main road no warnings are displayed.

Figure 5. Concept A: Intersection with yield sign, vehicles from right and left.

Concept A: Bus lanes

When a truck is approved for driving in the bus lane the navigation displays a green lane and an arrow telling the driver to switch lane, Figure 6. In the same way the lane is portrayed red with an arrow in the opposite direction when the truck is not allowed in the lane any longer and should switch to the ordinary lane, Figure 7. To avoid driving in the bus lane on habit the lane is when passing marked red in the navigation when not allowed to drive in it. The color here is not necessary to differentiate, only viewing the arrows is enough to understand the information. This way of utilizing the navigation to portray access to a bus lane was one of the suggestions during the workshop. In the future when other vehicles than busses are allowed in these lanes they might be called something else, like flex lane, and with this concept the name of the lane is irrelevant.

Figure 6. Concept A: Approved to drive in the bus lane.

Figure 7. Concept A: Not allowed in the current lane.

4.3.4 Concept B

For concept B a larger number of symbols are shown in the HUD at the same time and more colors are used. Apart from the basis of the HUD in concept B is the speed limit of the road and the internet connection symbol always visible. For this concept, no internet connection is shown by lack of the internet connection symbol. Like in concept A a white speed sign is used to give recommended speed but it only appears when the recommended speed is not the same as the speed limit, shown in Figure 8.

Figure 8. Concept B: Approaching a red traffic light.

Concept B: Traffic lights

For traffic lights in concept B TTG is not displayed in the HUD, only recommended speed is shown to the driver together with a symbol showing why there is a recommended speed. In Figure 8 the driver is recommended to have a lower speed than the speed limit because of the red traffic light ahead. The traffic light symbols are also placed on the opposite side compared to concept A to see if the drivers prefer one of the sides. When the traffic light is green and there is enough time to pass, the recommended speed symbol disappears since there is a symbol of its own telling the speed limit.

Concept B: Intersections

When approaching an intersection with priority to the right the recommended speed is paired with a white yield sign symbol to indicate that a lower speed can avoid stopping at the intersection, shown in Figure 9. If needed to stop, similar to concept A, a stop sign is displayed in the HUD on the right. For intersections crossing a main road the yield sign symbol is colored when vehicles are approaching from right or left and is displayed together with the recommended speed, Figure 10. Suggested in the workshop was to highlight the yield symbol using AR, for concept B a variant of that is tested.

When turning left the yield symbol is the same independent of if the vehicles are coming from right or straight ahead and when turning left crossing a main road the yield symbol can indicate vehicles from all directions.

Figure 9. Concept B: Intersection with recommended speed, vehicle from the right.

Figure 10. Concept B: Intersection with yield sign, vehicles from right and/or left.

Concept B: Bus lane

Informing the driver of acceptance of driving in the bus lane in concept B is shown with the bus sign symbol, Figure 11. This was suggested both during the workshop and in the initial interviews. Changing the blue color to green was not done visually but during the second interview with the drivers they were asked about that as well.

When driving in the bus lane when allowed the bus symbol becomes smaller and moves down in the HUD to not disturb the driver more than necessary. When the bus lane is not allowed to drive in anymore the bus symbol becomes larger again and a cross is added over the bus symbol. The interface of the last two functions can be found in Table 3.

Figure 11. Concept B: Allowed to drive in the bus lane.

4.3.5 Feedback from Drivers

The second interview with the drivers were held using the graphics of concept A and B. The HUDs of both concept A and B can be found in the comparison in Table 3. When showed to the drivers the HUD were like the previous pictures displayed in a traffic situation. Relevant quotes from the drivers in the interviews have been gathered in Table 1 and Table 2 in the end of this section.

Traffic lights

The difference between concept A and B for traffic lights is not very big. Overall, the drivers' opinions on TTG and recommended speed were tested in this section. One other difference was the placement of the traffic light symbol which is on different sides of the navigation in the concepts, but only one driver had an opinion about that. The driver thought that the symbol should be placed on the left if turning left and vice versa. Another driver expressed the importance of the symbols not moving around.

A concern from the drivers were of the many different numbers displayed in the HUD. Confusion arose for all of the drivers at least once during the interview regarding the numbers. Contributing to this is that the drivers looked at two concepts with different numbers displayed in different ways which made it harder to understand all of the numbers on the second concept they viewed. In concept A, all of the drivers liked the TTG displayed but some were at first confused of the actual meaning of the number. This issue would probably be fixed when the seconds are actually counted down instead of the static pictures the drivers were presented during the test.

One driver likes the TTG much more than the recommended speed because he likes to think for himself but another driver thinks there is plenty of space for both. In concept B one of the drivers gets confused when the recommended speed disappears but also think it is something that you get used to. The same driver finds the recommended speed, current speed and legal speed as a distraction when there are other vehicles ahead that makes it impossible to follow the recommendation and the speed is lower than the restrictions. Another driver suggest that the speed should not be shown at all in the HUD in situations where the focus should be on the traffic situation, minimizing the number of symbols shown in the HUD. Overall concept A is a favorite for traffic lights for the drivers since it has TTG, but missing is the legal speed of the road.

Intersections

Concept A for intersections is a clear favorite among the drivers. The advantage is that the driver is informed of where approaching cars are coming from instead of a generic yield warning. The drivers who were presented concept B first accepted the yield symbol, Figure 9, but wished to get information about from where vehicles are approaching.

The white yield symbol in concept B is confusing to some drivers since it is used in an intersection with priority to the right. One driver thinks it should be colored to give more of a reaction but other drivers do not like traffic signs used in alternative ways. One driver thinks the sign can be white when approaching an intersection and be colored when a car is coming. The recommended speed, displayed together with the yield sign, was confusing as well for the drivers. The drivers who viewed concept A first could have recognized the white circle from earlier but they did not. The drivers who viewed concept B first needed an explanation but accepted it after that. Overall, drivers who were shown concept A first had a harder time to understand concept B and stated that the previous concept was better without trying to give suggestions of improvement of concept B.

Opinions of the stop sign used in Figure 4 to inform the driver to stop at the intersection were divided. Two of the drivers liked the symbol and thought it gave the information it should while the other three drivers did not think it was a good symbol since a stop sign represents standing still before continuing which is not the goal in this situation. It could also be interpreted as the need to stop immediately. One of the drivers mentioned that the regular traffic signs are “sacred” and should be used with care. The suggestion given was to make it white like the recommended speed symbol to amplify that is a recommendation dependent on the current traffic situation. Just by removing the red the symbol was approved by the rest of the drivers.

The drivers were also asked about receiving information about vehicles coming from the left in an intersection with priority to the right. All of the drivers would want to know about vehicles even though they do not have priority since you cannot trust other drivers to stop and in narrow intersections you might have to let the vehicle pass to be able to make the turn with a truck. Several suggestions came up on how to inform the driver of vehicles without priority. The first suggestion being having the same symbol independent of if the vehicle has priority or not. Second, having another symbol representing vehicle without priority like only a car without the red triangle around. Lastly, changing the current warning symbol for vehicles with priority to a yield sign and use the current warning symbol for warning about other vehicles.

An uncertainty was expressed regarding if it would be too much information in the HUD with all of these warnings for vehicles, which could be distracting to the driver. To test how much information that can be displayed in the HUD a simulator would be needed according to the drivers. In Figure 5 where two warnings are displayed the drivers did not think it was too much information but three warnings were never tested visually. One suggestion was to have the warning symbols in the navigation further apart from each other to make it less congested. One of the drivers also wanted the vehicle in the triangle to represent the reality by adding a symbol representing a two wheeled vehicle. When driving on a narrow street for example not as much space needs to be left for a two wheeled vehicle compared to a four wheeled for the vehicle to pass.

Bus lanes

The A and B concept for bus lanes are very different where concept B is based on the bus sign and concept A uses the navigation to display access. The bus sign displayed in concept B were confusing in two ways. One driver interpreted the bus sign just as information that there is a bus lane, which can be seen just by looking on the signs by the road. Two of the drivers interpreted the symbol as if they were driving in a bus lane and became confused because the sign in the street told them that it was the lane next to them. The last two took it as a reminder of the bus lane next to them that they cannot drive in.

The cross over the bus sign was interpreted as the bus lane ending which allowed them to proceed in the lane, which was not the intension. Since the drivers knew about the function access to drive in bus lanes from the last interview they could figure out what the intention was with the symbols but they did not think it was a good way of informing a driver even with experience of the intention of the symbols.

The drivers were then asked if a green and red bus symbol would have been easier to understand the meaning of instead of the standard blue one. They agreed that would have been a better way. Generally, three of the drivers did not approve of traffic signs used with their regular colors to mean something else than the ordinary meaning.

Concept A were much clearer to understand according to the drivers. The green and red marks of the lane in the navigation were approved by all of the drivers. They found it easy to understand without any prior knowledge and did not hesitate to follow the directions. The extra information regarding no access to the bus lane were also appreciated since it is easy to drive on habit. In some areas it is also tricky to keep up with where the bus lanes are and then it is nice to get visual help from the truck to drive correctly according to one of the drivers. For accessing bus lanes all of the drivers preferred concept A.

Internet connection

The internet connection symbol in concept B visible at all times were only preferred by one driver who did not think the extra symbol in the HUD was a problem. The other four drivers preferred concept A were a symbol is shown only when not connected to decrease the number of symbols appearing in the HUD. One of the drivers suggested to mark the symbol with something red to make it stand out more in the HUD when there is no internet connection and another driver suggested that everything in the HUD can become gray to indicate no connection.

Speeds displayed

A difference with the bases of the concepts is regarding display of the speed limit of the road. Four of the drivers liked concept B better where the speed limit was visible at all times, even though that information is given in the ICL. Only one of the drivers thought it was enough to have the recommended speed in the HUD. The speed limit presented with the colors of the traffic sign were approved by the drivers but some confusion existed regarding the white recommendation symbol. At first sight only one of the drivers understood the meaning but all of the drivers understood and thought it makes sense after an explanation. Suggested was to add some text such as R or REC beside the symbol to indicate that it is recommended speed.

One driver thought it was strange when the recommended speed disappeared in concept B when it was not needed. During the test most of the pictures shown had a recommended speed but in reality, most of the time driving that will not be the case. The recommended speed will not disappear, it will appear when needed. Another driver suggested to use the recommended speed less. When it is impossible to drive faster than the recommended speed because of other vehicles the information is redundant for example.

Overall

At the end of the interview the drivers were asked about which concept they preferred if nothing was changed. Overall three of the drivers preferred concept A and two of the drivers preferred concept B. One of drivers choosing concept B would have chosen concept A without a doubt if it had the speed limit symbol. The other driver choosing concept B emphasized that the bus concept was better in concept A and mentioned that TTG is not necessary.

The drivers choosing concept A mentioned the TTG as an important feature and one of the drivers mentioned missing the internet connection symbol from concept B but not so much it is better overall. Intersections were not mentioned by any of the drivers when discussing the best concept overall.

Table 1. Concept A: Relevant quotes from drivers.

	Relevant Quotes
Traffic lights	"It went pretty fast to figure out what it was about. […] I think the seconds might be better than the recommended speed right now. Because then I only need to look at the five seconds and then I can adjust the speed by myself. Because I have to go below the recommended 30 in the turn anyway, I cannot turn in 30 km/h."
Intersections	"If you are coming with a truck and trailer here for example or with a trailer then it might be that way, I have to stop and let him pass because I cannot turn in the intersection otherwise."
	"All the signs you have showed so far [all signs for intersections in concept A], exemplary, they are produced really good all of it"
	"If it would have some extra symbol that shows that it is a recommended speed now, it is not the legal speed limit. […] I would suggest a small R there in the corner, recommended."
	"Let's see. It is a lot to take in actually."
	"I think you should distinguish between the real road signs and their meaning and this. I feel that way anyway. The real road signs on the side of the road are sacred in some way."
	"That I do not like, I do not know why it have to be red there. […] The red warning triangle there, it seems like it is lively traffic."
Bus lane	"No sound, not in a HUD."
	"Really nice it is!"

Table 2. Concept B: Relevant quotes from drivers.

	Relevant Quotes
Traffic lights	”Then you will probably get irritated if it says drive 20 km/h and the one ahead go ten, then people will get annoyed at why have they written 20 when I cannot go 20.”
	“My gut feeling just says, no I will look at the road instead and drive as I have always done.”
	“That [actual speed] is not something you need to know at that point in that way, there it is more about keeping the flow in the traffic.”
	“Now the information [recommended speed] has done its job.”
Intersections	“I think that it could be some kind of indication on where the car is coming from. Is it coming from the right or is it coming from straight ahead.”
	“If you are driving 12 km/h then you are driving so slowly that you have time to look to the right to see if someone is coming, or left, so that you do not have to stop so that you can go on.”
	“Can the car recognize that it is a motorcycle, absolutely then you can show that it is a motorcycle.”
	“It is a bit colorless in some way and a bit cryptical, the other one was clearer that we talked about before. […] The first impression was, what the hell is this now, it might be best to just focus on the road instead of staring on that and think about what it means.”
	“Only a stop sign is somewhat confusing at first glance, when you learn the system then it is something else then you know. But stop is so definite, then you almost think that you should stop right away.”
Bus lane	“[If the symbol would have been green] I would have interpreted it as if I can go in the bus lane.”

4.4 Final Concept

The final concept is a mix of the concepts A and B where the best parts of both are brought together based on the feedback given by the drivers and during the workshop. The base of the layout is the same as for concept A and B with navigation and current speed in the middle of the HUD. Showing at all times is also the speed limit, like in concept B, since the drivers preferred that over only having the recommended speed. A comparison of different scenarios of the three concepts are shown in Table 3.

The internet connection symbol is for the final concept only shown when not working, like in concept A. The drivers asked for the symbol to stand out more in the HUD and therefore the symbol has been given a red color. Now it stands out more to make the driver aware of the situation since now no warnings and recommended speeds will be displayed.

4.4.1 Final Concept: Traffic Lights

The interface for traffic lights have the TTG countdown and when necessary also have the recommended speed displayed, Figure 12. Both of these functions where highly appreciated by the drivers and a combination of both of them is wanted to be able to receive recommendations but still have the ability to make own decisions. When the traffic light changes to green and the driver have time to pass, the white recommended speed sign will disappear which was not a problem in concept B. If there is not time to pass when the traffic light is green the white stop sign will appear to inform the driver.

Figure 12. Final concept: Approaching a red traffic light.

4.4.2 Final Concept: Intersections

The intersection interface is most similar to concept A where warning for vehicles are displayed together with the navigation to indicate from where the vehicle are approaching. An improvement recommended by the drivers were to use the yield triangle, like in concept B, instead of the warning triangle to indicate a vehicle in an intersection, shown in Figure 13. They also wanted information regarding other vehicles to be displayed where the warning triangle is used instead, Figure 14. For intersections when crossing a main road, the symbols are the same. The difference between the two symbols are not necessary to understand the first time the system is used, understanding that they indicate approaching vehicles is enough to be able to benefit from the information.

In combination with the warnings for vehicles the white recommended speed symbol shows how fast the driver should go to be able to drive through the intersection without stopping. If there is no speed that can make this possible, the driver is recommended to stop with the white stop symbol, Figure 13. The red and white stop sign is not used in this concept to avoid confusion that the driver has to legally stop, which was pointed out by the drivers.

Figure 13. Final concept: Intersection with recommendation to stop.

Figure 14. Final concept: Intersection with the two different warnings.

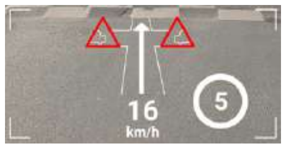
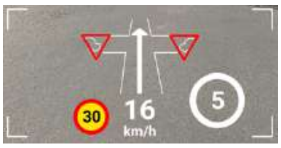
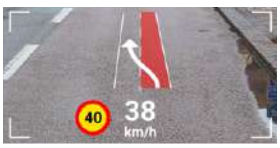
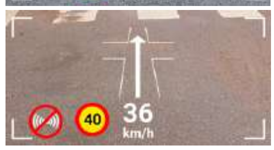
4.4.3 Final Concept: Bus Lane

The bus lane interface for the final concept is the same as for concept A. The only difference is the base that is slightly different in the final concept compared to concept A. The drivers liked the concept and did not have any improvement suggestions. The green and red colors is an effective way to tell the driver if the lane is approved or not to travel in, shown in Figure 15 and Figure 16. With this concept the drivers understand the meaning of the information without getting too much information. This interface could also for example be used in a similar way on roads with weight restriction on some lanes marking the lane with red and give directions of lane change.

Figure 15. Final concept: Approved of driving to the bus lane.

Figure 16. Final concept: Denied access to the bus lane with indication to change lane.

Table 3. Comparison between concept A, B and the final concept.

	Concept A	Concept B	Final concept
The base of the concept.			
Red traffic light with recommended speed.			
Green traffic light.			
Intersection with vehicle from the right.			
Intersection with recommendation to stop.			
Intersection with yield sign, vehicles from left and/or right.			
Intersection with left turn, warning for vehicles.			
Approved to drive in the bus lane.			
Driving in a bus lane when approved.			
Requested to leave the bus lane.			
Reminder of not approved to drive in the bus lane.		-	
No internet connection.			

5. Discussion

The final concept is not a finished product. In this study mockups have been used during tests to get an idea of how to use the new data that will be available in a smart city. As suggested by drivers in the interviews the concept now needs to be tested in a simulator to better understand how much information and how many symbols can be shown in different scenarios. So far, the drivers have been presented static pictures where information does not change which makes it easier to focus on the information in the HUD. Already with the static pictures there were scenarios when the drivers got confused, but that can also correlate to them viewing two similar but different concepts one after the other.

The simulator should be used to test the final concept in scenarios with more traffic information. A scenario not fully explored is when an intersection without traffic lights have a lot of traffic in it. In this scenario it might not be effective to warn about vehicles approaching from all directions but instead have a general warning for a lot of traffic. Especially intersections need to be further investigated to see in which scenarios warnings about approaching vehicles are beneficial. The drivers think it is always good with warnings and they approved of having three warning symbols in the navigation for the intersection function but in an intersection with a lot of traffic this might not be the best way to display the information since the driver will have a lot to think about regarding the traffic outside.

During the interviews it came up that all information is not needed at all times. Having the recommended speed was an appreciated feature but when a vehicle in front makes it impossible to drive faster, the information is not necessary any longer. There are most certain scenarios where information is redundant which should be further studied. This study has shown that drivers want to have the speed limit in the HUD at all times but similar to the recommended speed there can be scenarios where this information would not be missed by the driver. When a lot is happening in the traffic too much information in the view range can be a distraction for the driver and tests should be done to conclude which information is necessary in which situations and which information can be excluded.

The interviewed drivers have long experience, at least 20 years, and all are over 40 years old. With their knowledge about trucks they generally like to make decisions on their own and not give the truck too much room for making decisions on its own. The drivers were skeptical about having a city cruise control that deaccelerates accordingly with the recommended speed. Guo, Tang and Guo (2020) state that human capital is of importance when developing a smart city and in the same way the driver is an important factor in the produced concept. Guo, Tang and Guo point out technological literacy as one aspect for better implementation, in the same way drivers expressed in the interviews that younger people who use technology in another way might be able to take advantage of driver support functions in a more optimal way. Younger drivers might find new functions beneficial in a larger extent than experienced and/or older drivers, a study including a broader variety of drivers should be done to investigate this further.

When the city becomes more dynamic and more information than what can be seen by a driver is available it will not be the most efficient to drive the same route from A to B two different days. Focus in this study has been on what Scania can do with the smart city data to help the driver, and a smarter route planning is one thing mentioned that private companies can utilize the data for. The city can use the data to optimize traffic by using AI to regulate traffic signals and this can be beneficial for the GLOSA algorithm if traffic signals decide ahead of time when it will be red or green. Traffic optimization can also cause issues with a smart route planning, if the private and public sector do not work together the AI in the two different systems might work against each other which is not beneficial for anyone.

Route planning and optimization of loading points are functions that can benefit from the smart city data. A booking system for loading points is not something that can be developed only by Scania. The system needs to be somewhat universal so that all kinds of trucks can use the same system and all loading points in the area needs to be connected to the system for it to be successful. How to proceed with this must further be investigated. Route planning can on the contrary be developed inhouse at a larger extent but can benefit from collaboration with the city's optimization plans as mentioned.

6. Conclusion

Driving in the smart city Stockholm in 2030 will be a more demanding task for an experienced driver since the city will become more dynamic. Speed restrictions will fluctuate and some streets will be closed during some hours of the day and the smart traffic lights will be used to optimize overall traffic. The truck will have access to data from smart sensors in the city which can be used to give the driver more information to make better decisions in this new environment. Data from intersections and traffic lights as well as the possibility to make exceptions from traffic rules using internet communication has been used to produce a concept for displaying information to the driver.

The final concept, which can be found in Section 4.4, includes a HUD which projects the information in the drivers view range for the driver to not look away from the road. The concept includes design for the three functions intersections, traffic lights and bus lanes that will be available when more data is shared from the smart city. The information displayed in the HUD, made possible from the new data, includes time to green for traffic lights, warning for approaching vehicles from out of sight streets in intersections, access to bus lanes and recommended speed for intersections and traffic lights. Through this information the driver can manage the speed of the truck in a more foreseeing way to avoid unnecessary stops and drive more energy efficient. This also results in a more harmonic driving experience since the drivers can plan their journey further ahead of time and do not have to stress when for example approaching a traffic light since the truck tells the driver if they will be able to pass or not. The final concept reflects what the drivers want to know when driving in a smart city.

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Appendices

Appendix A

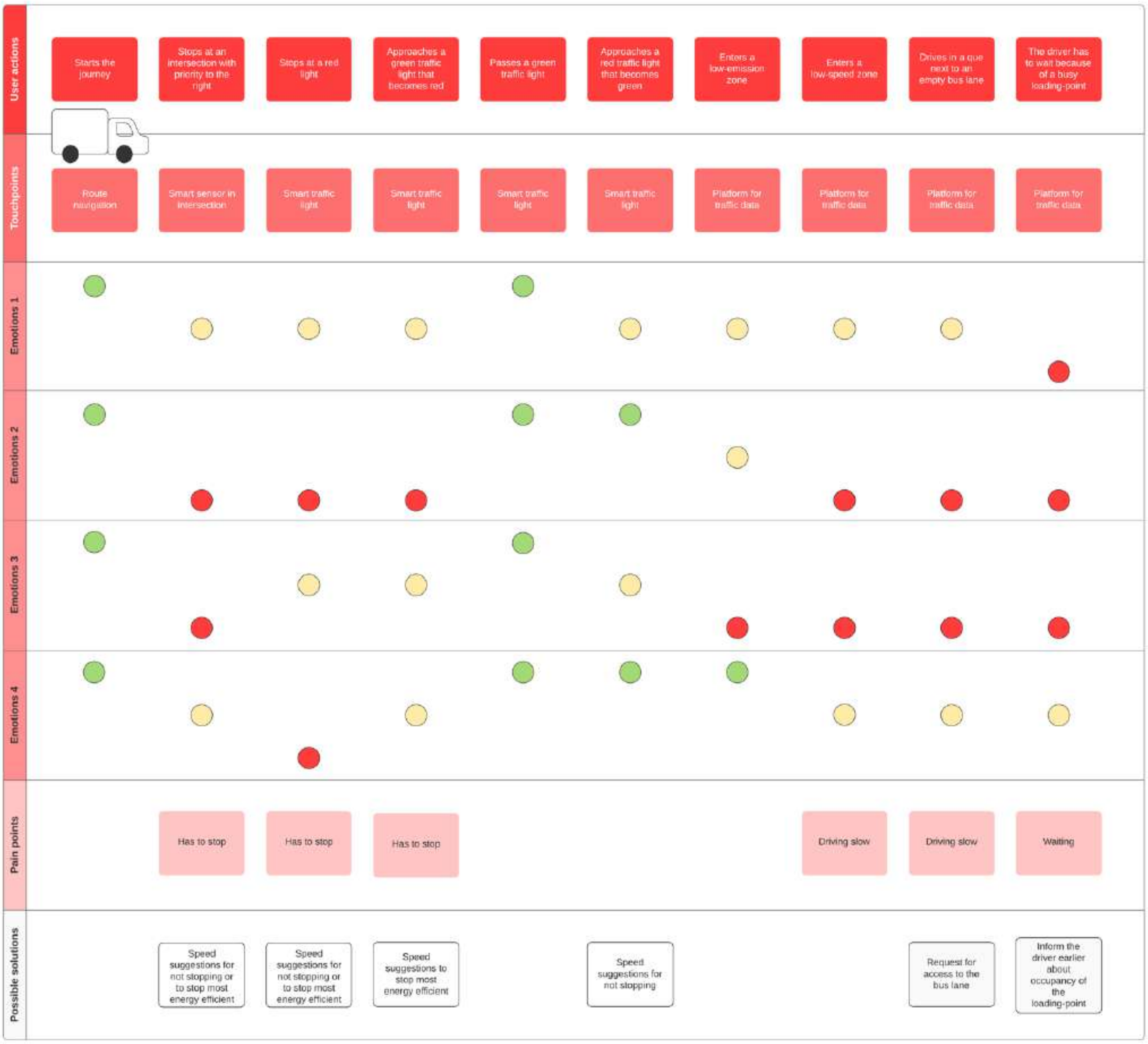

Figure A. User journey map.

Appendix B

Table B.1. Concept A: The original quotes from drivers before translation.

	Relevanta citat
Trafikljus	”Gick ju ganska snabbt att räkna ut vad det handlade om. […] De där sekunderna tycker jag nästan är bättre än den rekommenderade hastigheten just nu. För då kan jag bara titta på dem där fem sekunderna och sen kan jag anpassa min hastighet själv. För jag måste ändå under de där rekommenderade 30 i svängen för jag kan inte svänga i 30 km/h”
Korsningar	”Kommer du då med lastbil och trailer här till exempel eller med släp då kanske det är så, jag måste ju stanna och släppa förbi honom för jag kan inte svänga i korsningen annars”
	”Alla skyltar som du har visat hittills [alla skyltar för korsningar i koncept A], exemplariska, de är jättebra framställda och alltihopa.”
	”Om den skulle ha någon extrasymbol som visar att det här är en rekommenderad hastighet nu, det är inte den gällande hastighetsbegränsningen. […] Jag skulle kunna tänka mig ett litet R där i hörnan, recommended.”
	”Nu ska vi se. Vad mycket det blir att läsa av egentligen”
	”Jag tycker man ska skilja på de verkliga vägmärkena och deras betydelse liksom och sen i det här. Det känns så i alla fall. De riktiga vägmärkena som sitter längs vägen är heliga på något vis.”
	”Den där tycker jag inte om, jag vet inte varför den ska vara röd där framme. […] Den där röda varningstriangeln där, det verkar som att där är det livlig trafik alltså.”
Bussfil	“Nej inget ljud, inte i en HUD.“
	“Kanonfint är det.“

Table B.2. Concept B: The original quotes from drivers before translation.

	Relevanta citat
Trafikljus	”Då blir man väll säkert irriterad om det står där kör i 20 km/h och de framför åker i tio, då kommer folk irritera sig på att varför har de skrivit 20 när jag inte kan åka i 20”
	”Magkänslan blir bara, nej jag tittar på vägen istället och kör som jag alltid har gjort.”
	”Det där [faktiska hastigheten] är inget som man måste veta just där och då på det sättet där handlar det mer om att hålla flytet i trafiken.”
	”Nu har den informationen [rekommenderad hastighet] gjort sitt liksom.”
Korsningar	”Jag tycker att det kanske kunde vara någon liten indikering på vart bilen kommer från. Kommer den från höger eller kommer den rakt framifrån”
	”Om du åker 12 km/h då går det så sakta fram till väjningsplikten så du hinner se höger om det kommer någon, eller vänster, så att du inte behöver stanna så att du bara kan åka på.”
	”Kan bilen känna av att det är en motorcykel, absolut då kan man ju peta in det att det är en motorcykel.”
	”Det är lite färglöst på något sätt och lite kryptiskt sådär, det andra var tydligare som vi körde förut. […] Första intrycket var, vad fan är det här nu då, det kanske är bäst att ha fokus på vägen istället för att sitta och stirra på det där och klura på vad det betyder”
	”Bara en stoppskylt det blir lite förvirrande vid första anblicken, när man lär sig systemet då är det ju en annan sak då vet man ju. Men stopp det är ju så definitivt, då tror man nästan att man ska stanna direkt.”
Bussfil	”[Hade symbolen varit grön] hade jag tolkat det som att jag fick köra i bussfilen.”