FUDVI

Future Layouts for Driver Positions & Visual Information in Trucks

Public report

Project within Vehicle Development
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Content

1. Summary

This project started from the assumption that truck drivers sit differently when driving in different traffic situations with typical vehicles for city distribution transports as well as for long-haul transports. In order to study this, work was divided into four work packages:

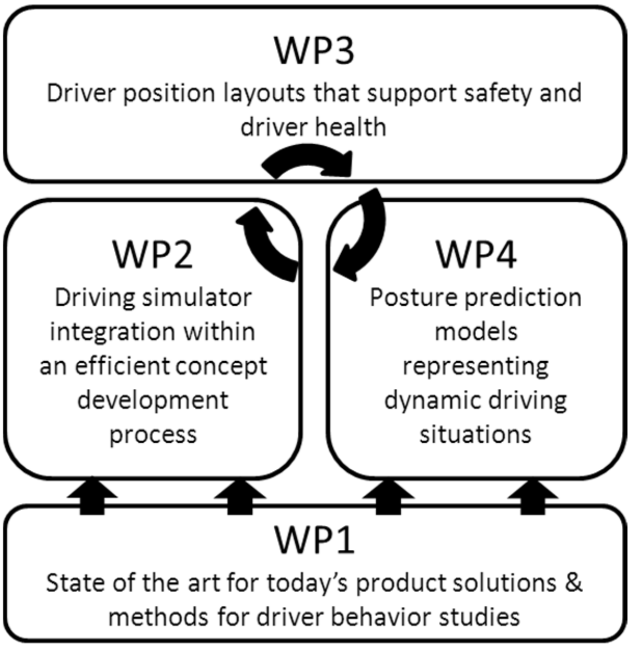


Figure 1. Work packages within FUDVI

To perform investigations relative to the assumption, it was necessary to choose research tool, representative vehicles and representative test persons. To facilitate exploration of a multitude of concept variables, it was proposed to use a configurable driving simulator as main research tool. To cover a large proportion of the European truck population, it was decided to focus on a heavy truck tractor with connected semi-trailer where the cab is positioned high above the ground, and a medium-heavy rigid truck where the cab is positioned lower above the ground.

Figure 2. Medium-heavy rigid truck for city distribution transports (left) and heavy truck tractor with connected semi-trailer for long-haul transports (right)

In order to study both extreme sitting postures as well as transitions between different sitting postures, it was necessary to secure three typical traffic environments that could trig these behaviours. The first traffic environment was a city environment with guarded and unattended crossings, driving in lanes, roundabouts, and a parking situation at a goods terminal. The city environment had also to be populated with a multitude of other vehicles and vulnerable road-users. The second traffic environment was a highway environment with ramps to enter and exit the highway, unattended crossings and typical truck stops at the road-side. This highway environment was populated with various other vehicles. The third traffic environment used in the project was a longer motorway with two lanes in each direction that could support overtaking situations. Also this environment was populated with a variation of vehicles.

Figure 3. Traffic environments – city, highway and motorway

The tests have been performed with truck drivers having significant experience from driving the included vehicle types. Five research studies have been performed during the project:

1. Field study to investigate how drivers actually behave when driving real trucks on ordinary roads
2. Validation study to compare the driver behaviours when driving in a driving simulator compared with when driving real trucks on ordinary roads (outcomes from the field study).

3. Research study 1 where driver behaviours for the two type vehicles in city and highway traffic were compared when driving with traditional rear-view mirrors and Camera Monitor System counterparts.
4. Research study 2 where driver behaviours in city and highway traffic were studied when driving with developed concepts for the two type vehicles including variants for indirect vision devices and alternative locations for vehicle information.
5. Research study 3 where driver behaviours in city and motorway traffic were studied when driving with refined concepts for the vehicle combination of the truck tractor with semitrailer.

Figure 4. Views from the validation study (driving simulator above and real truck below)

As part of WP1 and WP2, methods have continuously been developed during the project. These developments comprise:

- Use of interviews based on questionnaires
- Observations with analysis of video films
- Investigations into image processing as support for analysis of driving postures
- Automatic navigator instructions instead of manual driving instructions
- Use of simulator data and sensors to track head motions
- Eye-tracking to follow the visual behaviour of the drivers

Several new work procedures and processes have also been established related to the use of driving simulators as a product development tool:

- How a driving simulator is used for these kind of studies
- How alternative concepts of truck geometries and HMIs are implemented into the driving simulator
- The necessary responsibility split for planning, performing and analysing results from driving simulator studies

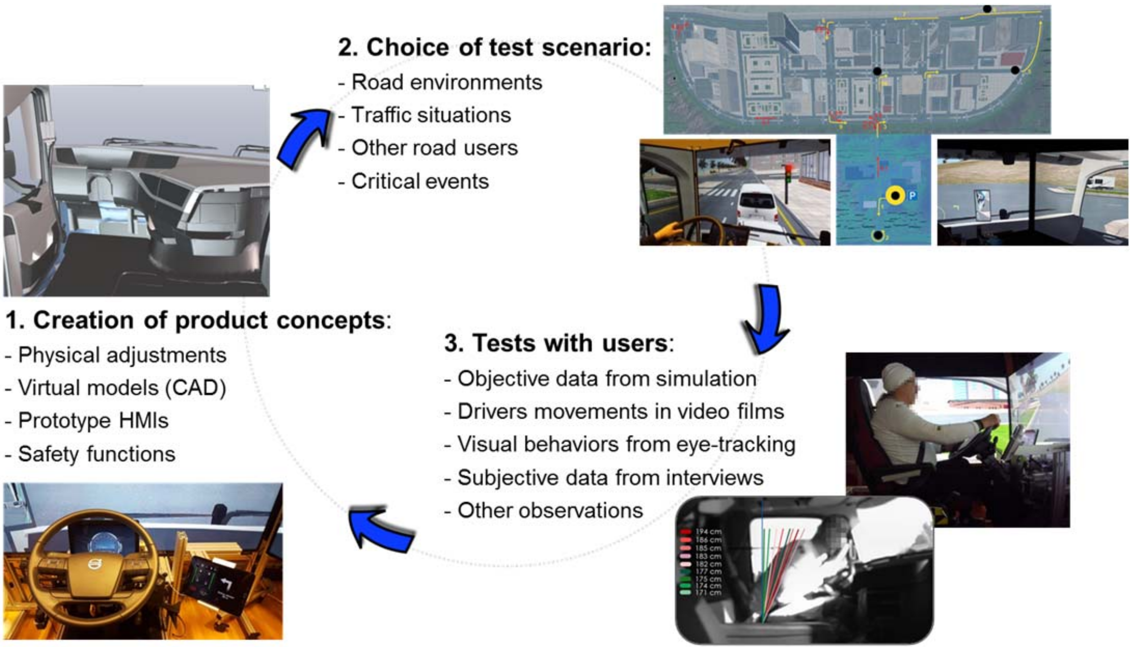


Figure 5. Process illustration for use of a Configurable Driving Simulator

The entire project has been run during three and a half year. It started with background studies in 2014 to dig into the field of research. Then a longer period took place of developing and fine-tuning the driving simulator as the main research tool. Around that time, the original PhD student left the project and was replaced by another person. After that, explorative research studies could be started. These were followed by research investigations of chosen parameters corresponding to internal and external factors. During the project, different pieces of documentation have been prepared like academic papers, presentation materials for conferences, book contributions, and internal method documentation.

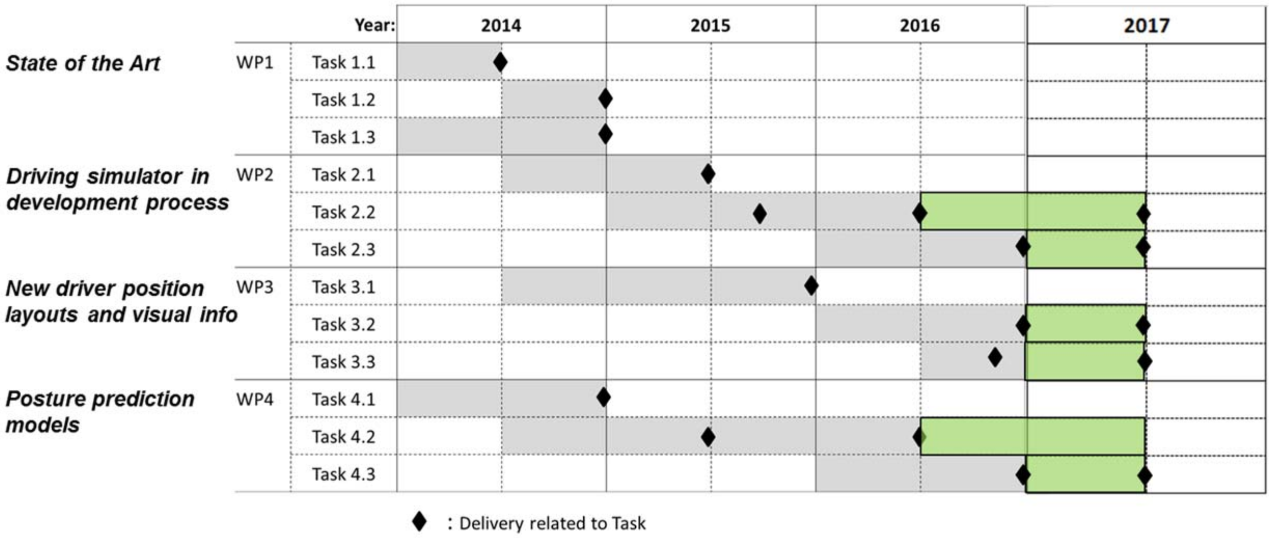


Figure 6. Project time-plan and deliverables

2. Sammanfattning på svenska

Denna rapport motsvarar projektet Framtida Layouter av Förarplatser och Visuell Information i Lastbilar. Detta är ett projekt som löpt under 3.5 år från 2014 till 2017 i ett samarbete mellan Volvo Lastvagnar och Chalmers med stöttning av medel från VINNOVA.

Projektet har drivits i fyra arbetspaket:

- Arbetspaket 1: Nulägesanalys vad gäller produktlösningar och metodik för studier av förarbeteenden
- Arbetspaket 2: Integration av körsimulatorer i en effektiv konceptutvecklingsprocess
- Arbetspaket 3: Nya layouter för förarplatser som stödjer säkerhet och förares hälsa
- Arbetspaket 4: Predikteringsmodeller för körställningar motsvarande dynamiska körförhållanden

Projektet initierades eftersom utvecklingen av förarmiljöer hos lastbilar tycks ha stannat av samtidigt som det kommer nya tekniska lösningar med potential att i grunden förändra förarplatsers utformning. Parallellt med de nya tekniska lösningarna har även förbättrade möjligheter till virtuell utvärdering dykt upp. Körsimulatorer brukar främst användas för utvärdering av förargränssnitt under körning mestadels rakt fram. Detta projekt har emellertid syftat till att även använda körsimulatorer som verktyg vid studier av förares körställningar, rörelsebeteenden och visuella beteenden. Inverkan från såväl interna faktorer (såsom justerområden och placering av information) liksom externa faktorer (såsom vitt skilda trafikmiljöer) har ingått. Dessa saker måste studeras under körning, och då utgör körsimulatorer ett kostnadseffektivt alternativ som samtidigt stöttar undersökningar av mer avancerade koncept som kan vara svåra att realisera eller farliga att utvärdera på vanlig väg.

Målsättningarna med projektet har varit flera. Projektet har velat etablera mer kunskap kring utformning av förarplatser och placering av visuell information. Dessutom behövde processen för studierna i körsimulator kartläggas, eftersom den ger stora möjligheter till ledtidsreduktion och mer högkvalitativa resultat genom den repeterbarhet och datainsamling som en laboratoriemiljö stödjer. För det tredje skulle insamlingen av information kring förares körställningar och beteenden kunna ligga till grund för predikteringsmodeller att implementera i andra virtuella simuleringsverktyg såsom datorstödd analys med digitala mänskliga mannekänger.

Projektet har haft som ambition att ta fram resultat som är giltiga för lastbilsförare som kör en majoritet av medeltunga och tunga lastbilar på den europeiska marknaden. Detta har inneburit ett fokus på så kallade frambyggda lastbilar där hytten är placerad ovanpå motorn. Dessutom har de vanligast förekommande fordonsvarianterna för respektive lastbilstyp valts ut. För medeltunga lastbilar innebär det en så kallad jämnlastare med lågt placerad hytt som själv bär lasten i ett skåp på det egna fordonet. För tunga lastbilar innebär det en fordonskombination bestående av en dragbil med påhängsvagn där hytten är placerad högre över marken.

Bakom det medvetna valet av dessa typfordon ligger även att de innebär två helt olika nivåer av komplexitet när det gäller framförandet, både vad gäller produktlösningar motsvarande typiska körsituationer och hur stor plats fordonen tar i gatumiljön.

Efter en period av initial inläsning av forskningsområdet har projektet i huvudsak drivits framåt genom fem forskningsstudier med erfarna lastbilsförare som testpersoner:

1. Fältstudie för att undersöka hur förare beter sig under körning med lastbil på allmän väg
2. Valideringsstudie för att säkra att förares beteenden i körsimulator är jämförbara med deras beteenden vid körning på allmän väg
3. Forskningsstudie 1 med variation av interna och externa faktorer: Förares beteende undersöktes för bägge typfordonen vid körning i stads- liksom landsvägsmiljö. Inverkan från två olika koncept för indirekt sikt undersöktes – traditionella backspeglar jämfört med när de ersatts av kamera-display system.
4. Forskningsstudie 2 med variation av interna och externa faktorer: Förares beteende undersöktes för bägge typfordonen vid körning i stads- liksom landsvägsmiljö. Här studerades även inverkan av olika koncept för indirekt sikt liksom presentation av visuell fordonsinformation. Dessa hade valts ut och anpassats för respektive typfordon.
5. Forskningsstudie 3 med variation av interna och externa faktorer: Förares beteende undersöktes för typfordonet tung dragbil med påhängsvagn vid körning i stadsmiljö liksom på motorväg. Inverkan av två olika koncept för indirekt sikt liksom fordonsinformation studerades.

Parallellt med forskningsstudierna har körsimulatorverktyget kontinuerligt förbättrats vad gäller inkluderade körfall, körmiljöer och prestanda.

En hel del resultat har uppnåtts kopplat till innehållet i de olika arbetspaketen. Det har visat sig att lastbilsförare sitter och beter sig olika vid körning av olika typer av transporter under påverkan av både interna och externa faktorer. Kopplat till detta har det även visat sig vara fördelaktigt med alternativa förarplatslayouter motsvarande de skilda beteendena och behoven i olika typer av transporter. En del konceptlösningar har visat sig vara lovande att gå vidare med samtidigt som andra har kunnat sorteras bort.

I arbetspaket 1 *med nulägesanalysen* har erforderliga metoder, körmiljöer och referenskoncept kunnat etableras.

I arbetspaket 2 *rörande körsimulatorn i en effektiv konceptutvecklingsprocess* har körsimulatorverktyget kunnat valideras och processer kunnat dokumenteras som stöd för implementering av olika koncept liksom för utförande av studier.

I arbetspaket 3 *rörande nya förarplatslayouter* har de väsentliga konceptvariablerna kunnat identifieras och användas för att välja de koncept som är mest lovande för respektive fordonstyp. Körsimulatorn har även kunnat användas som demonstrator för att visa upp de utvecklade koncepten.

I arbetspaket 4 *för prediktering av körställningar* har existerande klassificering kunnat knytas till hur förarna satt i de olika körsituationerna. Dessutom har bakgrundsinformation om alternativa modeller samlats in liksom ytterligare kunskap om interna och externa faktorer som påverkar förarnas beteenden.

Resultat finns dokumenterade i en mängd publikationer, och viss spridning av resultat har gjorts genom nationella och internationella konferenser. Många slutsatser har kunnat dras. De viktigaste i korthet är:

- Olika fordonsslag bör ha anpassade förarplatslayouter eftersom körförhållandena är så pass olika.
- Det är en fördel att samtidigt studera flera olika discipliner och aspekter vid utformningen av förarplatser eftersom balansering dem emellan ändå behöver göras (t.ex. fysisk ergonomi vid körning och vila, utformning av förargränssnitt, krocksäkerhet, ljud och vibrationer).
- En konfigurerbar körsimulator utgör ett effektivt verktyg för att kunna utvärdera tidiga koncept under representativa körsituationer.
- Lastbilsförare har ofta en bra förståelse av hänsyn som behöver tas när fordonen utformas. Detta är en källa till kunskap som bör utnyttjas mera.

Baserat på slutsatserna kan även följande huvudsakliga rekommendationer ges till kommande forskningsprojekt:

- Automation med självkörande fordon kommer till stor del att ändra förutsättningarna för hur förare (eller medåkande ”operatörer”) sitter. Kopplingen till reglage och förargränssnitt försvinner eller behöver förändras.
- Det behövs bättre lösningar för att packa de kompletta fordonen så att förutsättningarna för lastbilsförare kan förbättras.
- Körsimulatorer behöver vidareutvecklas vad gäller prestanda (vilket även kan minska risken för simulatorsjuka) och bibliotek med representativa körmiljöer och körfall (som även motsvarar olika behov hos olika marknader).
- Med behovet av att göra simulerade körutvärderingar uppkommer även svårigheter att få tag på ett tillräckligt antal representativa lastbilsförare att använda som testpersoner.
- Automatiserad datahantering och analys inklusive möjlighet till bildbehandling behöver säkerställas som stöd för denna typ av användarstudier i körsimulator.
- Att studera visuellt beteende inklusive ögon-, huvud- och kroppsrörelser är ett nytt forskningsuppslag. Här skulle man även kunna studera totalen av vad olika typer av sikt och sikthjälpmedel kan bidra med (vilket även kan kopplas till minimerade risker för oskyddade trafikanter).

3. Background

The overall layout of the driver environment in trucks has been relatively unchanged for the last 40 years. Minor upgrades have taken place continuously, but the technical development and market requirements have not resulted in any major development steps.

This means that the current driver environments still suffer from some intrinsic flaws:

- Vehicle length regulations limit the available driver position length.
- The visual situation is very difficult with small window openings, complex mirror systems, and vehicle information presented far from the gazing direction on the road ahead.
- Driving postures are far from optimum for drivers of different sizes as there are limitations in adjustment ranges and where main driving controls can be placed.
- The drawback of inappropriate driving postures is aggravated by large and/or harsh cab movements that put high stresses on the bodies of the drivers.

Figure 7. The main packaging conflicts in a heavy vehicle combination and a medium-heavy rigid truck

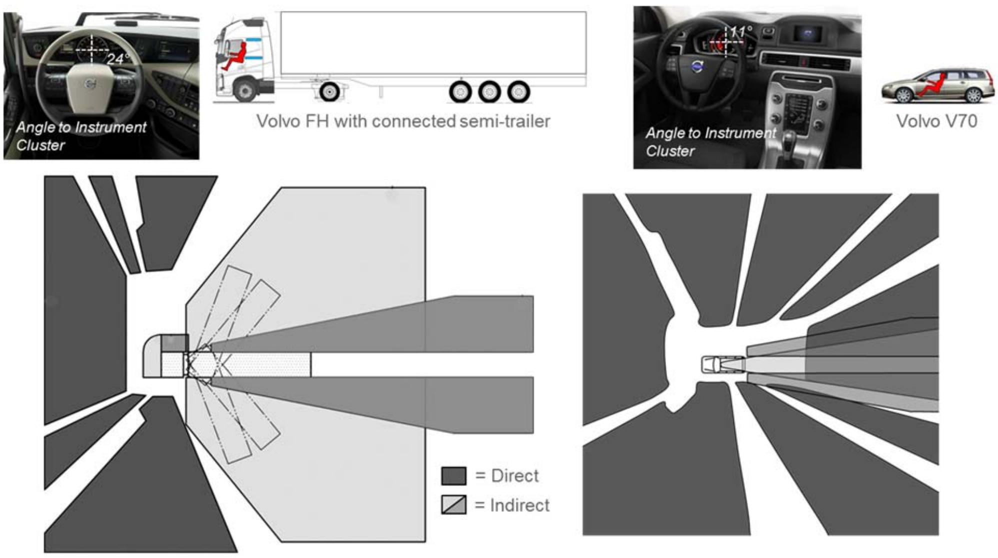


Figure 8. The vision situation in a truck compared to a passenger car – direct / indirect vision as well as the instrument cluster in relation to the horizontal

Figure 9. The influence of vibrations in combination with inappropriate postures

These factors have significantly contributed to incidents, accidents and work related injuries for drivers over the years, and sadly enough also incidents and accidents for other road-users.

The traditional approach to product development of trucks involves a series of expensive prototypes in order to test different configurations in physical mock-ups or on real roads. This means that product development has a bias towards keeping as much of the previous design as possible, in order to reduce cost and risk. The emergence of some virtual development tools has meant that more things can be verified before physical parts become available. There is however limitations to the virtual tool capabilities regarding what aspects can be simulated, as well as to what extent they correspond to the reality. This means that truck development still relies on physical prototypes to a large extent when it comes to verifying how solutions work in actual driving conditions.

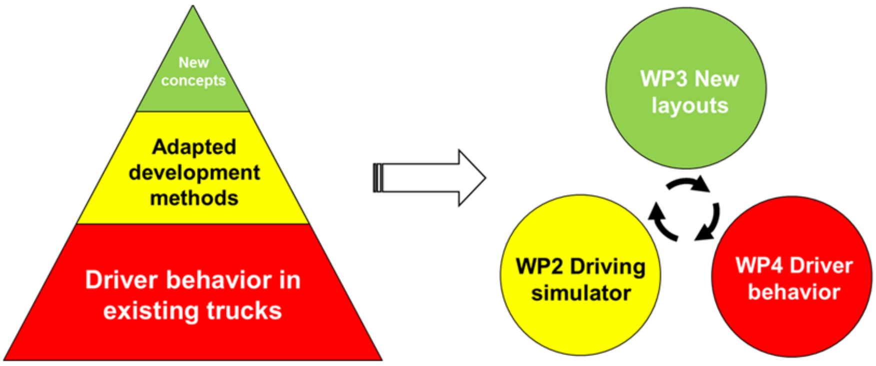


Figure 10. Illustration of traditional versus new approaches to product development involving the driving task – Support for a more agile and integrated way of working

The recent development of driving simulators can however bring about a change to this. In a realistic traffic environment, and with the aid from configurable driving simulators, completely different driver environment layouts can easily be evaluated without the need for resource intensive builds or thousands of kilometres of test driving that would otherwise be necessary. Different layouts and concepts can also be simulated in dangerous traffic situations, without any risks for accidents, for example evaluating visibility in critical driving conditions in urban environments.

New technology is also making it possible to question prevailing “truths” about how a driver environment should be arranged:

- The rapid development of digital camera technology has already started to open the field for additional or replacement viewing aids that – correctly applied – can enhance traffic safety.
- Various driver assistance systems can warn or aid the driver with appropriately placed input.
- Visual information (primary and secondary) can be provided in new locations thanks to new display technologies (e.g. Head Up Displays, touch displays or modern nomadic devices).

Such new technologies are particularly useful to evaluate in a simulator environment, where the location and properties of the visual information can be altered quickly and easily. From the evaluation it can be secured that the technologies will provide additional support instead of making the driving task more complex with connected risk for additional distraction.

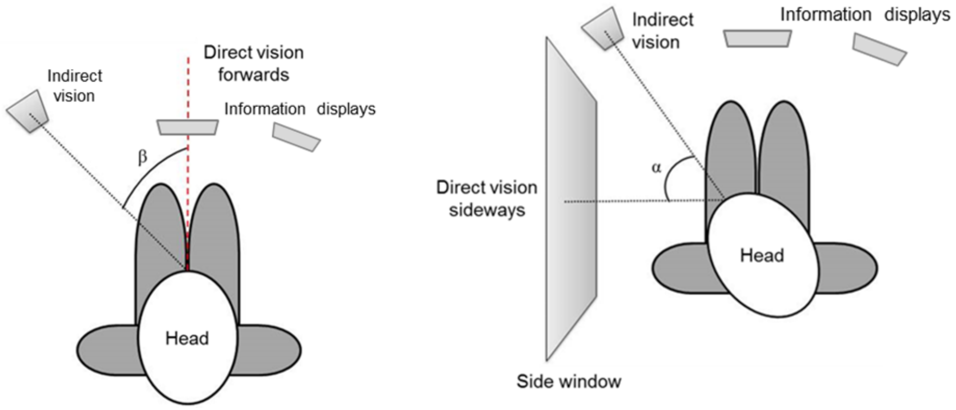


Figure 11. Differences in locations of visual information depending on transport type – relations to gazing direction references

The foundation for this research originates from Volvo’s internal studies of drivers in long-haul, distribution, and construction transport with focus on both driving postures and control usage as well as on how they prioritize different areas of vision input (via window openings and mirror classes). The content for studying postures is inspired by performed and planned studies at University of Michigan in order to establish input for updating the SAE J1516/17 standards for heavy trucks and buses.

The driving simulator that is used as main research tool has already been evaluated during university projects linked to Safe Efficient Transport (VINNOVA). These university projects have covered low speed manoeuvring, alternative vehicle control designs, and eco driving support at higher speeds. The Simovate project (VINNOVA) continued to do detailed validation of the performance of the configurable driving simulator, including a university project investigating future layouts of visual information to reduce cognitive workload.

The methodology to collect driver behaviour and posture data is based on procedures tried in internal studies as well as recent research into driver visual behaviour in actual driving which has been performed at Daimler.

New layouts regarding indirect vision devices are based on the recently developed ISO 16505 that allows replacing rear-view mirrors with Camera Monitor System (CMS). Volvo GTT coordinated the input to ISO 16505 for commercial vehicles, and the project leader of FUDVI provided a chapter “Vision in Commercial Vehicles with Respect to CMS” for the Handbook of Camera Monitor Systems.

Furthermore, Volvo was a leading and active partner in the national competence centre Virtual prototyping and assessment by simulation (ViP), funded by VINNOVA and hosted by Swedish Road Transport Institute (VTI). The objectives of ViP were to extend and improve the competence areas relevant for use of driving simulators: simulator technology, methodology and applications for driver-vehicle interaction and human-machine-interface (HMI). Several results from ViP connect to the needs within this project, e.g. tools for creating traffic environments, methods for recording driver behaviours and knowledge on how to efficiently integrate simulators within the development process.

4. Purpose, research questions and method

Purpose

A seven bullet description of the purpose was provided as part of the project application:

1. The results will provide firm documentation for updating standards and guidelines related to driver positioning and the positioning of safety relevant information, visual information in general, and vision information.
2. The results will support lead time reduction, evaluation results of higher quality, and thereby support for more correct decision making related to concept decisions. There are also environmental and resource benefits related to this, as fewer development loops will be needed and fewer late changes take place that need verification on both test tracks and ordinary roads.
3. The results will form firm evidence of in what direction traditional driver environment layouts should develop to reach new levels of safety and driver comfort.
4. The results regarding posture prediction models will support research into collision safety in two ways. It will provide input to drive standardisation of representative postures for performing impact simulations and tests. It will also help to provide more detailed posture input for impact simulation and tests representing specific driving conditions.
5. The results will support research and integration between simulation of ergonomics, collision safety and vibration comfort. The simulation software programs are all utilizing driver manikin models where results depend on how accurately the manikin postures represent the reality.
6. The results will be used to enhance Swedish expertise in work environment for truck drivers; performing virtual product development; and in utilization of driving simulators as an integrated part of product development.
7. The results will provide means and input data for the Swedish Road Administration to better take into account driver behaviour when planning and developing new roads. The models and input data will also come useful for the Swedish Road Transport Institute (VTI) and other institutes performing automotive research.

All of these seven aspects are answered at least in part. It has however not been possible to investigate and come to the same level of results regarding 4, 5 and 7.

In the case of posture prediction models, a change in direction based on the initial investigations into the state of art, meant focus was rather put on qualitative than quantitative studies. More is outlined about this under “5. Objective” and “6. Results and deliverables”.

In the case of integration between simulations of ergonomics, collision safety and vibration comfort, the outcomes regarding choice of driving postures have opened up for questions to be analysed in relation to coming automated vehicles.

In the case of the link to planning and developing new roads, several traffic environments have been modelled to support the research evaluations. There has also been some shown interest in doing common research around the interaction with Vulnerable Road Users, e.g. as relating to bike promotion organizations (“Cykelfrämjandet” in Swedish) and a coming regulation of proximity vision and detection.

Research questions within performed studies

There are several hypotheses and related research questions that have been investigated during the project. An overview over them as connected to each of the performed studies is provided below.

The main hypotheses of **the field study** were:

H1: “Drivers have different postural behaviour when driving on highways than in inner-city traffic.”

H2: “The drivers are expected to use a more active sitting posture in urban driving environments.”

Figure 12. Alternative driving conditions

The main hypotheses of **the validation study** were:

H1: “Drivers are expected to act similarly in real traffic and in the driving simulator environment when performing ordinary driving tasks.”

H2: “There can be specific situations in low speed manoeuvring and more complex urban situations, where the limitations of a driving simulator results in a changed behaviour.”

The main hypotheses of research study 1 that focused on **alternative ways of providing indirect vision** were:

H1: “There is a difference in postural behaviour when driving with rear-view mirrors compared to when driving with camera monitor systems”

H2: “The drivers will choose more extreme preferred postures as well as make more repositions when driving in an urban environment compared to highway driving.”

H3: “The drivers of a heavy vehicle combination make more repositions compared to drivers of a smaller medium-heavy vehicle without connected trailer when driving in an urban environment.”

Figure 13. Main concepts in research study 1 (heavy vehicle combination above and medium-heavy truck below)

The main hypotheses of research study 2 that explored **alternative locations for different types of visual information** were:

H1: "The drivers of a heavy vehicle combination have less active head movements when driving with a camera monitor system with displays placed closer to the driver compared to when the displays are placed on the A-pillars."

H2: "The drivers of a heavy vehicle combination feel freer to adjust their steering wheel in a more preferable position when driving with a head up display instead of an instrument cluster."

H3: "The drivers of a heavy vehicle combination do not have to take their focus from the road in order to read the information on an instrument cluster when driving with a head up display."

H4: "The drivers of a heavy vehicle combination find a lane change support helpful and comfortable while driving."

H5: "The medium-heavy distribution drivers feel freer to adjust their steering wheel in a more preferable position when the instrument cluster is placed outside the steering wheel."

H6: "The medium-heavy distribution drivers have more active head movements when driving with rear-view mirrors compared to when driving with camera monitor systems."

H7: "The medium-heavy distribution drivers find a rear proximity support helpful and comfortable to better determine the truck position when reversing."

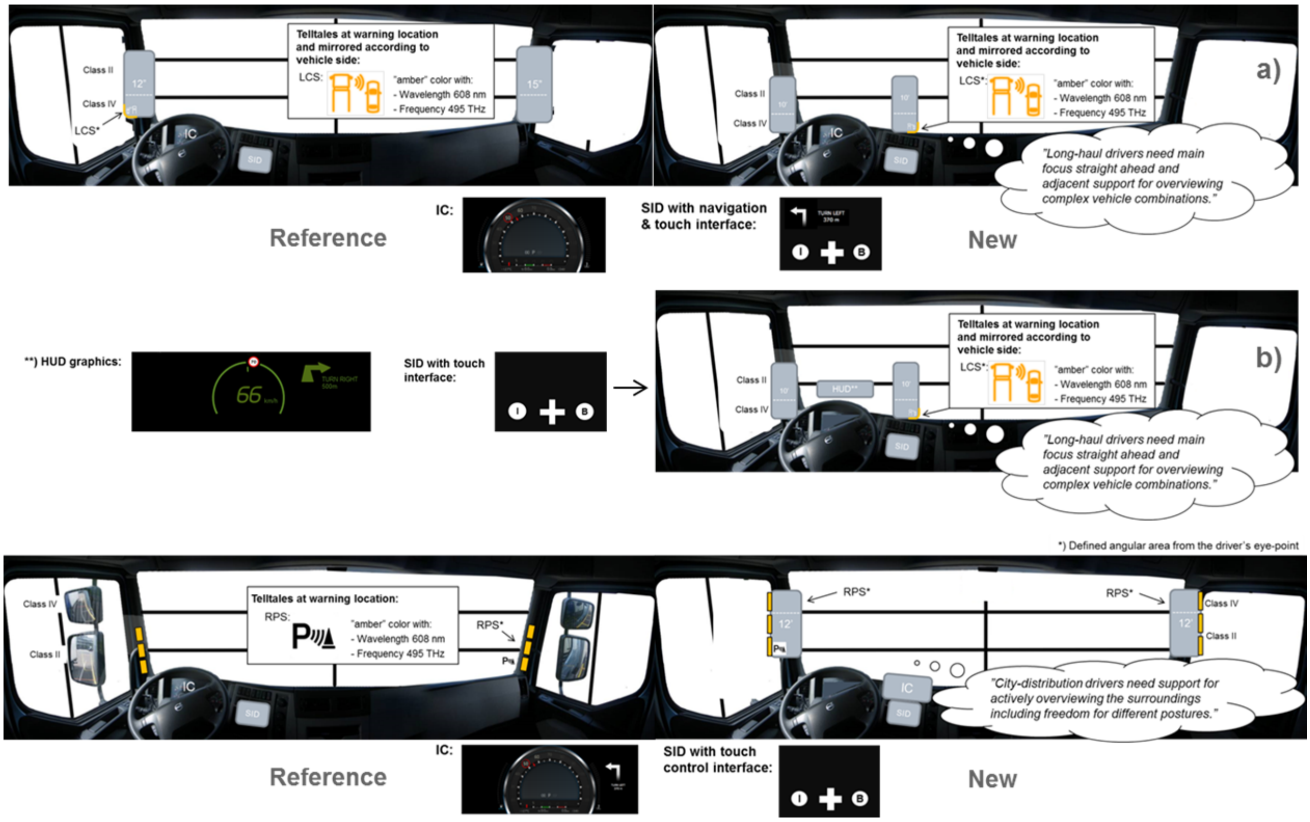


Figure 13. Main concepts in research study 2 – heavy vehicle combination (above) and medium-heavy distribution vehicle (below)

The main hypotheses of research study 3 that investigated changed behaviours based on **visual information layouts adapted to one transport type** were:

H1: "Drivers of a heavy vehicle combination will experience benefits from having visual information closer to the main viewing direction onto the road ahead."

H2: "The drivers of a heavy vehicle combination feel freer to adjust their steering wheel in a more preferable position when driving with a head up display instead of an instrument cluster."

H3: "The drivers of a heavy vehicle combination have less active head movements and gazing behaviour when driving with a camera monitor system with displays placed closer to the driver compared to when driving with traditional rear-view mirrors."

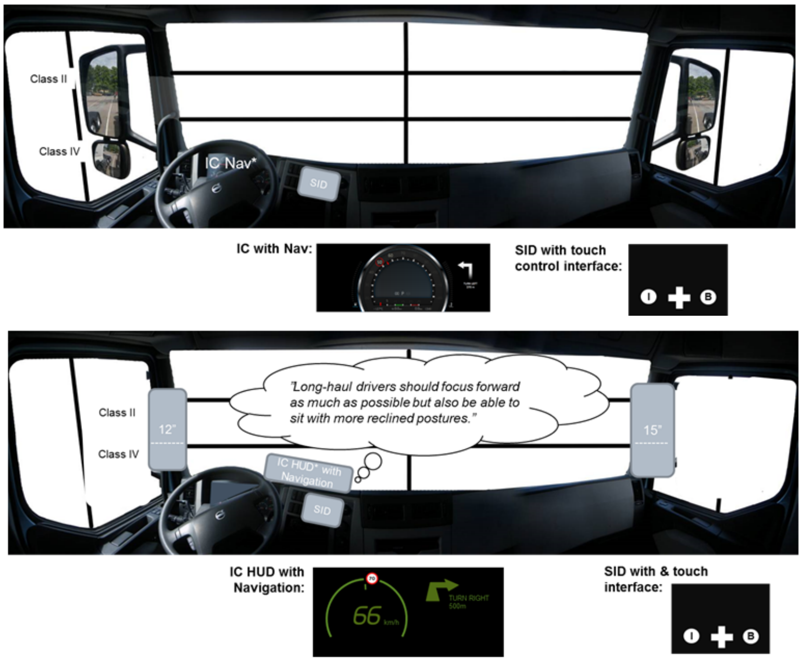


Figure 14. Main concepts in research study 3 – reference (above) and new (below)

Methods

The methods used for performing the research have been successively updated and made more complete during the project. They concern two main method categories. The first category covers methods needed to perform studies of driver behaviour. The second category covers development methods.

The following six methods have been developed in order to study driver behaviour:

1. Method for driver observations on road with support from a GPS navigator
2. Method for studies in a driving simulator with support from an artificial GPS navigator
3. Method for studies of driving postures and postural behaviour in a driving simulator
4. Method to analyse postures from films
5. Method to analyse head movements based on sensor data
6. Method to analyse gazing behaviour based on eye-tracking data

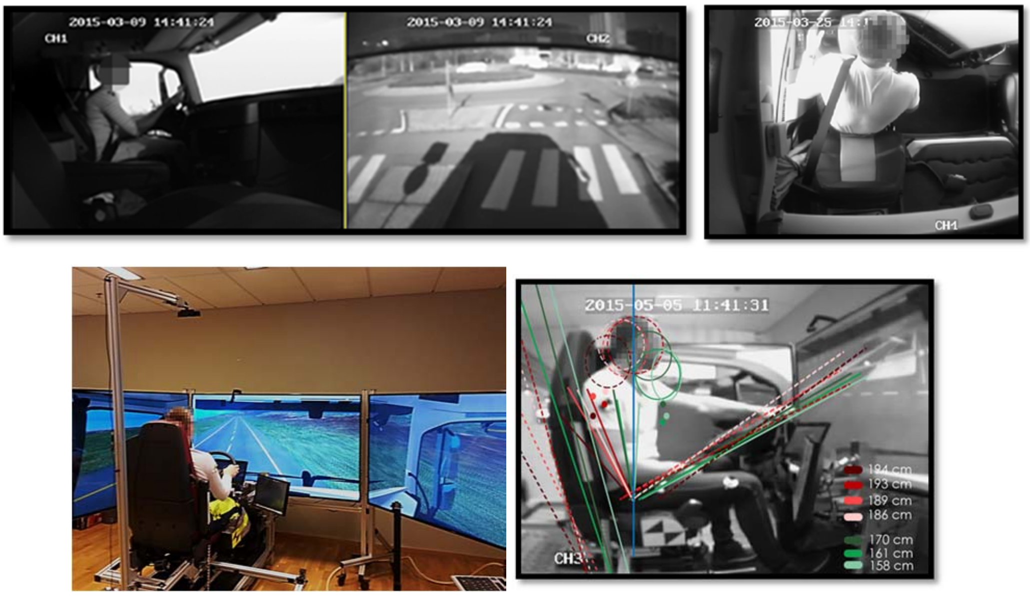


Figure 15. Methods to evaluate driver behaviour – real truck (above) and driving simulator (below)

The following development methods have been prepared:

1. Method for implementing alternative CAD concepts that represent different vehicle types into a configurable driving simulator
2. Method for implementing alternative HMI concepts regarding timing and placement of information into a configurable driving simulator
3. Method for varying seat and steering wheel adjustment ranges in a configurable driving simulator
4. Method for combining physical and virtual QR-codes to support eye-tracking a configurable driving simulator
5. Method to define and represent alternative driving situations and critical driving conditions in a configurable driving simulator
6. Method to order software updates to implement new concepts into the configurable driving simulator

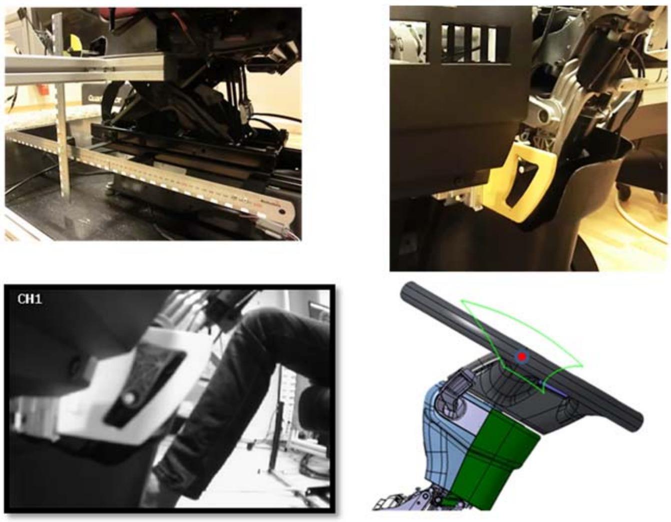


Figure 16. Development methods – seat and steering wheel adjustments

5. Objective

Original objectives

The primary goal of the project has been to develop new, preferred and optimized layouts for driver positions and visual information to increase safety (direct / indirect vision as well as driver assistance) and well-being (reduced physical and mental loads). These new layouts are to support driving postures confirmed as beneficial for both city distribution and long-haul transport tasks regarding the relation between seat, steering wheel, pedals and visual information. The proof of the new layouts is to be provided from studies of both normal and critical driving situations.

Secondary goals of the project have been to establish reliable posture prediction models and to define an efficient integration of driving simulators in the concept development process.

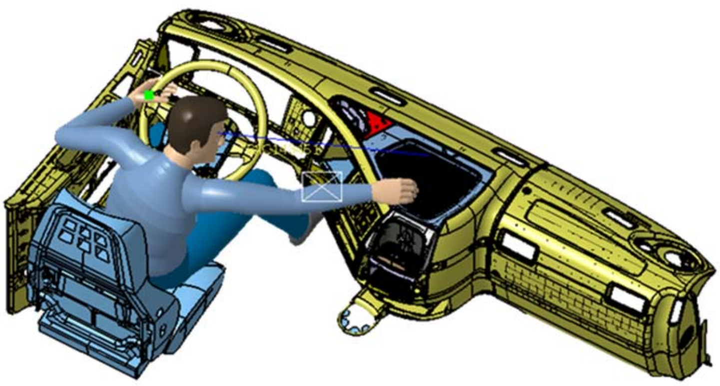


Figure 17. Manikin example from an ergonomics CAD simulation tool

The posture prediction models should provide more reliable input than the existing standards and be implemented into existing ergonomics CAD simulation tools for virtual development. These posture prediction models should also take into account the rapidly changing truck driver population with an increasing number of women, younger as well as older drivers. Reliable posture prediction models are lacking to a great extent as less research is made into heavy vehicles than what has been possible to accomplish for passenger cars.

Driving simulators need to be well integrated in the concept development process to secure efficient and successful usage. Questions like how studies are prepared, how data is collected, and how data analysis is turned into reliable results should be answered. The corresponding answers would form procedures to follow, but can also highlight potential improvement areas.

The results corresponding to these goals were to be directly applicable to Medium-Heavy and Heavy Cab Over Engine (COE) trucks, but they should also be relevant for other commercial vehicles used on road. The COE trucks form the dominant truck design layout in most markets outside North America (where conventional “bonneted” trucks are more common).

Main deviations

The state-of-art analysis revealed that a gap in research knowledge existed regarding how truck drivers’ motion patterns and visual behaviour are influenced by external factors. This meant that the original intention of investigating how internal factors influence truck driving postures was dropped.

Figure 18. Internal and external factors related to the driving conditions

It showed also to be hard to get in touch with a sufficient number of experienced truck drivers that covered a larger anthropometric portion of the general truck driver population. This resulted in that the research studies had to become more qualitative instead of quantitative with lower statistical significance levels than originally intended.

Finally, the needs for continued development of the configurable driving simulator tool meant that sharp research studies had to be started later than planned. This has limited how far the results have reached.

6. Results and deliverables

General results

It has qualitatively been proven that:

- Truck drivers sit and behave differently in different types of transport and under influence from different events and driving conditions.
- There are both internal and external influences on truck drivers' postural and driving behaviour. The internal influences come from different locations of the main types of visual information. The external influences come from different driving conditions and situations.
- Alternative layouts for visual information and the drivers' location within a vehicle influence the work environment and driving safety in different ways depending on if the vehicle type is mainly developed for use in city traffic or long-haul traffic.
- It has been proven that it is feasible to use a configurable driving simulator at early project stages to facilitate evaluation of radically different concepts of driver environments.
- It has been possible to secure results that are valid both for medium-heavy and heavy cab over engine trucks used in the European markets. Results cover the most common vehicle types of a rigid truck with box-type superstructure and the vehicle combination of a truck tractor with connected semi-trailer.

In addition to these general results, the results from each Work Package are explained below. These are based on the listed planned deliverables from the original project application.

Work Package 1: State of the art for today's product solutions & methods for driver behaviour studies

It has been secured that the majority of typical heavy and medium-heavy trucks are covered thanks to the choice to focus on the high volume truck variants of a heavy truck tractor with connected semi-trailer and a medium-heavy rigid truck.

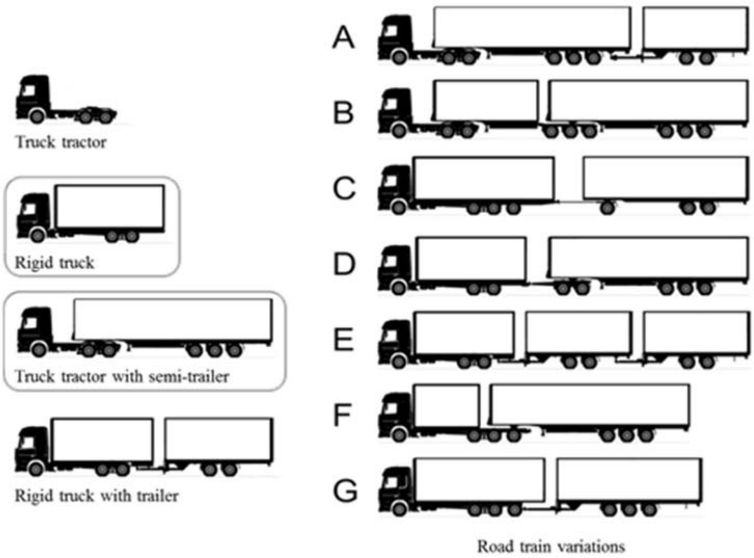
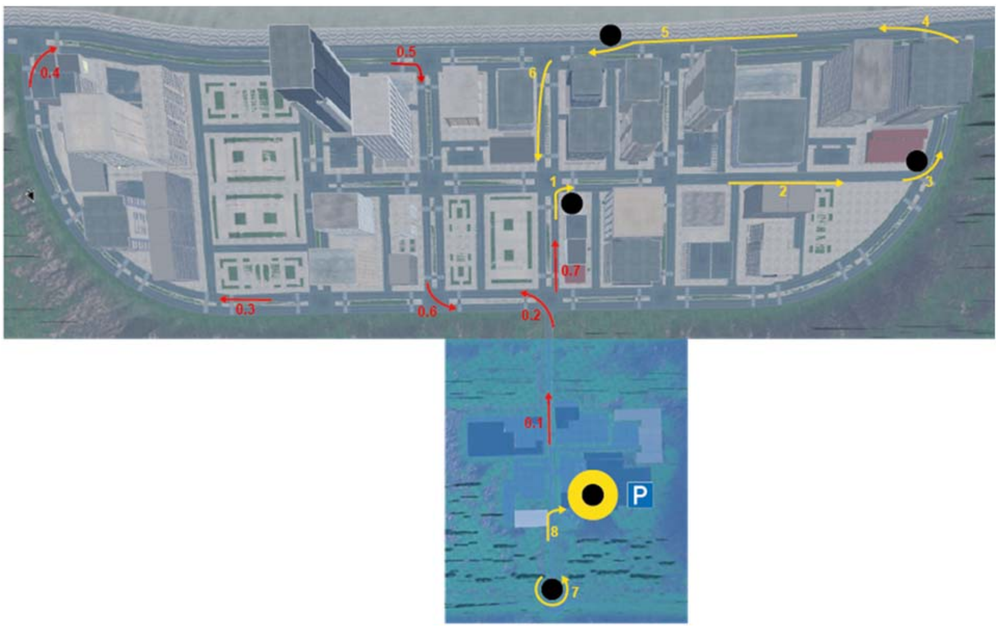


Figure 19. Included truck variants compared to others

The existing layouts for visual information have been identified for use as references to the new concepts that were developed. These layouts cover traditional rear-view mirrors, instrument cluster for vehicle information, and secondary displays for secondary information like navigation.

The necessary traffic situations for performing the studies have been defined. These are city environments with other road users and critical driving situations like lane changes, tight turns and low speed manoeuvres; highway driving with critical driving situations like entering the highway; and motorway driving with critical driving situations like overtaking situations.



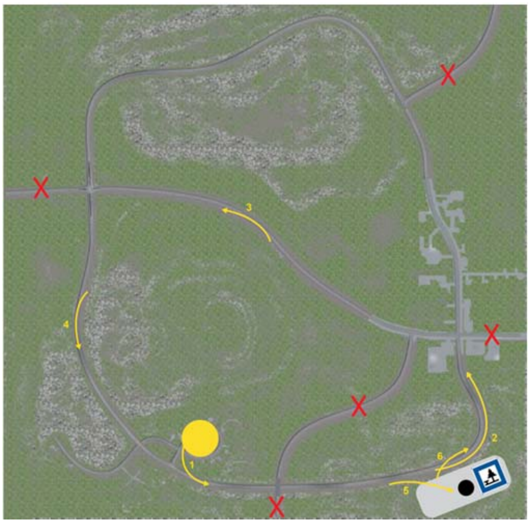


Figure 20. Included traffic environments – top views of city (above) and highway (below)

Different methods for analysis of driving postures and driver behaviour have been studied and developed. Examples of these are questionnaires to use in interviews; observation and analysis via video films that can be supported by image processing; use of sensor data to analyse head movements; as well as eye-tracking to study the vision behaviour of drivers.

Work Package 2: Driving simulator integration within an efficient concept development process

The use of a configurable driving simulator has been validated against driving a real truck on public roads. A significant reduction in product development lead time has been proven. This comes both from a big cut in the time needed when preparing the concepts to be evaluated, and from that the time periods for doing the actual evaluations become much shorter.

Results have been shared internally at Volvo GTT and Chalmers. Dissemination has also taken place externally at Transport Forum 2016 and 2017 as well as at the International Conference on Applied Human Factors and Ergonomics 2015 and the Driving Simulation Conference Europe in 2016.

Figure 21. Shared documentation at conferences – presentation materials and posters

Process documentation and method descriptions have been prepared. Key examples are how driver environment concepts are implemented into the driving simulator tool (both in the form of CAD geometries and HMI prototypes); how studies are performed in a configurable driving simulator; and how data from a driving simulator study is analysed into useful results.

Work Package 3: Driver position layouts that support safety and driver health

It has been possible to identify and study main concept variables including the relation in between them and how they influence how well drivers can perform the driving task.

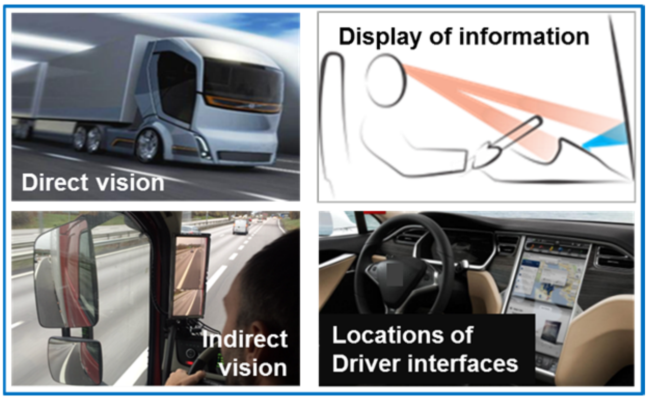


Figure 22. Key concept variables that have been covered

Conclusions have been made regarding benefits and drawbacks of the new concepts for placing and providing visual information in relation to the existing reference concepts.

The driving simulator has provided the intended function of being a demonstrator for different product types and transport segments when involving truck drivers of different sizes and previous driving experiences.

Work Package 4: Posture prediction models representing dynamic driving situations

It has been possible to connect the existing classes of driving postures to the respective transport segments and critical driving conditions.

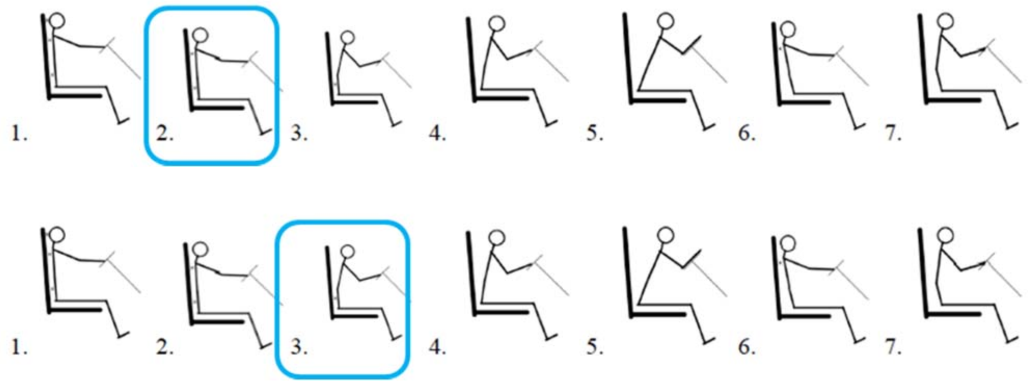


Figure 23. Main driving postures used in the different transport segments – long-haul (above) and city distribution (below)

Alternative bases for prediction models for driving postures have been analysed. A remaining knowledge gap was identified and investigated regarding how external factors like driving conditions influence the postural behaviour of truck drivers.

A final prediction model for driving postures has not been possible to establish. Instead it has been possible to identify influences that should be used as input for establishing such a model.

Deviations from intended results and main reasons behind them

There are some planned results that the project has not been able to deliver. These are:

- Models for predicting driver postures
- Models for positioning visual information
- Statistically proven results regarding the dependence between driver sizes and influence from internal factors like provided adjustment ranges and where information is placed.

The main reasons behind these deviations are:

- The scope of the project has been too big compared to the available project budget.

- It has been hard to gather a sufficient number of experienced truck drivers with a large enough anthropometric variation according to the initial project ambitions.
- The configurable driving simulator that formed the main research tool needed more additional development and adaptation than expected in order to cover the full needs within the research project.
- The direction of the project was changed from influence of internal factors on driving postures and visual information to influence from external factors on postural and visual behaviour. This lead to adaptations of the planned activities.

7. Dissemination and publications

7.1 Dissemination

How are the project results planned to be used and disseminated?	Mark with X	Comment
Increase knowledge in the field	X	This is valid for all three of WP2 Driving simulator usage, WP3 Driver position layouts & display of visual information, and WP4 Knowledge about postures.
Be passed on to other advanced technological development projects	X	Outcomes regarding new ways to present and combine visual information forms useful input. There are also some things learnt that fit well into the research into future automated vehicles.
Be passed on to product development projects	X	WP2 Driving simulator usage and WP3 Driver position layouts & display of visual information form input to other projects.
Introduced on the market		
Used in investigations / regulatory / licensing / political decisions	X	Things that have been learnt about driver position layouts and how visual information can be displayed and combined form input to standardization work that can also be used as input for coming regulations.

7.2 Publications

Here are the listed publications that have resulted from the project. These are both in the form of academic papers, presentation materials and posters at conferences, and printed standards and handbooks that have been supported by the research.

Koohnavard, T. (2017)**** Optimized layout of indirect vision and main vehicle information in an articulated vehicle combination for long-haul transports – A driving simulator study of consequences for truck drivers' postural and visual behaviour, Part III. Department of Product and Production Development, Division of Design and Human Factors, Chalmers University of Technology, Gothenburg, Sweden.

Koohnavard, T. (2017)*** Alternative locations for indirect vision and main vehicle information in highway and urban transports – A driving simulator study of consequences for truck drivers' postural and visual behaviour, Part II. Department of Product and Production Development, Division of Design and Human Factors, Chalmers University of Technology, Gothenburg, Sweden.

Koohnavard, T. (2017)** Driving with Rear-view Mirrors or Camera Monitor Systems - A driving simulator study of consequences for truck drivers' postural and visual behaviour, Part I. Department of Product and Production Development, Division of Design and Human Factors, Chalmers University of Technology, Gothenburg, Sweden.

Koohnavard, T. (2017) [WP4] Driver behavior in long-haul and distribution trucks based on external factors. Transportforum 2017, Swedish Road & Transport Research Institute (VTI), Linköping, Sweden.

Blomdahl, P. (2017) [WP3] Future applications of new technology in the layout of driver positions in trucks. Transportforum 2017, Swedish Road & Transport Research Institute (VTI), Linköping, Sweden.

Saluäär, D. (2017) [WP2] Use of driving simulators in early phases of product development – technical and method-related challenges. Transportforum 2017, Swedish Road & Transport Research Institute (VTI), Linköping, Sweden.

Koohnavard, T. et al. (2016) Validation of a Movable Truck Driving Simulation Tool – Comparing Truck Drivers' Sitting Postures in a Simulator and in Field Truck Driving. Driving Simulation [VR] Conference 2016 Europe, Paris, France.

Blomdahl, P., Terzis, A. et al., (2016) [WP3] [WP4] Vision in Commercial Vehicles with Respect to Camera Monitor Systems, Handbook of Camera Monitor Systems, The Automotive Mirror-Replacement Technology based on ISO 16505. Springer International Publishing AG, Switzerland

Sylvén, J., Viðarsdóttir, K.L. (2016) [WP3] Cockpit Layouts for Different Transport Segments. Department of Product and Production Development, Chalmers University of Technology, Gothenburg, Sweden.

Knagenhjelm, J., Olsson, A. (2016) [WP4] Recognizing Postures and Head Movements from Video Sequences. Department of Mathematical Sciences, Gothenburg University and Chalmers University of Technology, Gothenburg, Sweden.

Blomdahl, P. (2016) [WP2] [WP3] [WP4] Visual & Physical Ergonomics in Heavy Vehicles – Realities & Future Needs. Transportforum 2016, Swedish Road & Transport Research Institute (VTI), Linköping, Sweden.

Karlsson, MA., Ohlson, E., Osvalder, A.L. (2015) [WP4] Driving postures, postural changes and influencing factors – A literature study. Division of Design and Human Factors, Chalmers University of Technology, Gothenburg, Sweden.

Ohlson, E. (2015)* Field study analysis. Division of Design and Human Factors, Chalmers University of Technology, Gothenburg, Sweden.

Ohlson, E., Osvalder, A.L. (2015)* Truck drivers' postural and visual behavior – An explorative study to understand expectations on current designs and future vehicles. 6th International Conference on Applied Human Factors and Ergonomics (AHFE 2015) and the Affiliated Conferences, Chalmers University of Technology, Gothenburg, Sweden.

Chatzopoulou, E., Vlassopoulou, K. (2015) [WP4] Comfortable driving in the future. Department of Product and Production Development, Division of Design and Human Factors, Chalmers University of Technology, Gothenburg, Sweden.

International Organisation for Standardisation (2015) [WP3] ISO 16505 – Road vehicles – Ergonomic and performance aspects of Camera Monitor Systems – Requirements and test procedures. ISO/TC 22 Road vehicles, Subcommittee SC 17 Visibility, ISO, Geneva, Switzerland.

UMIT Research Lab (2014) [WP2] Simovate – Innovative product and process development through simulation. Department of Physics, Faculty of Science and Technology, Umeå University, Sweden.

*) This corresponds to the Field study within FUDVI.

**) This corresponds to Research study 1 within FUDVI.

***) This corresponds to Research study 2 within FUDVI.

****) This corresponds to Research study 3 within FUDVI.

[WP1]) This is related to WP1 “State of the art for today’s product solutions & methods for driver behavior studies” in FUDVI.

[WP2]) This is related to WP2 “Driving simulator integration within an efficient concept development process” in FUDVI.

[WP3]) This is related to WP3 “Driver position layouts that support safety and driver health” in FUDVI.

[WP4]) This is related to WP4 “Posture prediction models representing dynamic driving situations” in FUDVI.

8. Conclusions and future research

General conclusions regarding the project approach

It has been interesting to run this project. In relation to the three topics that have been covered, one continue to ask:

"Why are driver environments in trucks so traditional?"

"Can this be changed thanks to new technologies?"

"What approaches are needed make this change?"

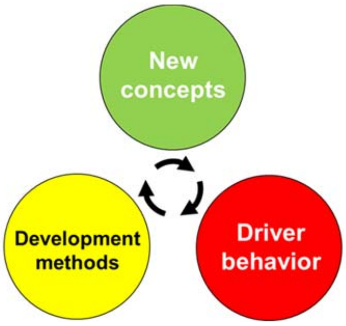


Figure 24. The need to work simultaneously with New development methods, New concepts and New ways to evaluate driver behaviour

A general conclusion is that priorities and needs are different in the main different transport segments like long-haul or city distribution transports. Some limitations that will need continued work outside the scope of this project are the general packaging problems together with existing dimension regulations and the fact that trucks, superstructures and semi-trailers come from different suppliers. This means it becomes harder to get the development going towards holistic and more optimized solutions.

The project results landed in the greatly different driving conditions for a long-haul vehicle compared to a city distribution vehicle.

Figure 25. Typical driving conditions of a long-haul vehicle

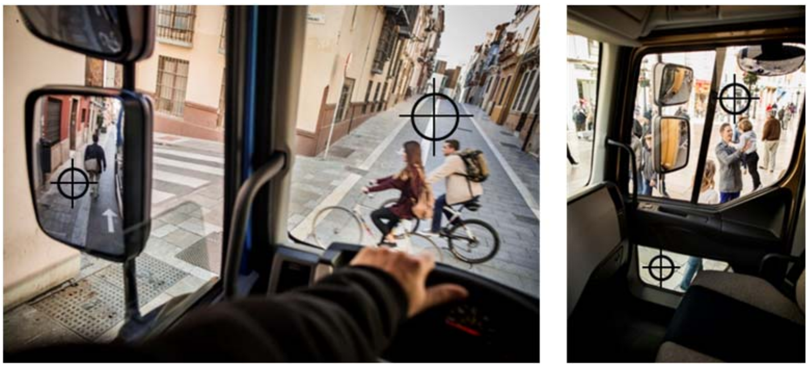


Figure 26. Typical driving conditions of a city distribution vehicle

From the difficult packaging conditions in trucks at the same time as the driver environments need to support different activities of providing safety as well as comfort both while driving, resting and working, it is clear that more integrated approaches are beneficial where several aspects and disciplines should be addressed together and not individually one by one. By such an approach more balanced solutions can be achieved with priorities according to the needs of the drivers as the main users of trucks.

Figure 27. Work with related disciplines

An additional conclusion is that the truck drivers often understand well the difficult prioritizations as well as the underlying considerations that need to be made to achieve the best solutions to meet their needs. This speaks for that truck drivers should be involved to a greater extent when evaluating new solutions that influence their working life. We do not need to be afraid to try out new approaches together with truck drivers.

Especially when new technologies allow for major changes of how vehicles are designed, it is important that we have the tools to reconsider their actual functionalities with fresh eyes. This project has tried to integrate studies of altered preconditions for physical ergonomics, visibility, and HMI solutions in actual driving conditions. Thanks to the configurable driving simulator tool, this becomes possible at early development stages.

General learning from performing the project

Some general learning from performing the project is listed below:

- It has shown hard to make initial plans and plan ahead when a research project investigates new fields and is dependent on new methods that are not completely established in advance.
- A tight cooperation between the project members from industry and the academy is very important.
- Responsibility splits among different project roles have to be sorted out both on the general level between different project parties, but also on a detailed level (e.g. regarding who does what when planning, preparing and performing driving simulator studies).
- Some level of hick-up results if key persons are replaced during a project.
- There is a need for planned regular follow-up meetings, especially if project members do not have the research project as their main task.
- There can often be a difference in focus between the industry, that tends to emphasize product development and applied science, and the academy, that tends to emphasize scientific stringency and basic research.
- The general approach for this project of simultaneously researching an alternative development process, product concepts, and new methodologies, have resulted in many dependencies that can cause delays in comparison with an original time-plan.
- For this type of research, there is a lack of more automated analysis tools to reduce the amount of manual work and facilitate the handling of larger amounts of data. With the on-going developments of e.g. "internet of things" and "big data" management, there are for sure both opportunities and tools to make life easier for the researchers.

WP1 State of the art for today's product solutions & methods for driver behaviour studies – Conclusions and Recommendations

State of the art was both investigated for product solutions and methods that would be used during the research project.

For product solutions, the following findings were made:

- The main influential factors on driving postures and postural change have been identified via a thorough literature study.
- There is a major conflict and compromise between the driver position length that drivers would like to have and the width of a lower bunk to support comfortable sleeping. The total cab length has to be shared between these different needs, and as it is today, already medium-size truck drivers can complain about that they cannot reverse the seat enough.

- Seat belts form issues for certain driver sizes and influence how they sit (e.g. that the belt does not locate comfortably around the neck of a shorter driver, which can mean that the driver subconsciously bends away from it into an askew posture).
- The connection to main controls and interfaces that is necessary during manual driving limits the way truck drivers can sit. This has been a conscious included limitation within this research project. However, in the light of automated vehicles, it would be interesting to start up continued research into how drivers vary their postures if they do not need to be connected to the same degree or at all.
- There is often a general thinking integrated into the solutions of an OEM to achieve the beneficial postures, best traffic safety, etc. based on evidence and historical experience. It can be interesting to investigate if there is a difference between these recommended driving postures and the way truck drivers sit if they are completely free to adjust themselves as they want.

Regarding methods, the following conclusions have been made:

- It is possible to come quite far by only using questionnaires when starting research into what governs how drivers sit when driving. A study has been made where results from use of questionnaires were compared to results from video observations in actual driving, and video observations in a driving simulator.
- Validation of the configurable driving simulator tool has taken place to establish that drivers behave similarly as in real driving conditions when comparing preferred postures under corresponding driving conditions. The extreme movements of drivers are however smaller. This is probably a result from that a fixed platform driving simulator was used which means drivers do not get influenced by external forces. At this same time this can help to achieve more clear-cut results as vibrations do not form additional noise to how the drivers behave.
- It is important that the driving simulator is flexible enough in its design so it does not influence the concepts that are intended to be evaluated.

WP2 Driving simulator integration within an efficient concept development process – Conclusions and Recommendations

The use of simulation techniques is a natural part of today’s development processes. A driving simulator means an actual truck driver can perform a simulated driving task at the same time as a new solution can be tested in a relevant driving situation. The benefits from this are:

- Shorter lead-times with lower development cost
- Lower risk for studying and testing new, more advanced solutions
- Opportunities to explore a larger number of concepts before selecting one of them

The configurable driving simulator used in this project holds several benefits that match the intended development approach:

- It allows for flexible definition of vehicle concepts (including geometrical layouts, alternative adjustment ranges, as well as HMI prototyping).
- A large percentage of virtual concept representations can be included together with physical parts.
- The surrounding visualization of the vehicle concept and traffic environment means test drivers are properly immersed into the driving task.
- Updates of virtual views based on head-tracking reflect the way it works in reality.
- Logged data from the simulations in a laboratory environment get available for analysis according to what aspects are under study (head movements, camera views, interaction history with controls, and the vehicle positioning on the roads).
- The simulator platform is still small enough to be moved between different parts in the development organization or in order to get to where truck drivers can participate in studies.

Figure 28. Configurable driving simulator used within the project.

There are however remaining issues that would improve the use of the driving simulator tool further. The following five topics should be addressed in coming research:

1. Realism of simulator (e.g. performance and experienced distances; feeling of steering, brake and speed awareness)
2. Managing & minimizing simulator sickness
3. Availability of representative end users (i.e. experienced truck drivers)
4. Modularity and re-use of road environments and traffic scenarios (e.g. open interfaces, model libraries, common file formats and standardization)
5. Data management – Automatic analysis, continuous growth of knowledge in data base from previous studies, image processing and use of sensors

WP3 Driver position layouts that support safety and driver health – Conclusions and Recommendations

From the beginning of the project it was intended that mainly internal factors should be altered to see how they influenced drivers' sitting postures and their ability to take in the complete information about the driving situation. However, the background studies in WP1 to establish the state of the art told the knowledge gap existed elsewhere.

From this exploration phase came the added focus on how external factors influence truck drivers' postural and visual behaviours. As a consequence of this, the conceptual variations got more limited to where visual information can be provided. Still all main kinds of visual information were covered: direct vision, indirect vision, vehicle information, secondary information and visual warnings.

The conceptual variations that have been explored during the project are:

- The sideways location of the driver within the vehicle
- Alternative ways of providing indirect vision views (both traditional mirrors and by camera monitor systems)
- Alternative locations for the vehicle information (via differently located instrument clusters or as head up display)
- Alternative locations for indirect vision views (thanks to camera monitor systems that break the physical limitations of mirror surfaces)
- Integration of visual lane change warnings or rear proximity warnings in addition to the indirect vision views (as facilitated by camera monitor systems)
- Touch display as a generic development tool for alternative HMIs

Figure 29. Some concepts that have been evaluated

The general conclusions from these concept evaluations are that:

- Alternative layouts can give specific benefits in different transport segments. That is, it is not for sure that the arrangement of visual information should follow the same standardized pattern in all transport segments.
- Truck drivers are to a great extent aware of the fundamental principles behind and consequences from different driver environment layouts. This means that even new layouts that break away from the traditional norm can be accepted if they are based on sound reasoning.
- Technologies that increase the flexibility of how the driver environments can be arranged will help to meet the needs from several currently growing trends (ranging from traffic congestion, via V2X facilitated by connectivity, to the move towards automated vehicles).
- The importance of making layouts that support natural human behaviour has been investigated. It has both been investigated what happens if indirect vision views are presented in another location in relation to the driver than they actually appear (e.g. so that left is not left any longer), and what happens if indirect vision views are not shown in connection with the direct vision views useful in the same driving conditions. In both these cases it was clearly shown that breaking away from what is natural creates experienced safety risks and lower precision when manoeuvring.

- Truck drivers are much more dependent on indirect vision in comparison to direct vision than passenger car drivers are. This has to be remembered when indirect vision views are altered.
- There are alternative layouts for the different types of visual information that can greatly help to reduce distraction.
- The long-haul drivers preferred a layout with camera monitor systems on the A-pillars and a head up display for vehicle and secondary information.
- The distribution drivers preferred more traditional layouts with rear-view mirrors in current locations and an instrument cluster behind the steering wheel.

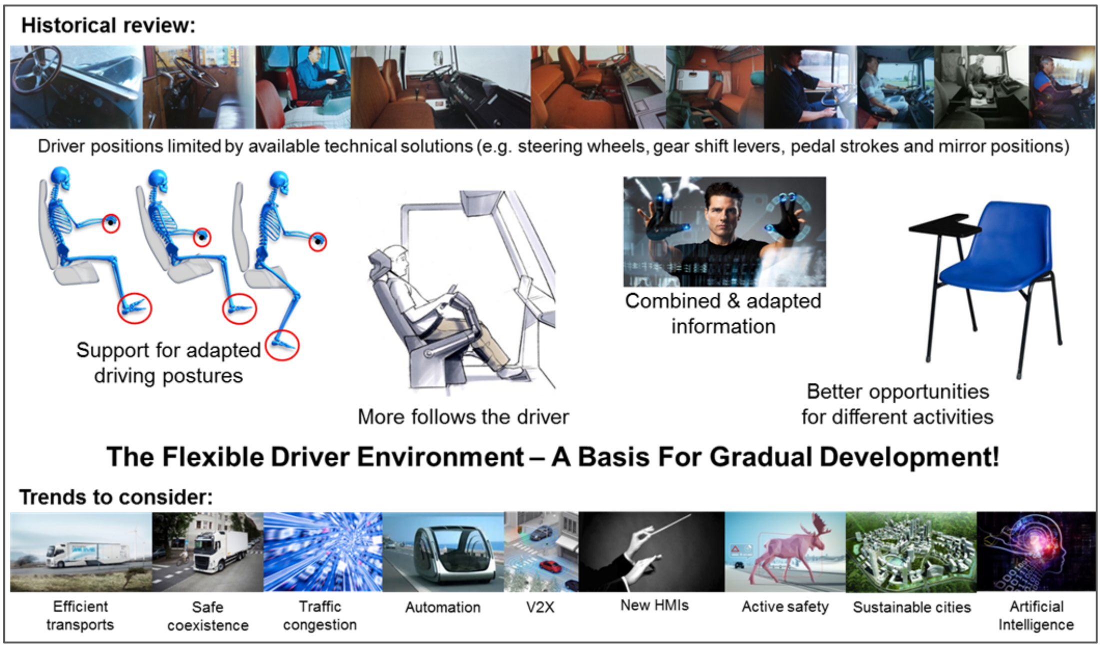


Figure 30. Flexibility in solutions to support gradual development

For detailed solutions it has been interesting to see that:

- The sideways location of the driver needs to be handled with care. When driving in ordinary urban conditions, a more centred driver location leads to manoeuvring issues, and additional vision aids are needed (e.g. close-up side views on both sides of the vehicle).
- Camera monitor systems are preferred over traditional rear-view mirrors based on the functional layout benefits they give with reduced blind-spots and more flexible positioning opportunities.
- Drivers are very sensitive to additional installations that protrude above the instrument panel as these block critical vision under ordinary driving conditions.
- An instrument cluster installed outside of the steering wheel (instead of behind it) showed benefits in city driving.
- Head up display locations above the steering wheel work fine and are appreciated with specific benefits during long-haul driving (where the lowered distraction opportunities

from smaller changes in gazing direction have also been possible to quantify geometrically in relation to passenger car circumstances).

- Rear proximity support in addition to the indirect vision views was appreciated.
- Lane change warnings should only be visual and tuned to only appear when judged as needed.
- It was possible to perform low speed manoeuvres in city environments without having indirect close-up vision views. This can probably tell that these views in existing vehicles are not that helpful and that they could be improved.
- Visual information influences what steering wheel location drivers are selecting in case some of the information gets hidden.
- Head up displays can get obstructed by the steering wheel, so it is necessary to secure visibility of the full display area for all driver sizes and sitting postures or that individual adjustments are secured to reposition the display image.
- User interfaces that are easy to use from good reach conditions and straightforward operation can be less sensitive to if general mapping principles are fully supported (this was the case for the tried interface for adjusting indirect vision views).

There are also remaining issues that should be studied in coming research:

- The pretty large steering wheel diameters in current trucks limit the opportunities for alternative layouts for visual information and also the postures truck drivers are able to choose.
- The combination of indirect rear-view, indirect close-up, direct vision and use of proximity warnings should be investigated further.
- The lack of automatic analysis tools limits the number of alternative concepts and respondents that can actually be studied.

WP4 Posture prediction model(s) representing dynamic driving situations – Conclusions and Recommendations

Figure 31. Typical urban driving situation with a big influence from visibility.

Some general conclusions and recommendations from this Work Package are:

- Differences in traffic environments have a big impact on the postural behaviour of truck drivers. Hence the choice to focus on external factors was correct.
- Drivers did not vary their driving postures much depending on concepts. It seems they have a general driver position they are used to.
- It is necessary to investigate how a wider range and bigger number of truck drivers can become available for this type of research. A higher number of test persons are needed to increase confidence in the conclusions that can be made. It would also help to identify individual variations that could form similar patterns within subgroups of drivers.
- More consideration should be put on representative traffic environments that can be tuned even more to the typical usages of different truck types. The random variation to avoid predictability in events should also be developed further. This is specifically important if the main purpose is to investigate effects on driver behaviour from external factors.
- The visual behaviour of truck drivers, including eye-movements, head movements and posture changes in order to search for visual information according to driving condition, should be the field of an own research project. With secured tools for more automatic analysis (e.g. thanks to image processing and computer learning) it would be possible to make effective studies to draw stronger conclusions regarding this interesting topic.
- Truck drivers have a lot of valuable input that can both be gathered via interviews and from observation. It is recommended to continuously build a data base of increasing knowledge.
- Reliability of new technology is an aspect that makes truck drivers reluctant to change existing and proven solutions.
- Sound warnings are very annoying to truck drivers. Focus should if possible be limited to providing well designed light information and warnings.
- It has proven possible to perform this type of postural behaviour studies in a driving simulator with external influence from significantly different traffic situations. The sufficient time duration has been established that secures results at the same time as problems of simulator sickness are limited.
- The analysis of postural behaviour and head postures based on video films is very time-consuming and monotonous, even though advanced analysis programs exist. It is recommended that even better methods are developed where computer power can be used to make the analysis more automated.
- Head tracking (that is anyway an included part of the used configurable driving simulator) forms an additional useful source of data. The methodology for doing the corresponding analysis was developed during the project.
- It is also possible to utilize additional vehicle data from the driving simulation to compare driving behaviour and level of performance of different test persons which can be influenced by different concepts. Indicators such as timing, chosen speeds, number of collisions and how the vehicles are positioned on the road should be included if they can give additional information according to the topic of the research.

Figure 32. Examples of driving scenarios that were used – traffic lights, overtaking car in city, roundabout, overtaking moped, overtaking car on motorway, and a truck stop.

Some specific conclusions and recommendations from this Work Package are:

- Traditional rear-view mirrors make drivers more active in their movements as they encourage the drivers to move with respect to the mirror in order to change their field of view.
- Head postures vary more than body postures, especially in environments where driving relies on visual input.
- Drivers are more active with respect to extreme postures in urban environments compared to high-way environments. The preferred and most common posture was however the same in both traffic environments.
- Drivers of heavy truck combinations moved significantly more with rear-view mirrors than with camera monitor systems.
- Drivers of heavy truck combinations moved more in urban environments than drivers of a medium-heavy rigid truck.
- Drivers of the medium-heavy rigid truck used more extreme postures.
- Vision obstructions have a big influence on postures and feeling of security when driving especially in urban areas and when doing low speed manoeuvres.
- For posture analyses, a low number of key camera views should be selected and the maximum information from them secured via efficient analysis tools.
- Optimized camera positions and angles are easily prepared in CAD with input from ergonomics CAD simulation of representative manikin sizes to secure that they will cover all posture variations.
- Contrast under different light conditions need to be considered. Here light conditions in a laboratory environment are much easier to control than out on the road – which forms an additional benefit of performing driving simulator studies.
- As it has shown that truck drivers often have a lot of valuable input to provide, semi-structured interviews are recommended that allow the respondents to express themselves in an explorative way.
- Taller drivers repositioned more than short when driving a heavy vehicle combination.
- Taller drivers take more extreme postures when driving a medium-heavy rigid truck.

- Shorter drivers tend to reposition more than longer drivers, especially in urban traffic environments.
- Panning of the rear-views from a camera monitor system can provide sufficiently large fields of view compared to what drivers can achieve from head movements in combination with traditional rear-view mirrors.
- There are specific critical driving conditions that require the most extreme body postures (e.g. a wedge condition where one road connects to another at an angle).
- Concepts that influence the general scanning behaviour of using a combination of indirect and direct vision exaggerate differences in driving style or postural behaviour.

9. Participating parties and contact persons

Here follows a list of contact persons at the parties involved within the project.

CHALMERS

Chalmers, Division Design & Human Factors, Department of Product and Production Development:

- Tina Koohnavard, M.Sc., Researcher
- Lars-Ola Bligård, Ph.D.
- MariAnne Karlsson, Professor

VOLVO

Volvo Group Trucks Technology, Vehicle Engineering:

- Patrik Blomdahl, Technology Specialist for Physical Ergonomics
- Dennis Saluäär, Research engineer
- Michael Dahl, Ergonomics Engineer and Driving simulator assistant
- Martina Söderberg, Clinic assistant
- Henric Danielsson, Function Owner for Indirect Vision Devices
- Christer Lundevall, HMI Simulation specialist