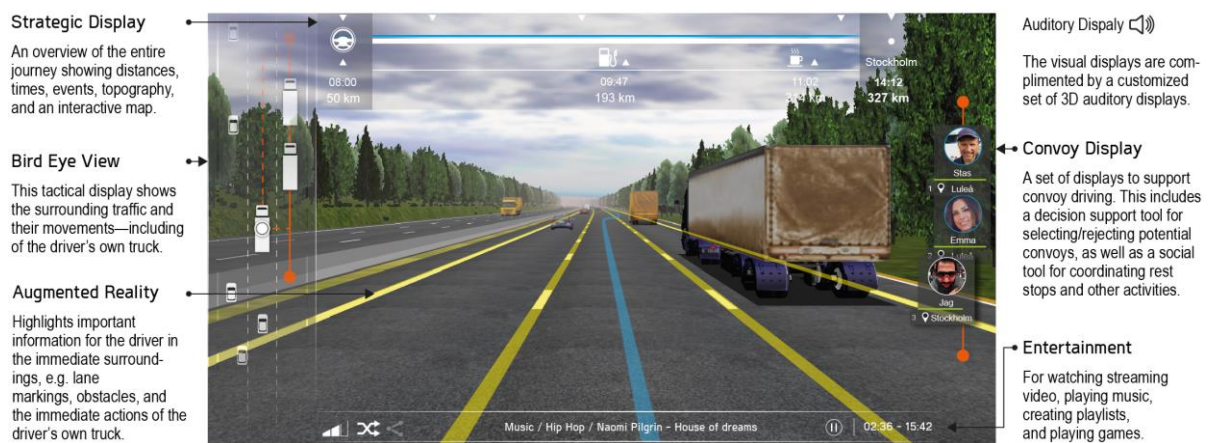


Methods for Designing Future Autonomous Systems (MODAS)



The MODAS project was completed within Fordons & Trafiksäkerhet Program Area C, Driver Support and Related Interface between Driver and Vehicle (“Förarstöd och relaterade gränssnitt mellan förare och fordon”).

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8th June, 2015

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FFI in short

FFI is a partnership between the Swedish government and automotive industry for joint funding of research, innovation and development concentrating on Climate & Environment and Safety. FFI has R&D activities worth approx. €100 million per year, of which half is governmental funding. The background to the investment is that development within road transportation and Swedish automotive industry has big impact for growth. FFI will contribute to the following main goals: Reducing the environmental impact of transport, reducing the number killed and injured in traffic and Strengthening international competitiveness. Currently there are five collaboration programs: **Vehicle Development, Transport Efficiency, Vehicle and Traffic Safety, Energy & Environment and Sustainable Production Technology.**

For more information: www.vinnova.se/ffi

1. Executive summary

Within the MODAS project, a design method for future cab design was developed and implemented. This method supports the design of next generation truck cabs that include advanced automated technologies. These automation technologies induce a paradigm shift in the driver-vehicle relationship. The design method built upon the Goals (Mental) Models, Observability, Controllability (GMOC) model and was implemented to create a novel driver environment for supervising and controlling a highly autonomous truck. The driver environment was integrated into Scania's truck simulator and was assessed with a novel assessment technique. Four simulator scenarios were created and the MODAS interfaces were integrated such that drivers could experience different future traffic scenarios using the novel supervision and control interfaces. The driver environment included a Head Up Display, a novel Instrument Cluster, a 3D audio display, and a mobile tablet device. All interfaces were developed and assessed through thorough an empirical approach involving consultation with professional drivers and senior engineers. As part of the development work, 21 data collection activities were conducted (e.g. workshops, observations, simulator studies) involving 158 consultations with professional truck drivers, and an additional 50 consultations with expert engineers or other participants. The project and its results have received much positive attention in Sweden and around the world.

2. Background

Modern technologies have the potential to create a paradigm shift in the role of the driver in any vehicle-driver system. Already automatic gears, adaptive cruise control, and other similar technologies, have greatly reduced the physical task of driving. As advanced automation technologies are introduced, the role of the driver changes from "driving" to "supervising". To design driver environments for new technologies, traditional design approaches typically identify the human and technical constraints to system efficiency in the current (existing) system and create solutions accordingly. For the technologically evolving situation in the automotive domain, however, the value of such a design approach is limited and the failure to consider the changing driver-vehicle relationship may result in tragedies similar to those observed following the introduction of auto-pilot aviation technologies (Air France Flight 296, Indian Airlines Flight 605; Degani, Shafit, & Kirlik, 1996) and indeed automation interaction disasters already exist in road transport (Karlsson, 2012). Designing new driver environments to accommodate advanced technologies will benefit from avoiding a legacy systems approach but in the absence of an existing system, system design is difficult. For example, for future systems, not only is system analysis impossible, but system design becomes more of an art than a science. The design method created within MODAS removes some guesswork associated with future system design.

3. Objective

Trucks of today are primarily driven by people. On the basis of current technical trends, it is likely that trucks of the future will be primarily driven by the technology itself (that is, self-driving, or [partially] autonomous). Within the MODAS project, we focused on the driver and their roles and needs in these future trucks. One goal of the MODAS project was to design a truck cab for the supervision and control of a highly autonomous truck. However, due to the challenges mentioned in the Background section, without additional methods and tools, it will be difficult to reach this goal. Consequently, a second goal was to develop a generic method that can be used for future systems design. Finally, after developing and applying the method, the final goals were to assess the final product in terms of driver acceptance and benefits for driver performance.

In summary, the four objectives of the Methods for Designing Future Autonomous Systems were to:

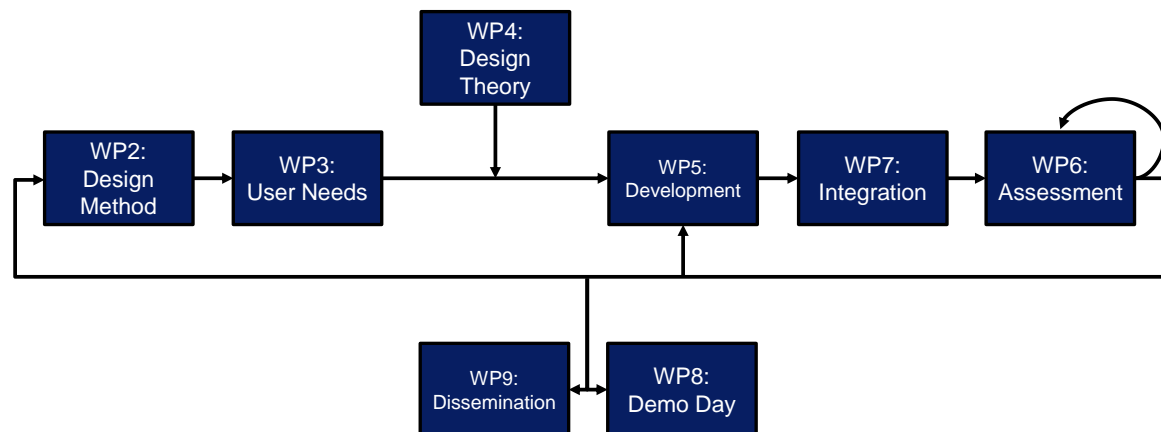
1. Create a system development method for future (non-existent) systems design.
2. Apply the method to develop a prototype cab for a highly autonomous truck.
3. Develop a method for assessing user acceptance of the concept interface.
4. Develop a method for assessing performance in highly autonomous trucks.

4. Project realization

Work was completed within six key workpackages with three additional workpackages to support management, demonstration, and dissemination activities. The workpackages (and their institutional leader) were:

- WP1: Management (Scania)
- WP2: Design method (Uppsala)
- WP3: User Needs (Scania)
- WP4: Theory (Interactive Institute)
- WP5: Display Development (Interactive Institute)
- WP6: Assessment (Technical University of Luleå)
- WP7: Simulator Integration (Scania)
- WP8: Demonstration (Scania)
- WP9: Dissemination (Uppsala)

The project was structured as follows:



Overall structure of the MODAS project

A more detailed description of the project realization is presented below, but in summary, the project produced its output via the following flow:

- The design method was created in the Design Method workpackage (WP2)
- The design method was applied in the User Needs workpackage (WP3) to generate design requirements
- Current theory regarding multimodal cab design was reviewed and extended in the Design Theory workpackage (WP4)
- On the basis of the User Needs (WP3) and Design Theory (WP4), interfaces were developed in the Development workpackage (WP5)
- The interfaces were integrated in the simulator in the Integration workpackage (WP7)
- When the interfaces were integrated with simulator scenarios, the interfaces were assessed in the Assessment workpackage (WP6)
- The outcome of the assessment influenced the Design Method (WP2, and thus the design) as well as the assessment method (WP6)
- On the basis of the work completed in workpackages 2 to 7, information was Disseminated (WP9) and the content for the Demonstration Day (WP8) generated.

The design work included three iterations of development.

Within the Design Method Workpackage (WP2), the overall design method was developed. This design method, a variant of which has been used to develop rail signaling systems, was adapted and refined for MODAS on the basis of the User Needs (WP3). The key activity of the Design Methods was to define the process of systems development that will be adhered to throughout the project. A challenge in developing the design method was to identify a process that considers future technologies that are not yet available. Additionally, the design method was developed at the same time as it was applied. The implication of this is that the Design Method and User Needs workpackages worked closely throughout the project.

The User Needs workpackage (WP3) was tightly coupled with the Design Method Workpackage. Whereas the Design Method Workpackage defined a general method for systems development, the adaptation and implementation of this for the truck domain occurred within the Driver Needs workpackage. This workpackage was thus dedicated to understanding the (future and emerging) driver needs.

Within the Design Theory workpackage (WP4), the theoretical knowledge required for the design of the multimodal future driver environment was reviewed and developed. Work here considered both auditory and visual modalities. For both, an analysis of previously conducted research on mappings between audio/visual parameters and real-world parameters was conducted.

Within the Development workpackage (WP5), the driver environment was constructed using the methodology developed in the Design Methods (WP2) workpackage, on the basis of the Driver Needs (WP3), and using the theoretical knowledge from the Multimodal Affordances (WP4) workpackage. Auditory displays were developed in parallel with the visual displays. Included within this workpackage was the initial design, building and evaluating of the auditory and visual information displays prototypes (more thorough, holistic, evaluation was conducted within the Assessment workpackage). During the design process, auditory and visual displays were evaluated and refined in an iterative way. An additional feature of the Development workpackage was the successful collaboration with the Umeå Institute of Design (UID). Fourteen students from UID participated in the MODAS project by using the core MODAS research questions as design seeds. Students produced films illustrating their solutions which were shown at the Demonstration Day (WP8).

Within the Integration workpackage (WP7) the auditory and visual displays developed in the Development workpackage were integrated into Scania's driving simulator. This work included making upgrades to the simulator hardware and software to cater for the project needs. A Multimodal Display Engine was created to facilitate the flow of information from the simulator to multiple display technologies and modalities. Integration work was also required to support Assessment.

Within the Assessment workpackage (WP6), a method for assessing the supervision and control of an autonomous vehicle was developed and used. A current method for assessing secondary task performance in manually driven cars is the Lane Change Test which assesses the 'smoothness' of a lane change during manual driving while performing a secondary task. Such a test is invalid when considering autonomous lane changes. With this in mind, a new method for assessing 'driving' was required. The result is both a methodology for selecting performance measures (the "Failure GAM²E") method and a list of traditional and novel measurements.

Within the Management workpackage (WP1), four project meetings were held every six months. The meetings were hosted by; (1) Scania, (2) Luleå Technical University and Interactive Institute Swedish ICT, (3) Uppsala University and Scania, and (4) Scania. Within the Demonstration workpackage (WP8) the final prototype developed within the project was presented to the public. Within the Dissemination workpackage (WP9) the work produced within this project was submitted for publication in international peer reviewed journals and at international conferences.

5. Results and deliverables

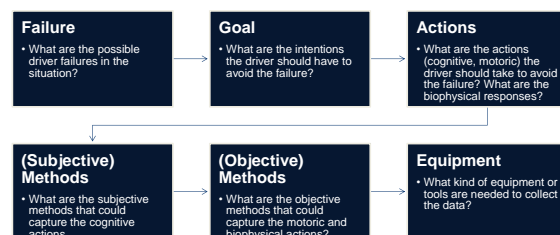
5.1 Delivery to FFI-goals

The MODAS results contributed directly to FFI's Fordons & Trafiksäkerhet Program Area C, Driver Support and Related Interface between Driver and Vehicle ("Förarstöd och relaterade gränssnitt mellan förare och fordon"). The project achieved the following key outcomes:

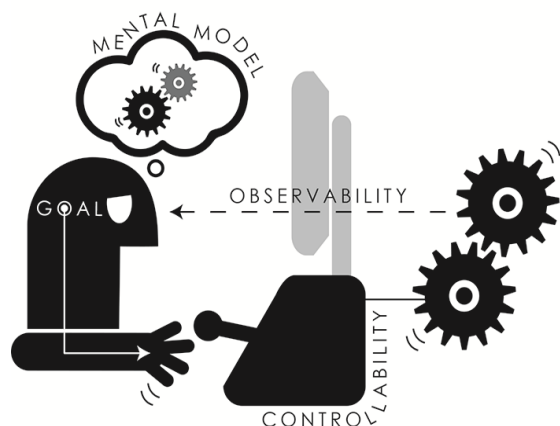
Contributions to the Transport Industry: A prototype future driver environment was built and integrated into Scania's driving simulator. The multimodal cab concept is a state of the art cab for controlling a truck with multiple future automated driving technologies.



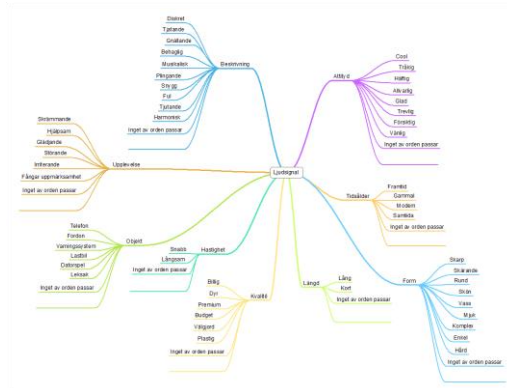
Contributions to Academia and Transport Industry: A new framework for assessing driving was developed. This framework, considers goals and actions and can be used for assessing manual driving and autonomous control and supervision.



Contributions to the Industry in General: A method for future systems design was developed that can be used for designing ‘future’ systems in a variety of industrial socio-technical domain.



Contributions to the Academia and Industry in general: A tool for assessing the user acceptance of auditory displays was developed. This tool can be used for any domain that makes use of auditory displays.



In general the MODAS project contributed to reducing fatalities within the road transport industry by developing solutions for safer and more efficient supervision and control of autonomous trucks. The project pushed forward Swedish innovation as evidenced by the significant interest in the project results globally. Additionally, the inclusion of the Umeå Institute of Design gave an opportunity for the project to influence the work of an additional 14 students.

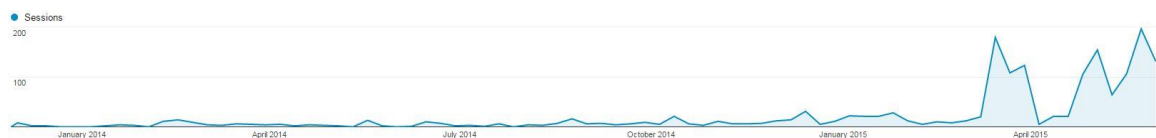
6. Dissemination and publications

Project dissemination occurred via several key activities:

1. Project Blog
2. Print and TV Media
3. Organizational Dissemination
4. Demonstration Day
5. Publications at Academic and Industry Events

6.1 Project Blog

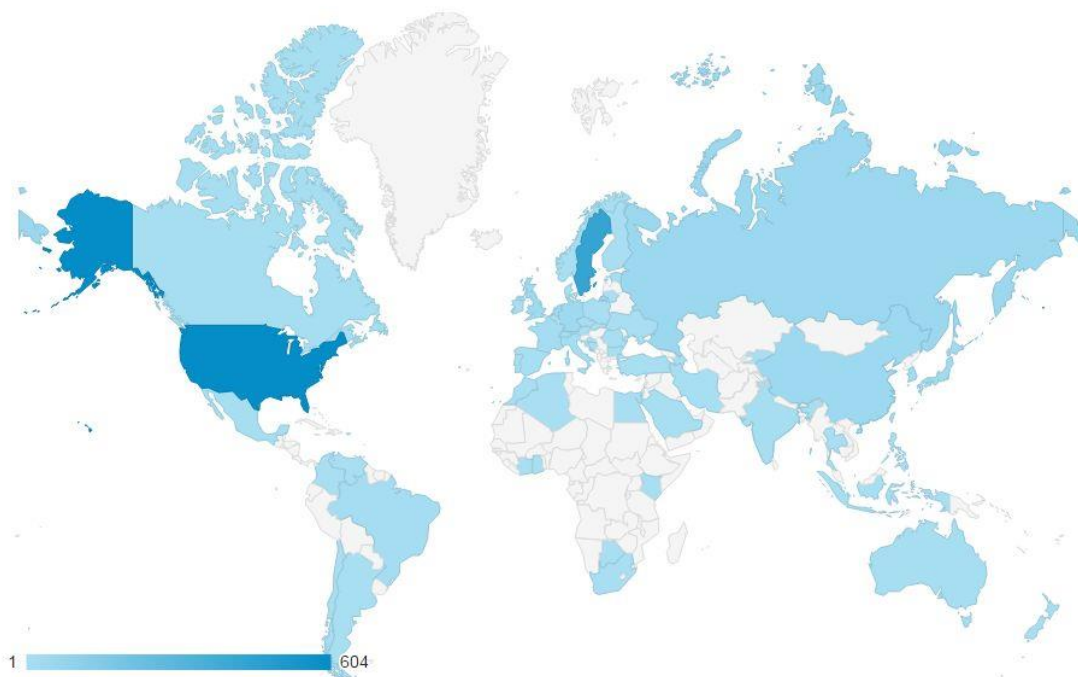
A key dissemination tool that will be retained for an additional period is the MODAS Project Blog (<http://blog.scania.com/modas/>). Since the initiation of blog, it has been accessed with increasing frequency (all data obtained from Google Analytics).



Number of times project blog access over final 12 months of MODAS

The blog has been accessed from sixty one countries. The list of countries from which the MODAS project was accessed is presented below (in order of number of sessions/visits).

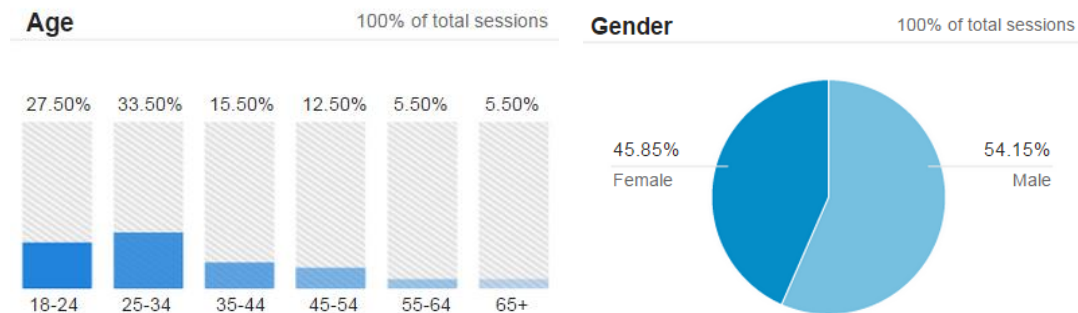
1 United States	22 Ukraine	43 Venezuela
2 Sweden	23 South Africa	44 Azerbaijan
3 Undefined	24 Bulgaria	45 Bosnia & Herzegovina
4 Russia	25 Spain	46 Botswana
5 China	26 Hong Kong	47 Côte d'Ivoire
6 Germany	27 Argentina	48 Chile
7 United Kingdom	28 Switzerland	49 Algeria
8 South Korea	29 Czech Republic	50 Ghana
9 Netherlands	30 Denmark	51 Croatia
10 Japan	31 Indonesia	52 Kenya
11 Estonia	32 Iran	53 Kyrgyzstan
12 France	33 Norway	54 Lithuania
13 Brazil	34 Saudi Arabia	55 New Zealand
14 Canada	35 Turkey	56 Philippines
15 India	36 Austria	57 Puerto Rico
16 Italy	37 Belgium	58 Portugal
17 Mexico	38 Egypt	59 Romania
18 Australia	39 Finland	60 Slovakia
19 Taiwan	40 Ireland	61 Thailand
20 Colombia	41 Israel	
21 Poland	42 Morocco	



Map showing project blog visit frequency

The blog was accessed 1710 times and incurred 3632 page views. Other than the home page (36% of page views), the News page (20%), Publications page (10%) and Overview pages (7%) accounted for the majority of the page views.

The site was accessed by a primarily younger audience that included slightly more males than females.



Basic project blog demographics information

6.2 Print and TV Media

The MODAS project has appeared in several Television and Print Media. SVT's Rapport program featured MODAS at 19:30 on the 27th January.



Images from SVT Rapport

The project has also featured in two print publications within Sweden; Ny Teknik and Ländstidningen Södertälje. Information about the project has also be reproduced online in several other languages, including, for example, Greek (<http://www.autotritipro.gr/>) and Russian.



Screen images from Ländstidningen Södertälje and Ny Teknik

6.3 Partner Dissemination

The MODAS project has been featured on two contributing organization websites:

Scania Careers: <http://blogs.scania.com/career/2015/05/21/a-look-into-the-future/>

Scania Newsroom: <http://newsroom.scania.com/en-group/2015/04/27/a-look-into-the-future/>

Scania Sweden: <http://www.scania.se/om-scania/nyheter/arkiv/2015/q2/en-blick-in-i-framtiden.aspx>

Interactive Institute Swedish ICT: <https://www.tii.se/modas>

Additionally, a dissemination film was jointly produced by Interactive Institute and Scania CV AB. The short film summarizes some key innovations from the project and as of 5th June, 2015 had received 685 views. The film is accessible here:

<https://www.youtube.com/watch?v=C4IMOo6KX3Q>.

6.4 Demonstration Day

On the 22nd January a public (by invitation) Demonstration Day of the MODAS project was hosted by Scania CV AB. Invitations to the event were initially distributed to around 50 people. Recipients of the invitation were encouraged to forward the invitation to other potentially interested persons. In total fifty persons attended the event. This included 35 persons unaffiliated with either the project, or the partner institutions. The Demonstration Day consisted of both presentations (morning session) and a demonstration and poster session in the afternoon. Presentations were given on the following topics:

1. Project Overview; Dr. Stas Krupenia
2. The GMOC Design Model; Dr. Anders Jansson
3. Innovation in Multimodal Cab Design; Dr. Johan Fagerlönn
4. Assessing Autonomous Driving; Dr. Camilla Grane

The afternoon consisted of:

1. Poster on Driver Interactions
2. Poster on Design Method
3. Poster on Assessment Method
4. Poster on Design Solutions
5. Film of contributions to MODAS by Umeå Institute of Design students
6. Film and Demo of Auditory Display Development
7. Screen showing live streaming from inside simulator
8. Experiencing the MODAS solutions inside the Scania Truck Simulator



Demonstration of Auditory Displays (left), live stream from the simulator (right)

6.5 Publications

- Bodin, I., Axelsson, A., Vännström, J., & Jansson, A. (*in preparation*). Eliciting Future Strategies and give Input to In-Vehicle Design Using Formative Strategies Analysis Approach.
- Bodin, I., & Krupenia, S. (2015). Who cares about Cognitive Work Analysis?. To be Presented at the *59th Annual Meeting of the Human Factors and Ergonomics Society*, 26-30 October, Los Angeles, CA, USA.
- Bodin, I., & Krupenia, S. (*submitted*). Activity Prioritization to focus the Control Task Analysis. Submitted to *Journal of Cognitive Engineering and Decision Making*.
- Duffield, T., & Krupenia, S. (2015). Drivers' Interaction Preferences in Autonomous Vehicle Multimodal Interactive Systems. To be Presented at the *59th Annual Meeting of the Human Factors and Ergonomics Society*, 26-30 October, Los Angeles, CA, USA.
- Grane, C. (2013). Automated driving puts new demands on driving evaluation methods. In *Proceedings of the Nordic Ergonomics Society (NES) Annual Meeting*, 11-14 August, Reykjavik, Iceland.
- Grane, C. (*submitted*). Methods for assessing driver behaviour in manual and automated driving. Submitted to *The Annual Meeting of the Human Factors and Ergonomics Society Europe Chapter*.
- Jansson, A., Stensson, P., Bodin, I., & Axelsson, A. (2014). Authority and level of automation: Lessons to be learned in design of in-vehicle assistance systems. In *Human-Computer Interaction: Applications and Services, Part III* / [ed] Masaaki Kurosu, Springer Berlin/Heidelberg, 2014, 413-424.
- Krupenia, S. (2013). Autonomous Vehicles: If the technology exists, why can't I buy it. Presentation given to the European Cooperation in Science and Technology (COST) ACTION 1102 (Towards Autonomic Road Transport Support Systems), Prague, Czech Republic, 21st March, 2013.

- Krupenia, S. (2013). Designing for Automation in Future Commercial Heavy Vehicles. Innovative Centre for Embedded Systems (ICES) Safety Seminar—Safety Issues with Automation. Västerås, Sweden, 14th June, 2013.
- Krupenia, S. (2013). Designing for Automation in Future Commercial Heavy Vehicles. *4th Automotive Cockpit HMI Conference*. Bonn, Germany, 24 – 27 September, 2013.
- Krupenia, S. (2013). Designing for Automation in Future Commercial Heavy Vehicles. Presented to the *University of Wisconsin-Madison Human Factors and Ergonomics Society Student Chapter*, Madison, WI, USA, 9th October, 2013.
- Krupenia, S. (2013). Designing for Automation in Heavy Vehicles and the MODAS Project. Presented to the *Virginia Tech Transport Institute*, Blacksburg, VA, USA, 11th October, 2013.
- Krupenia, S. (2013). The Methods for Designing Autonomous Systems Project and the Problem with Automation. Presented to the Umeå Design Institute 1st Year Masters students in Interaction Design, Umeå, Sweden, 13th November, 2013.
- Krupenia, S. (2014). Using the Goals, Models, Observability, Controllability (GMOC) Framework to develop Highly Autonomous Systems: Examples from the MODAS Project. *Joint SAFER (Competence Area Design and Human Factors)/ Human Factors Collegium i Göteborg Seminar on Automation and Interaction Design*, 20th May, Gothenburg, Sweden.
- Krupenia, S. (2015). Process and Outcomes of the Methods for Designing Future Autonomous Systems (MODAS) Project. To be Presented at *Car HMI Conference*. Berlin, Germany, 25 – 26 June, 2015.
- Krupenia, S. (2015). Driver vehicle interaction: Results from the MODAS project on future autonomous systems and discussion of new ideas. Presented to the *Integrated Transport Research Lab (ITRL) Lunch Seminar & Workshop Series*, KTH, 25th March, 2015.
- Krupenia, S., Fagerlönner, J., Jansson, A., Bodin, I., Axelsson, A., Ahlm, V.,...Vännström, J. (in preparation). Developing a 1st Iteration Concept HMI for Supervising and Controlling a Self-Driving Truck. To be submitted to *Ergonomics in Design*.
- Krupenia, S., Fagerlönner, J., Jansson, A., Grane, C., Bodin, I., Axelsson, A., Vännström, J. (in preparation). Development and Assessment of Concept HMI for Supervising and Controlling a Self-Driving Truck. To be submitted to *Ergonomics in Design*.
- Krupenia, S., Selmarker, A., Fagerlönner, J., Delsing, K., Jansson, A., Sandblad, B., & Grane, C. (2014). The 'Methods for Designing Future Autonomous Systems' (MODAS) project: Developing the cab for a highly autonomous truck. In T. Ahram., W. Karowski., & T. Marek. (Eds.). *Proceedings of the 5th International Conference on Applied Human Factors and Ergonomics (AHFE2014)*, Krakow, Poland, 19-23 July, 2014.
- Vännström, J. (2014). A design and assessment method for future autonomous systems. Presented at *Elektronik I Fordon*, Göteborg, 8-9 April, 2015.

7. Conclusions and future research

Future Internal and external projects have been initiated in response to the MODAS project. A follow up research project involving Uppsala University and Scania has been funded by FFI that investigates certain aspects of human automation handovers (the MOTHAD project). Scania has also initiated an internal project that, using MODAS as input, attempts to identify cab solutions for the shorter term implementation.

8. Participating parties and contact person

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