Application within FFI Trafiksäker automatisering

Intelligent, Interactive and Connected (I^{2}Connect)

Next Generation Driver Support Systems

Requirements and Proof of Concept for Increased Road Safety and Personalized Human-Machine Interaction

Date: 05-09-2023
Coordinator (Paul Hemeren, paul.hemeren@his.se, 0709 502042):

The applicant consents to the programme advisory board being given the complete application, including ***the project description***.

Yes ☒ No ☐

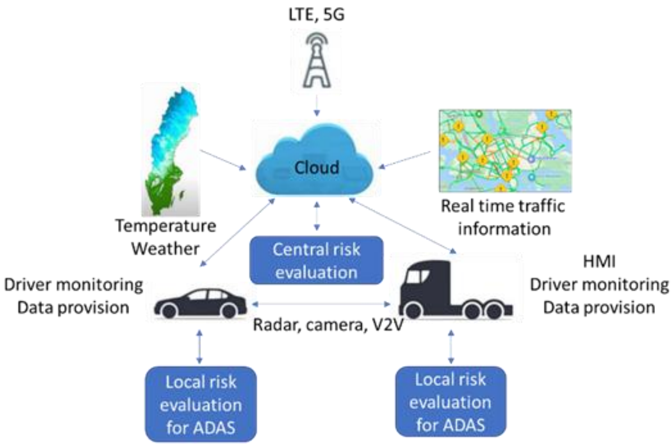
Is it a reworked application that has previously been assessed by the FFI quality review group?

Yes ☒ No ☐

If yes, specify the reference number: 2023-00767

Summary

The I2Connect focuses on Advanced Driver Assistance Systems (ADAS), emphasizing comprehensive safety assessment through car-to-cloud integration, external sensing inputs, and driver monitoring. The project aims to develop a prototype ADAS system to improve real-time risk detection and refine driver information and warnings, particularly addressing rear-end collisions involving heavy trucks and cars, as well as intersection collisions between heavy trucks and cyclists.



Motivation:
Rear-end crashes in between cars and commercial heavy goods vehicles (HGV) and Crossing accidents are common accidents in statistics for HGV. HGVs were involved in 45 000 of all crashes and 14.2% of fatal crashes in Europe, indicating an overrepresentation of HGV involvement in fatal crashes, even though they only represent 3% of the traffic volume.

Method:

The project will identify relevant scenarios, collect the data from several sources, Use the collected data from several sources, develop fusion and distribute a risk assessment in between the clouds and vehicles on the road.
Demonstrator vehicles will be developed, including a heavy truck (Scania) and several equipped cars (Smart Eye), will collect data in normal traffic situations. The demonstrators will include data from radars and cameras as well as driver state (Smart Eye). Road-side traffic sensing (Viscando) as well as weather data will complement data collection in a cloud. Cloud risk assessment (HIS) is distributing relevant data to the connected vehicles based on geographic position.

Participants:

The prototype truck and cars include a local risk assessment using the cloud information and ego vehicle information supporting Level 1 (manual) up to Level 4 driving. The demonstrators in this project will concentrate primarily on implementing driver information and warning for a HGV.The **University of Skövde (HiS)** is the main applicant and **Scania**, **Smart Eye**, and **Viscando**, are partners that see the need and contribution of vital traffic data and infrastructure for the project's achievement. All partners include academic experts specializing in AI, IF (information fusion) IoT, and cloud-based connectivity between computational modeling and driver monitoring to create a more developed HMI for ADAS.

Time:

The project will run from 2023-12-01 until 2026-05-31 and has a total cost of 15 183 445 SEK, out of which 7 576 388 SEK is sought from Vinnova. A collaboration with several other research projects will be established such as Enhanced ADAS, NordicWay 3, VTX, AI-AWARE (Drive Sweden).

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Background and goals for the project

Advanced Driver Assistance Systems (ADAS) aim to enhance road safety, efficiency, and driver experience through information provision, warnings, or vehicle intervention. Nevertheless, current market-available ADAS often underperform, causing confusion and distraction for drivers, ultimately leading to misuse or deactivation – especially in situations where ADAS are expected to support drivers. These limitations primarily stem from the systems' restricted situation awareness and non-adaptive human-machine interfaces (HMIs). Building further on our recent pre-study (FFI 2022-01652), we will in this project specifically address these challenges in the context of heavy trucks. We strive to unlock the potential of, in this area unexplored, AI-techniques to process driver state and intention data, along with external and cloud-connected information. The resulting improved situation awareness will enable more informed ADAS decision-making and more adaptive HMIs.

Challenges to be addressed

Heavy vehicles (from now referred to as trucks) are involved in a significant number of road accidents worldwide. While they represent a smaller portion of total vehicles on the road, their involvement in accidents can have substantial consequences due to their size and weight. Accidents involving trucks tend to be more severe in terms of fatalities and injuries compared to accidents with smaller vehicles. The size and weight of trucks can lead to greater damage in collisions. Various factors contribute to these accidents, including driver behaviour (e.g., speeding, fatigue, distraction), road conditions, weather, and vehicle-related issues (e.g., brake failures). Research based on European statistics show that the three most common accident scenarios are:

- Rear-end crashes with cars and commercial vehicles as collision partners.
- Conflicts between a truck that is turning right and a cyclist that goes straight.
- Conflicts with a pedestrian crossing the road in front of the truck.

These accidents mostly happen in rural areas, however, serious injuries and fatalities of Vulnerable Road Users (VRUs) such as cyclists and pedestrians occur mainly in urban areas.

Many of these accidents could potentially be prevented, or at least mitigated, through the use of ADAS. However, recent studies show that ADAS systems available on the market today are not performing well and that they are often confusing or disturbing to drivers, leading to improper use or disengagement of such systems (Adiutori, 2020; CarComplaints, 2020; Green Cars Congress 2021). An investigation conducted by Scania further highlights that truck drivers frequently disengage ADAS in complex traffic scenarios – situations in which these systems are inherently designed to provide support.

This can to a large extent be explained by a few key obstacles for ADAS that vehicle manufacturers, including Scania and its parent organization TRATON, are committed to addressing in the development of the next generation of these systems:

- **Limited situation awareness**: Existing ADAS are largely based on the contribution of individual data from vehicle-based sensors such as radars and cameras. While these sensors capture rich data about the traffic in the immediate vicinity of the vehicle, their capacity to detect critical situations, such as a potential crash is hindered by the quality and isolated interpretation of this data. They lack the ability to "perceive" an accurate interpretation of traffic data.
- **Overreliance on data from onboard Sensors**: Existing ADAS systems primarily depend on data from onboard sensors like radars and cameras. While these sensors are valuable, they may have limitations in accurately perceiving certain situations, especially in complex or adverse weather conditions.
- **Limited driver state monitoring**. Existing ADAS in heavy trucks do not sufficiently monitor the state of the driver. This lack of driver monitoring can lead to situations where the system is unaware of the driver's attentiveness or fatigue, potentially causing safety risks. On passenger car side, the driver state monitoring has shown its potential, and regulatory and safety rating bodies are increasingly emphasizing that this technology will be required for trucks.
- **Non-adaptive Human-Machine Interfaces (HMI)**: The interfaces through which ADAS communicate with drivers are often not adaptive to individual needs and preferences. This lack of adaptability can result in driver confusion and distraction, as warnings and information may not be presented in an optimal way.

These challenges are interrelated and addressing them requires a holistic approach.

The way forward: Comprehensive situational awareness based on evidence theory

Recent advancements in camera-based driver monitoring systems (DMS), smart infrastructure-based sensing, and Vehicle-to-Everything (V2X) communication technologies are anticipated to provide the missing pieces in ambient traffic and in cabin sensing. These technologies offer valuable data streams about drivers (e.g., driver state and physiology), ambient traffic (e.g., trajectories and intentions for other road users) and environment factors (e.g., weather, road conditions). By integrating and fusing these diverse data sources, a comprehensive situational awareness can be formed based on evidence-theory grounds, thereby enhancing the accuracy and effectiveness of ADAS.

For instance, consider a scenario where a truck following a car might lead to a rear-crash accident. In such cases, the ADAS faces a dilemma in determining whether the situation arises due to the truck driver's state or external traffic conditions, thereby necessitating an adaptive adjustment of the HMI. Moreover, the severity of the projected rear-crash could be interpreted distinctively when analyzing data solely from within the vehicle or from external sources. However, combining these diverse data sources is expected to mitigate the uncertainty surrounding the potential rear-crash event.

The resulting enhanced situational awareness from strengthening evidence data captured from the multitude of sensors enables ADAS to advocate adaptive and personalized HMI, while tailoring interactions and interventions to the unique characteristics and conditions of individual drivers and driving conditions. Yet, the impact of such ADAS enhancements on driver safety, overall efficiency, and the driving experience remains largely unknown.

Aim and hypothesis

The project fills the knowledge gap in ADAS design by examining the integration of data derived from DMS, smart infrastructure-based sensing and V2X, through a theory-grounded data fusion subsystem. The aims is to assess how this integrated data can significantly enhance the accuracy of ADAS, and to what extent novel adaptive HMI features induced from this fusion subsystem can exert a positive influence on driving safety, efficiency and experience.

Our hypothesis is that an ADAS able to "turn" *weak evidence* from multiple data sources in real-time into *strong evidence* will obtain an awareness of the situation that outperforms corresponding systems that lack such a capability. This will enable more adaptive HMIs and lead to enhancement of traffic safety, efficiency and driving experience.

This project primarily focuses on two common heavy truck accident scenarios: A) rear-end collisions with passenger cars, and B) collisions between turning trucks and cyclists at intersections (referred to as "use cases").

We aim to create a proof-of-concept prototype for each of these scenarios demonstrating functionalities that are likely to bring great potential for future vehicles (2029+ timeframe) in terms of safety, efficiency and user experience. These enhancements to ADAS will be evaluated with drivers, and insights from the evaluations will be turned into HMI design guidance to inform future ADAS development as well as support discussions with regulatory, standardization and safety assessment bodies.

The project will utilize methods from the AI research that are currently largely unexplored in ADAS design. By using Evidence theory, we will aggregate ambiguous data about driver state and recognized intentions as well external and cloud connected data to eliminate uncertainty stemming from inconclusive data. The resulting enhanced situation awareness is set to empower ADAS decision-making capability to anticipate actionable decisions and make recommendations for individual drivers. To enable this, the project will develop a research platform for processing evidence fusion algorithms and exchanging data via a cloud infrastructure. The fusion methodology involves different evidence combination rules, depending on the traffic situation. Explicit knowledge about traffic regulations, rules of conduct, severity of potential accidents, typical driver behavior, common faults, etc. will also be incorporated. The evidence theory approach will allow for transparency, which not only is required by EU regulations (E Commission et al. 2021) but also to establish and express what needs to be improved in order to enhance safety and to prompt appropriate HMI accordingly.

Research questions

The main research question that will be addressed in the project is *What strategies can be employed to ensure that future ADAS systems are effectively incorporating and capitalizing on subtle data cues from emerging sources like driver monitoring and connected traffic systems?* These strategies should aim to improve situation-awareness and enhance driver behavior and experience while simultaneously improving overall driving safety and efficiency.

To guide our investigation, this main research question is broken down into the following sub-questions:

- *RQ1: What requirements are posed on future ADAS utilizing driver monitoring and external data with varying degrees of uncertainty based on a) user needs and expectations, b) upcoming regulatory and safety rating requirements, and c) capability of driver monitoring and external data?*
- *RQ2: What future ADAS utilizing driver monitoring and external data would be valuable in terms of safety, efficiency and user experience in short and long term perspective?*
- *RQ3: What architectural framework is best suited for efficiently collecting and utilizing V2X data, and implementing evidence fusion algorithms in real-time?*
- *RQ4: What evidence theory fusion models and evaluation methods are best for achieving a holistic level of situation awareness, while enhancing user experience, and effectively utilizing novel HMI functions within the context of ADAS?*
- *RQ5: How will drivers' behavior be influenced by using ADAS based on the proposed fusion models incorporating connected, driver monitoring, and traffic monitoring data?*

Measurable objectives for the project

The project aims to create two proof-of-concept prototypes for next-generation ADAS systems designed specifically for trucks. These systems will incorporate innovative data sources and fusion techniques for situation assessment. In essence, we anticipate a higher level of acceptance among drivers for these ADAS functions, with a greater number of drivers choosing to keep them activated throughout their journeys. This, coupled with improved accident avoidance capabilities, is expected to yield several benefits compared to ADAS lacking these innovative features:

- A 50% reduction in the frequency of accidents for both rear-end and cyclist-intersection scenarios.
- A 70% decrease in false warnings to truck drivers, signifying improved risk detection and reliability.
- A 50% reduction in system disengagement, offering more precise and context-aware warnings tailored to driver state and expected reactions.
- A 30% decrease in harsh braking incidents, thanks to more timely warnings and information that reduce abrupt or belated actions.

Novelty and innovation level

The project goes beyond traditional approaches and explores new avenues for improving road safety by exploring evidence data that were not fully investigated before. The main contribution of this project is to produce and share data about driver's state, external and connected traffic context, based on which we utilize the promising information fusion methods in Evidence Theory to establish an awareness of the situation, predict its development in the near future and compute safety levels. More specifically:

- **Integration of multiple data sources that are not used in current ADAS in trucks**. That is, unlike conventional ADAS that rely on limited onboard sensors, this project aims to combine data from various sources, including camera-based driver monitoring and external traffic systems. This holistic approach provides a comprehensive understanding of both traffic conditions and driver intentions, allowing for more effective interactions between the system and driver.
- **Predictive capabilities:** Rather than focusing solely on current data, the project emphasizes the prediction of traffic situations and driver intent. This forward-looking approach enhances ADAS by anticipating potential issues and enabling timely interventions.
- **Evidence Theory (ET) utilization:** The project leverages real-time execution of Evidence Theory algorithms within a tailored cloud infrastructure for harnessing correlations between data concerning

driver state, vehicle dynamics, and connected traffic conditions. This innovative approach will mitigate accident risks where trucks are involved, and facilitate information dissemination to neighboring vehicles for improved safety outcomes, as illustrated in the use case of Figure 2. To our best knowledge, real-time Evidence Theory is largely unexplored in ADAS design, and the project will as such generate new knowledge in this emerging field of AI.

- **Centralized cloud-based infrastructure:** By implementing a centralized cloud-based infrastructure with Vehicle-to-Everything (V2X) communication, the project will demonstrate how all road users can be provided access to richer, more holistic and consistent information beyond what each individual vehicle's onboard sensors can provide. This infrastructure enhances ADAS capabilities not only for the truck but also for surrounding road users, while minimizing individual system costs. Although cloud-based data distribution has to a limited extent been demonstrated earlier (e.g. Volvo connected vehicle cloud (Ericsson, press-release (2018)) , centralized fusion of real-time data on road users movements and intentions from multiple sources has, to the best of our knowledge, never been implemented before.
- **Adaptable HMI:** The project focuses on creating smarter, more human-centric HMIs. These interfaces utilize both driver-specific information and a comprehensive understanding of the traffic situation to provide optimal support. The combination of evidence theory and intelligent HMIs enhances ADAS responsiveness to drivers' needs.

Limitations

To align with the allocated budget for this project, certain limitations will be placed on its scope:

- The primary focus will be on heavy trucks. While the nature of professional driving imposes distinct requirements, particularly in driver monitoring, due to factors such as the physical design of trucks and the work environment, it is anticipated that the essence of the insights derived will be transferable to other vehicle categories.
- The project's concepts and demonstrations will primarily address ADAS corresponding to SAE Levels 1 and 2 that provide information and warning to drivers. Nevertheless, the solutions and insights generated throughout the project will possess a level of generality that makes them adaptable to higher automation levels (SAE Levels 3-5).
- Only a specific selection of use cases will be prioritized for demonstration, yet the requirements will be derived with a broad range of traffic scenarios in mind. In particular, the project will focus on addressing the two most frequent accidents (rear-end collisions and collisions between turning trucks and cyclists in intersections).
- The project will emphasize the development of proof-of-concept solutions (TRL 6) rather than fully functional implementations.

Project deliverables

Project deliverables are provided as part of work packages.

Potential

The projects potential to contribute to FFI's overall impact goals

The project's contributions are aligned with FFI's overall impact goals, as it focuses on demonstrating innovative ADAS solutions that substantial enhance road safety, driving efficiency, and environmental sustainability while ensuring that these benefits are accessible to all road users. The project's specific targets for safety and efficiency improvements further emphasize its commitment to achieving these objectives. Furthermore, the project will generate substantial new knowledge and innovation, and strengthen international competitiveness of Swedish stakeholders. It will also inform development of standards and safety policies, as well as help building long-term competence development in Sweden.
In particular, to fulfill the goal "*FFI has demonstrated solutions that make society's road transport fossil-free, safe, equal, and efficient*", the project will make contributions in several key areas:

- **Safety improvement:** The project aims to enhance road safety by developing ADAS that reduce the frequency of accidents involving heavy trucks, specifically in two critical use cases: rear-end collisions and collisions in intersections with cyclists. These ADAS features are designed to improve road safety by ca 50% (to be demonstrated in a driving simulator studies for the two selected use cases).

- **Efficiency improvement**: Through innovative ADAS features with improved situation-awareness and adaptable HMI, the project seeks to reduce frequency of harsh braking incidents by 30% and reduce disengagement of ADAS by 50% (to be demonstrated in a driving simulator study for the two selected use cases). These reductions are anticipated to lead to smoother driving and a substantial increase in overall transport efficiency.
- **Fossil-free transportation:** Although not explicitly stated in the project description, the implementation of ADAS systems can indirectly contribute to reducing the carbon footprint of road transport. Enhanced efficiency and safety will lead to reduced fuel consumption and emissions, aligning with the fossil-free transport objective.
- **Equality in road safety:** The project is designed to ensure that these safety and efficiency enhancements are accessible to all road users, regardless of their gender or background. This contributes to the goal of equal road safety, promoting fairness and inclusivity in road transport solutions.
- **Demonstrated solutions:** The project's proof-of-concept ADAS prototypes with novel and adaptable HMI concepts serve as concrete demonstrations of how technology can contribute to safer, more efficient, and fossil-free road transport. These demonstrations are aligned with the goal of showcasing real-world solutions, as validated through demonstrations and evaluations.

To fulfill the goal of *"FFI has developed sustainable solutions that have been implemented and accepted by users and society"*, the project will make contributions in the following area:

- **Improved user experience**. By enabling and developing adaptive and personalized HMI concepts, the project strives to enhance the overall user experience and ensure that the developed ADAS solutions are well-received by truck drivers, and at the end by society as a whole. In particular, the project seeks to reduce disengagements of ADAS by 50% and reduction of false warnings by 70% (to be demonstrated in a driving simulator study for the two use cases), which will serve as a proxy for system acceptance and its potential to be used in practice.

To fulfill the goal of *"FFI has contributed to the road transport system's development through innovation, partnerships, and collaboration"* the project aims to make substantial contributions in key areas:

- **Innovation**: The project pioneers advancements in ADAS for trucks through novel data fusion, situation assessment, and adaptive HMI, and thereby guides future developments in the sector.
- **Partnerships and collaboration**: By bringing together a university (HiS) and industry leaders like Scania (large company), Smart Eye (SME) and Viscando (SME), the project promotes knowledge sharing and cross-sector cooperation, fostering an innovation-friendly ecosystem in road transport. Additionally, the project will establish an external reference group and strengthen national and international collaboration with prominent stakeholders in the field.
- **Skills development**: HiS, along with other project partners, will pioneer the application of Evidence Theory in a novel context, expanding the understanding of its practical use. They will also integrate research findings into educational programs, preparing future professionals and researchers in smart transportation systems to address evolving road transport challenges. Scania will acquire new knowledge on the role and potential of camera-based DMS as well as data from the infrastructure sensors. Another skill development incorporates design and recommendations for adaptive HMI, introducing an innovative concept to the trucking industry. Smart Eye and Viscando will learn how to integrate their systems in trucking applications, which is currently an unexplored area for them.
- **Infrastructure**: The project introduces a centralized cloud-based infrastructure for data exchange and communication among road users, enabling advanced data fusion and supporting future smart transportation developments, including vehicle-to-everything (V2X) communication.
- **Policy and regulatory insights**: When establishing ADAS requirements, the project will account for both current and expected regulations, including forthcoming safety assessment criteria set by EuroNCAP. Simultaneously, project partners will actively participate in discussions related to standardization and regulations, ensuring that the insights gained from the project are used to shape the development of regulations and standards specifically for heavy truck ADAS.
- **Business model exploration**: Although the project's primary focus is not on business model exploration, this new collaboration between Scania and the consortium has the potential to unveil fresh business prospects for all stakeholders involved.

Contribution to FFI Safe Automated Driving
The project will contribute to the sub-programmes' mission in several ways as described in the Table below.

FFI Goals	Project Contributions
“Safe automated vehicles“	Enhanced ADAS features developed in this project will promote safety by fusion of surrounding vehicles as well as connected traffic and infrastructure, including internal driver state and intentions. The provided ADAS enhancements will support vehicles in automation levels from SAE L2, and pave the way for subsequent levels.
“Safety for road users inside and outside the vehicle”	The combination of data collection from floating vehicles, that includes driver monitoring, and infrastructure in real time via a cloud database allows potential problems in infrastructure and driving situations to be detected in real time allowing advanced warning and updated driving recommendations. Intuitive HMIs are advocated.
“Integration of vehicles and infrastructure for safe transport solutions”	The project collects data from both vehicles and infrastructure sources providing driving recommendations based on nearby vehicles and infrastructure.
“Enabling methods and techniques with clear application for the development and implementation of safe automation”	Integrating real-time data collection from both vehicles and infrastructure through a cloud-based database enables the swift identification and reporting of potential issues in either the vehicle or infrastructure. This allows a fast correction of problems in the development cycle.

Internationalization
Each project partner has strong international connections. Scania is part of TRATON and will share insights with researchers from MAN (Germany) and Navistar (USA). Similarly, Smart Eye and Viscando have international reach and influence in technology sectors e.g., in Germany and Norway. HiS has well-established collaborations with multiple other universities and intends to use these to channel out insights and for experience exchange. All project partners are part of collaboration platforms SAFER and Drive Sweden and will use these for dissemination interconnection on both national and international level.

The projects contribution towards hastening the implementation that is needed to, in the long term, achieve the sub-programmes mission as it is described in the FFI roadmap.
The contributions in this project described in the table above (section “Contribution to FFI Safe Autonomous Driving” are necessary for achieving the next level Driver Support systems, in terms of both safety and acceptance. As described in this proposal, such improvements may not be attainable with incremental development of current ADAS technologies due to technical limitations of the latter. Transfer of results of this project to industry will enable and accelerate introduction of safer automation.

If the project refers to a mature field of study, does the project lead to large potential improvements in line with the vision in the FFI roadmap?
While ADAS are already available on the market, there are still evidential needs and requirements from both industry and authorities to improve functionality and efficiency of these systems. This project is anticipated to contribute to advancements in the design of these systems (fusion of data that is currently not utilized in ADAS, integration with infrastructure, a fusion method that is currently largely unexplored in trucking industry, adaptable HMI, etc.) and is as such anticipated to demonstrate safety and efficiency benefits.

State-of-the-art

The project builds on the recent FFI pre-study: “Driving Safety Scale and Scoring System: Turning Weak Evidences into Strong Safety Performance Scores (TWEAKS).

Project number: 2022-01652 (Pre-study)
Title: Driving Safety Scale and Scoring System: Turning Weak Evidences into Strong Safety Performance Scores
Program affiliation: University of Skövde
Decision-making agency: Vinnova FFI

Summary of results and conclusions (full report is attached to the proposal):

- Sophisticated fusion of data from various sources (traffic infrastructures, external traffic interactions, internal vehicle behavior, advanced driver monitoring) stands in contrast to current ADAS systems, which primarily rely on vehicle dynamics and data from onboard sensors like cameras and radars, focusing on the immediate vicinity of the vehicle.
- Anticipatory real-time capabilities, including predictive processing, are vital for interactions with AI systems. This approach paves the way for more adaptive and personalized Human-Machine Interface (HMI) interactions, a significant departure from existing ADAS systems that typically offer static and non-personalized HMIs.
- Deep Learning (DL) is undoubtedly a potent technology, yet it exhibits certain limitations, notably its substantial computational demands, limited explainability, and susceptibility to robustness issues – qualities of paramount importance in effective ADAS. As a result, the exploration of an alternative approach, utilizing Evidence Theory for information fusion, emerges as a viable strategy to amalgamate multiple methods and attain thorough safety assessments.

Feasibility

Project contents

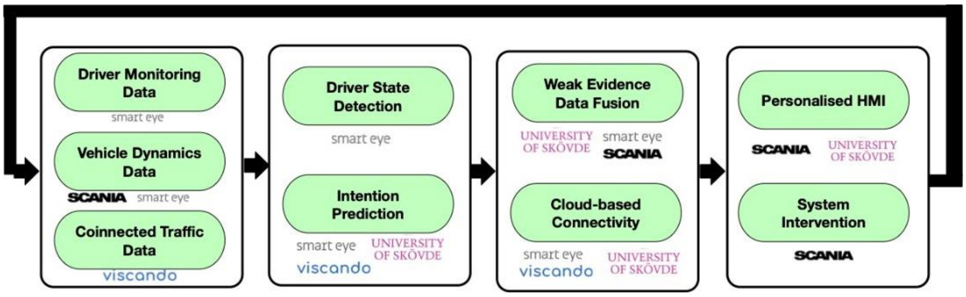


Figure 1. Project Workflow and Partners' Participation

Project activities

The project activities will be distributed across six work packages, denoted as WP 0-5, which will run largely concurrently, as illustrated in Figure 3. WP0 and WP5 are primarily responsible for the overall project management and dissemination of results, both within the consortium and to external stakeholders.

In essence, WP1 will focus on refining the selected two use cases: rear-end accidents between trucks and cars and intersection accidents between trucks and cyclists. It aims to establish functional requirements for ADAS tailored to these use cases. This will be done by employing a range of different methodologies, including literature review, interviews, workshops and observational studies in real traffic. Based on these requirements, WP1 will also develop a high-level description of the most promising ADAS solutions (one for each use case), which will subsequently be developed in WP2 and demonstrated in WP3. One of these solutions is anticipated to be relevant for the market in near-term (2029), while the other one will be more relevant for the market in long-term (beyond 2029).

In WP2, a research platform will be created to encompass all technical sub-systems essential for the proposed ADAS. These include:

- The cloud platform and analytics, including the V2X communication abstraction layer for data exchange between infrastructure and vehicles.
- Data fusion algorithms able of combining various data utilizing Evidence Theory.

- Algorithms for situational awareness.
- Adaptable Human-Machine Interfaces (HMI).

The development of these sub-systems will rely on small-scale user-in-the loop evaluations in relevant set ups (VR, video, driving simulators, vehicles) depending on the task and its maturity.

WP3 will focus on the integration of the sub-systems developed in WP2 into truck demonstrators (one for each use case). This demonstration will take two forms: one will be implemented in an actual truck, while the other will take the shape of a driving simulator. It is, however, important to note that the goal is to develop and demonstrate proof-of-concept prototypes of ADAS for the selected use case (TRL 6), rather than to create fully functional solutions.

In WP4, these demonstrators will undergo evaluation for the selected use cases, involving extensive testing with truck drivers. The aim is to study safety, efficiency and driver experience effects of these ADAS, and compare to corresponding systems without the novel features (see Measurable objectives). In WP5, the demonstrators will be showcased to external stakeholders, including FFI representatives, on two separate occasions.

Working and research methodology

Overall, the project employs a systematic approach, integrating various methodologies and demonstrations, to develop, evaluate, and refine proof-of-concept prototypes of next-generation ADAS tailored to the two specific use cases:

- Identifying use cases and functional requirements:
    - Established methods from research and the automotive industry.
    - These methods encompass literature reviews, interviews, workshops, and observational studies, offering insights into real-world driver behavior and traffic scenarios.
- Data fusion and situation awareness assessment:
    - Draws from AI methodologies not extensively explored in ADAS design.
    - Utilizes Evidence Theory to combine potentially ambiguous data regarding driver state, intentions, and external/cloud-connected data.
    - Aims to eliminate uncertainties arising from inconclusive data, enhancing situational awareness and empowering ADAS for informed decision-making.
- Human-Machine Interface (HMI) design:
    - Informed by co-creation workshops, a collaborative approach involving experts, end-users, and designers and small-scale user evaluation studies
    - Promotes collective idea generation, problem-solving, and innovation, with activities like brainstorming, prototyping, and feedback sessions.
    - Focuses on user-centered solutions and addressing specific challenges through collaborative creativity.
- User evaluations:
    - Smaller-scale user assessments during subsystem development.
    - Two comprehensive user studies to evaluate overall performance in terms of safety, efficiency, and user experience.
    - Combines qualitative methods (surveys, interviews) and quantitative data (event frequency, driving behavior, driver state, etc.) for thorough evaluation.

This mixed-method approach ensures a comprehensive exploration of innovative ADAS functionalities while maintaining a clear focus on user (and market) relevance and impact.

WP0	Project Management & Dissemination
Leader (role and responsibility)	University of Skövde is the main contact point for this project assuming a coordination role. Dissemination is also coordinated.

Other participants (roles and responsibilities)	All
Description of contents	The project management ensures that each team member has a clear understanding of their role in the project, and that the project stays on track and within budget.
Method/approach (when relevant)	Key activities include (1) Project planning through periodical meetings and timely deliverables, (2) Resource management to allocate the material needed to demonstrate the project outcomes, and (3) Budget management to ensure that expenditures are within the approved budget. (4) Coordinate dissemination: In Journals as defined in WPs and one dissemination events for external stake where Trafikverket, VTI and Vinnova is invited.
Delivery and evaluation	This work-package runs through the entire project duration and is evaluated through regular progress reports to FFI.

WP1	**Needs and Requirements**
Leader (role and responsibility)	HiS, coordinates activities and makes sure that the deliveries are in line with overall objectives and expectations of the project.
Other participants (roles and responsibilities)	Scania, Smart Eye
Description of contents	This work-page contributes to RQ1 and 2: "*What requirements are posed on ADAS utilizing driver monitoring and external data with varying degrees of uncertainty considering a) user needs and expectations, b) upcoming regulatory and safety assessment demands, and c) capability of driver monitoring and external data?"* & "*What ADAS utilizing driver monitoring and external data would be valuable in terms of safety, efficiency and user experience in short and long term perspective??*". The work will be divided into the following tasks: **Task 1.1 (HiS, Scania):** Use case specification – identify which use cases are most relevant to focus on and describe them to a level that enables identification of functional requirements in Task 2.2. (D1.1) **Task 1.2 (Scania)*:*** Functional requirements based on user needs and expectations for the selected use cases, upcoming/anticipated regulatory and safety rating protocols (GSR, EuroNCAP) and capability of DMS and external data sources. (D1.2 and D1.4) **Task 1.3 (Scania, Smart Eye, HiS): D**river support functions based on the results from Task 2.1-Task 2.3 that the project will investigate further and demonstrate. One of these solutions is anticipated to be relevant for the market in near-term (2029), while the other one will be more relevant for the market in long-term (beyond 2029). (D1.3)
Method/approach (when relevant)	Literature review and interviews identifying the current state of the art as well as relevant use cases Co-creation workshops with project partners (and external experts when relevant) User studies in simulations (e.g., VR, video) and observational studies in traffic
Delivery and evaluation	**D1.1:** List of use cases in which fusion of new data sources (DMS, external traffic data, etc) could be beneficial to truck drivers **D1.2:** List of functional requirements based on user needs and expectations for the use cases identified Task 1.1 and upcoming/anticipated regulatory and safety rating protocols.

	D1.3: High-level description of selected drivers support functions that the project will investigate into more detail **D1.4:** One scientific paper (journal or conference)

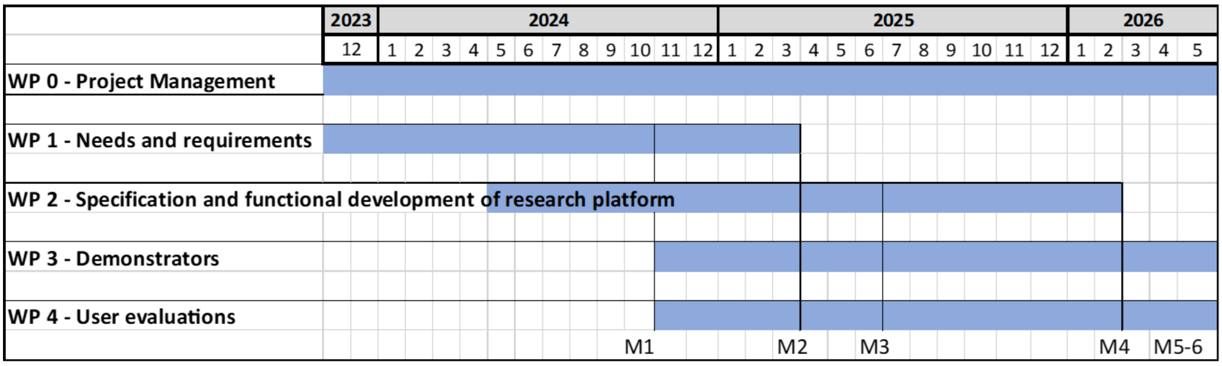
WP 2	Specification and functional development of research platform
Leader (role and responsibility)	Smart Eye coordinates activities, develops communication abstraction layer
Other participants (roles and responsibilities)	HiS: Data fusion and situation-awareness assessment Viscando: Test of infrastructure based communication Scania: Design HMI for novel ADAS
Description of contents	The WP will develop a research platform, or architectural framework, encompassing all technical sub-systems essential for the ADAS proposed in WP1. It contributes to RQ3: "*What architectural framework is best suited for efficiently collecting and utilizing V2X data, and implementing evidence fusion algorithms in real-time?*" and RQ4: *"What evidence theory fusion models and evaluation methods are best for achieving a holistic level of situation awareness, while enhancing user experience, and effectively utilizing novel HMI functions within the context of ADAS?"* The work is divided into the following tasks: **Task 2.1 (HiS, All):** Specification of the cloud-based connectivity platform with respect to data flows including how data is collected, transmitted, stored, and analyzed. (D2.1) **Task 2.2 (HiS, All):** Development of in vehicle platform including the situation awareness and a method to assess the overall safety level that will govern the HMI and interaction with driver. Information fusion will be used to aggregate the data flows specified in Task 2.1 utilizing Evidence Theory. Test-cases to validate situation awareness will also be developed here. (D2.2, D2.4) **Task 2.3 (Smart Eye, HiS)**: Development of the cloud based infrastructure including communication abstraction layer for vehicle and infrastructure with methods to read cloud-based database. The layer allows portability of database and provides multiple actors to exchange information. (D2.3) **Task 2.4 (Scania, HiS, Smart Eye):** Design of adaptable HMI for the proposed ADAS. To capture user needs, the design will be informed by co-creation workshops and small-scale user-in the loop evaluations. (D2.4, D2.5)
Method/approach (when relevant)	Selection of in-vehicle and cloud platform based on available COTS HW and software like location aware databases. Literature review of new developments within information fusion with regard to situation awareness, threat assessment and evidence combination. Review of existing cloud-based platforms for connected vehicles and infrastructure to identify their capabilities, as well as any challenges or limitations that need to be addressed Systematic analysis of data flows required for realization of the proposed ADAS. Develop a conceptual model that is tailored to user evaluation and test and validate the model, using simulations and real-world pre-collected data, under selected scenarios. Co-creation workshops and small-scale user in the loop studies.
Delivery and evaluation	**D2.1:** A dataflow specification and a platform for data sharing and analytics **D2.2**: An integrated in-vehicle platform serving as a central hub for data sharing and fusion analytics of evidence data. **D2.3:** The cloud platform including definition of communication abstraction layer **D2.4:** Specification of adaptable HMI **D2.5:** One scientific paper (journal or conference)

WP 3	Demonstrators
Leader (role and responsibility)	Scania: Coordination of the work, implementation of demonstrators
Other participants (roles and responsibilities)	Smart Eye: Driver state sensing, Communication and data exchange, data collection demonstrators. Viscando: Installation of infrastructure-based sensor system HiS: Support in the integration of situation awareness
Description of contents	This WP focuses on integration of the sub-systems developed in WP2 into two truck demonstrators (one for each use case) and data collection vehicles as well as infrastructure sensors. The work is divided into the following tasks: **Task 3.1** Development and test of the two demonstrators: one will be integrated in an actual truck, while the other will be integrated in a driving simulator. Development of 3 car demonstrators for on road data collection (D3.1). **Task 3.2** Development and test of the necessary infrastructure to support information exchange between the vehicles and the infrastructure. This will involve the installation of sensors and communication devices on the roads and the database for information exchange. (D3.2)
Method/approach (when relevant)	Implementation and technical testing of the demonstrators.
Delivery and evaluation	**D3.1:** Two truck demonstrator and 3 car data collection vehicles. **D3.2:** An infrastructure demonstrator

WP 4	WP4: User evaluations
Leader (role and responsibility)	Scania: coordination of the work, specification of evaluation protocols, test facilities, drivers, execution of user studies, data analysis, design guidance specification
Other participants (roles and responsibilities)	HiS: specification of evaluation protocols, data analysis, design guidance specification Smart Eye: specification of evaluation protocols, data collection and analysis
Description of contents	The overall goal of this work package is to demonstrate the feasibility and effectiveness of the proposed ADAS. The demonstrators will serve as proof of concept of these systems and will provide valuable insights into the challenges and opportunities of implementing infrastructure-based exchange and fusion of information for improved driving safety. This WP to RQ5: "*How will drivers' behavior be influenced by using ADAS based on the proposed fusion models incorporating connected, driver monitoring, and traffic monitoring data?*" **Task 4.1 (Scania, HiS, Smart Eye):** Specification of evaluation metrics and methods to be used in Task 4.2. Both subjective and objective metrics for assessment of safety, efficiency, and driver experience will be captured. (D4.1) **Task 4.2 (Scania, HIS, Smart Eye)**: Conduct evaluation with drivers using ADAS demonstrators from Task 3.1 and Task 3.2. (D4.2) **Task 4.3 (Scania, HiS, Smart Eye):** Analysis of results and conclusions. (D4.3, D4.4)
Method/approach (when relevant)	The evaluation protocols (i.e. methods and metrics) will be specified based on literature review and established practices. Both subjective (e.g., self-assessment of experience) and objective methods (e.g., distraction based on Smart Eye system) will be used. The evaluations will be carried out in experimental settings with truck drivers for the two use cases specified in WP1.
Delivery and evaluation	**D4.1:** User evaluation protocols. **D4.2:** User study execution **D4.3:** Results from the user evaluations of ADAS

	D4.4: One scientific paper (journal or conference)

Scheduling



Milestone	Description	Date
M1	List of user requirements	May 2024
M2	Connectivity platform and situation awareness fusion model	Nov. 2024
M3	Demonstrators for vehicles	June 2025
M4	Demonstrator for infrastructure	Oct. 2025
M5	Safety assessment from user perspective	Dec. 2025
M6	Recommendations to authorities	May 2026

Project financing

	Budget per participating party				Total budget/WP
	HIS	Scania	Smart Eye	Viscando	
WP 0 Project management	638 600	133 950	105 840	50 000	**928 390**
WP 1 Needs and requirements	838 600	939 500	929 200	150 000	**2 857 300**
WP 2 Specification and functional development	1 802 933	946 500	1 458 400	293 000	**4 500 833**
WP 3 Demonstrators	525 733	919 050	982 000	250 000	**2 676 783**
WP 4 User evaluations	1 000 245	1 786 000	1 433 894	0	**4 220 139**
TOTAL budget per part	**4 806 111**	**4 725 000**	**4 909 334**	**743 000**	**15 183 445**

Utilization

Research deliveries are tailored to meet the specific needs of the industrial partners and all of them intend to incorporate the findings into their technology and business roadmaps. The results from the project are as such expected to enhance their innovation and competitiveness on a global scale.

Scania currently offers a broad range of ADAS to our customers. However, these solutions do not incorporate rich data about drivers and ambient traffic. This project is thus an important step towards unlocking the potential of such data and understanding how we can improve our existing, or creating completely new, ADAS. By collaborating with Smart Eye and Viscando, we expect to broaden our knowledge on which data could be enabled by camera-based driver and ambient monitoring systems in future, and how situation-awareness in ADAS could be improved by combining these additional data. We also recognize the importance of harnessing these new data for adaptable and personalized HMI, with valuable HMI design guidance resulting from our collaboration with HiS. These insights will inform Scania's (and our parent organization TRATON's) future ADAS development, enabling us to better meet and exceed the expectations of our drivers and customers. Additionally, this knowledge will aid us in discussions with regulatory bodies (UNECE), standardization organizations (ISO), and safety assessment authorities (EuroNCAP).

Smart Eye has primarily customized its existing Driver Monitoring System (DMS) for passenger car drivers. Through our collaboration with Scania in this project, we have the opportunity to expand our system to address the unique requirements of truck drivers. The outcomes of this project will aid us in improving the driver state assessment within our license package. Additionally, Smart Eye is exploring the possibility of offering real-time support from a central location. This project serves as an initial trial for this feature, with the aim of market introduction if it proves successful.

Viscando expects to gain deeper understanding for how real-time traffic awareness data can enable improved or completely new ADAS. By providing data from infrastructure-based sensors for prototypes of novel ADAS and HMI, Viscando will, together with partners, identify, on one hand, requirements and research & development needs for sensors, data processing and sharing, and on the other hand, societal benefits and business opportunities enabled by the technology.

HiS will integrate the knowledge from this project to start a new master's program as well as courses within life-long-learning on smart transportation systems. These courses will be designed for professionals in the transportation industry, similar to the current WISER platform at HiS. Additionally, students in Computer Science, Information Technology, Cloud Computing, User Experience Design, and Data Science will be offered bachelor's and master's theses related to our research, linking the project outcomes with university education programs.

To ensure utilization and dissemination of project results outside the consortium, the project will:

- Publish at least 3 research papers in relevant conferences and journals.
- Associate project to SAFER and present results to their members.
- Engage in discussions via platforms such as Drive Sweden and AI Sweden.
- Give input and affect standardization and regulatory discussions in ISO, UNECE.

Actors

The University of Skövde coordinates and leads the project, with the representatives from Scania, Smart Eye and Viscando contributing through regular progress review meetings. Work package members convene bi-weekly to support task completion.
The project has a **Steering group** made up of project work-package leaders and the project coordinator.
To ensure the dissemination of project results beyond the consortium, an external **Reference group** will be formed, featuring stakeholders from Autoliv, SAFER, Drive Sweden, VTI, VCC and Trafikverket.

Partners:

SCANIA CV AB is a world-leading supplier of transport solutions, including trucks and buses for heavy transport in combination with an extensive product-related service offering. With around 52,100 employees Scania is present in around 100 countries. Scania is part of the TRATON GROUP together with MAN, Volkswagen Caminhões e Ônibus and Navistar – which warrants a large-scale spread of the results from this project in automotive industry across the globe. The Scania core team in the project consists of: Andreas Absér (Senior Human Factors Specialist), Johanna Vännström (Senior Human Factors Specialist) and Azra Habibovic (Human Factors and Automation Technology Leader with PhD). Technical expertise in the form of feature owners, prototype developers and test platform developers will be involved as needed.

Smart Eye AB is an SME founded in 1999 and headquartered in Gothenburg. The company specializes in human-centric AI solutions predicting and assisting human behavior in complex environments. With customers across five continents in various sectors, including automotive, aerospace, and media analytics, Smart Eye is a global leader in Driver Monitoring Systems (DMS) – a crucial component in this project for improving road safety. Smart Eye's DMS uses a multitude of advanced computer vision algorithms to track and understand driver state, issuing warnings for hazardous behaviors like drowsiness or inattention. The company actively participates in multiple Vinnova (FFI) projects dedicated to improving road safety. The project is led by Svitlana Finér (Project management, Phil Lic.) and involves Victor Brandt (Function Developer, MScEE), Torsten Wilhelm (Technical expert on driver state, PhD), Joel Severin (Communication and database development, MScEE).

At the **University of Skövde** the Informatics Research environment encompasses six research groups active in the areas of artificial intelligence, cognitive/interactive systems, distributed real-time systems, information systems, software systems and media, technology and culture. Synergy effects are achieved by integrating these research efforts in one research specialization. University of Skövde members in this project are Paul Hemeren (Associate Prof. in Informatics), Yacine Atif (Prof. in Computer Science), and Joe Steinhauer (Senior Lecturer in AI).

Viscando AB, an innovative start-up company from Gothenburg, helps making mobility and autonomy safer, more sustainable and efficient – in cities, on motorways and at industrial worksites. Using our 3D vision and AI based sensing technology, we perform detailed real-time traffic measurements, and provide both actionable insights on traffic safety and efficiency, and real-time awareness of road user movements, interactions, and accident risks. In recent years, Viscando has been collaborating with developers of ADAS and Autonomous Driving (AD) technologies, researching on applications of detailed traffic data from 3D&AI sensors for novel ADAS and AD features, but also for faster and more cost-efficient introduction of these technologies. Viscando team will mainly consist of: Yury Tarakanov (PhD, research & project lead); Ulf Erlandsson (CTO, technology leader) and Michael Bolbat (application engineer and data scientist).

Equality

The project team includes 5 females and 8 males, with females expected to contribute to around 40-50% of the work. Furthermore, 50% of leadership positions driving the industrial project's benefits from Scania and Smart Eye are held by females.

Regarding project outcomes, we will prioritize gender equality design when designing ADAS to enhance safety of all users. User requirements will be derived from an equal population of males and females. Similarly, our user evaluation will encompass drivers of both genders to ensure inclusivity in future ADAS development. This evaluation will explore gender-based differences in ADAS acceptance and effectiveness, considering their impact on safety levels.

Building on gender-related findings from our FFI-funded pre-study, particularly regarding HMI engagement and driving safety, we are well-prepared to enhance the acceptance and effectiveness of our gender-adjusted driving support systems.

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