HADRIAN:

Holistic Approach for Driver Role Integration and Automation Allocation for European Mobility Needs

Description of initial Automated Driving application descriptions

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1 EXECUTIVE SUMMARY

This document describes the initial application descriptions (IADs) of automated driving for the HADRIAN project that were developed by work package (WP) 1.1. The IADs describe the mission, environments, and user groups, who will be using the HADRIAN automated driving innovations. The IADs form an important source of requirements for the research and demonstration activities in all the following work in the HADRIAN project, specifically in work packages two to six. The IADs also form the input for the detailed application descriptions (DADs) that will be subsequently defined in WP 1.2. The IADs include the main concepts for the automated driving functionality, mobility scenarios for how they are intended to be used, and related initial requirements for the HADRIAN WPs, specifically for driver and environmental sensing, human-machine interaction, and safety. The IAD's were created based on collaborations in several workshops to which all the consortium partners were invited to contribute. In these workshops, different mobility personas where discussed and associated mobility needs were identified. For these mobility needs, mobility scenarios were subsequently developed that reflect how automated driving functionality could address these mobility needs. This document summarizes the results of these discussions and considerations while attempting to align them with the HADRIAN project objectives. The document also identifies the initial set of requirements for sensing the driver and environment, the human-computer interactions, and safety hazards. These initial requirements will be refined during the next steps.

Keywords: Concept of Operations, application description, scenario basedscenario-based development

2 OBJECTIVES

HADRIAN has three types of project objectives for safe, acceptable and trustable transition of human drivers between different levels of AD: Firstly, to comprehensively demonstrate safety, acceptability, and trustworthiness of developed HADRIAN solutions (Obj. 1-3); secondly, to develop required technology innovation bricks and provide numerous demonstrators to tangibly illustrate HADRIAN achievements (Obj. 4); and thirdly, to identify and create design & development methods for human-centred AD and to make HADRIAN achievements available to stakeholders including industry, public authorities, and research organizations beyond the project (Obj. 5). All three types of objectives are targeted toward successful human-centred system development beyond traditional methods of technology development.

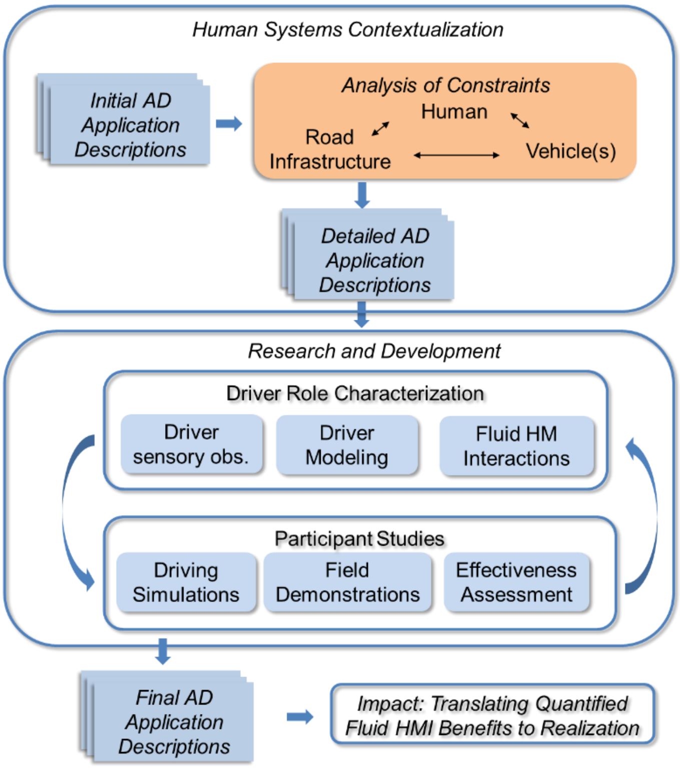

Figure 1. HADRIAN Approach

The main elements of the HADRIAN approach to meet these objectives are depicted in Figure 1. The approach starts by developing concrete and balanced human-system contextualizations from a review of currently dominant EU and world-wide mobility needs as well as benefit expectations. Specific mobility personas are identified and their mobility needs contextualized. These contextualizations are important to put the human in a socio-technical field that allows to sufficiently derive the most critical influences on his or her behaviour. The contextualizations and initial hypotheses about how automated driving functionality could address these needs are formulated in form of initial AD application descriptions. The IADs describe the mission, environments, and user groups, who will be using the HADRIAN automated driving innovations and are described in this document. Specifically, the IAD's reflect possibilities for how new definitions of the human driver role could result in safer and more acceptable automated driving systems. The IADs will be refined over the following six months to result in detailed application descriptions with more details and more vetting by the partners. Finally, at the end of the project, the final AD application descriptions describe the results and conclusions at the end of the HADRIAN project.

3 APPLICATION DESCRIPTIONS

The initial application descriptions (IADs) provide a first description of the HADRIAN automated driving innovations concerning their mission, environments, and user characteristics. The focus is on highlighting the innovative components that are hypothesized to achieve the HADRIAN objectives in terms of safety, trustability, and acceptability of a new driver role for automated driving. It is also outlined, *how* these HADRIAN innovative components are used, *by whom*, and in *what environment*. Therefore, the IADs represent a first description of these innovations for later refinement and research in the WPs. The final application descriptions will comprise all the findings of the HADRIAN project and are planned at the end of the HADRIAN project.

IADs have following components:

1. The **main innovative components** summarize the main HADRIAN innovative components on a functional level. These are described in this section.
2. The **mobility scenarios** describe how the HADRIAN innovative components are planned to be used.
3. The **initial requirements** for the HADRIAN WP's 2, 3, and 4. These are described along the mobility scenarios and target *driver and environment sensing needs*, *user-centered interaction needs*, and *safety hazards*. The mobility scenarios and initial requirements are described in section 4.

3.1 HADRIAN Innovative Components

There are four main innovative components that HADRIAN introduces that are described in this section.

3.1.1 HADRIAN Automated Driving Levels

We define six HADRIAN automated driving levels (ADLs) that are based on the SAE ADLs, but add additional features that are intended to improve the acceptability, trustability and safety of the associated driver responsibilities and tasks . The HADRIAN ADLs are based on the (SAE International, 2018) ADLs of partial (SAE ADL 2[1]), conditional (SAE ADL 3), and high automated driving (SAE ADL 4). However, the HADRIAN ADLs add specific assumptions that make them different from SAE J3016 ADL's, they are referred to as HADRIAN ADL 2, 3, and 3+ For the elderly driver, they are referred to as HADRIAN ADL 2E, 3E, and 3E+.The main differences of the HADRIAN ADLs compared to the SAE ADLs are three core features of the HADRIAN project. First, the transitions to and from automated driving are made more predictable to the driver by utilizing information from the road infrastructure and from other connected vehicles to guarantee sufficiently large minimum transition times to the driver and also to make the transitions more predictable and plannable in terms of the time that can be spent driving at specific ADLs. Secondly, the transition between ADLs is prepared and monitored by including driver monitoring and fluid, adaptive intervention offerings. Table 1

[1] ADL 1 and ADL 2(SAE J3016): Level 1 (*driver assistance*) and level 2 (*partial automation*) *features* are capable of performing only part of the *DDT*, and thus require a *driver* to perform the remainder of the *DDT*, as well as to *supervise* the *feature's* performance while engaged. As such, these *features*, when engaged, support, but do not replace, a *driver* in performing the *DDT*.

overviews the critical properties of these three different HADRIAN ADLs. And thirdly, the ADLs are dynamically adapted to the needs of the driver and his or her contextual situation.

Table 1. HADRIAN ADLs and their extension over the SAE levels

	Transition preparation time	Driver monitoring for	Driver monitoring for manual driving quality	Minimum duration of automated driving	Transition time to manual driving	Primary Driver Responsibility
HADRIAN ADL 2/2E	*No*	*Information Assistance & Suggestions to Transition*	*Yes*	*No*	*NA*	*Driving*
HADRIAN ADL 3	*Yes*	*Transition Assistance*	*No*	*At least 10 min (?)*	*Short (20 sec?)*	*Driving & non-driving tasks*
HADRIAN ADL 3E	*Sometimes*	*Information Assistance and Suggestion to Transition*	*Yes*	*At least 10 min (?)*	*Short (20 sec?)*	*Driving*
HADRIAN ADL 3+	*Yes*	*Transition Assistance*	*No*	*At least 30 min (?)*	*Long (1 min?)*	*Driving & non-driving tasks*
HADRIAN ADL 3E+	*NA*	*Safety Take-over*	*Yes*	*At least 30 min (?)*	*Long (1 min?)*	*Driving*

3.1.2 Fluid Interaction Support System (FIS)

The FIS regulates all interactions between the driver and the vehicle and clearly states the current state of the ADL in an appropriate way and indicates upcoming ADL changes. The FIS monitors the driver's physiological, mental and behavioral states and his/her activity and decides, whether his/her state is appropriate (i.e. Fit to drive [F2D]) for the current automation level. If this is not the case, it initiates appropriate interventions or gives suggestions. The FIS receives information from the control transition planner (CTP, see below) and displays it in an appropriate way to give the driver information about upcoming ADL changes and relevant planning information. The FIS supports the driver while transition of controls by, e.g., giving the most important information about the driving situation shortly before take-over. The FIS adapts the cabin to make the driver comfortable based on the current situation, driving level, and the driver’s activities. For example, if the driver is napping in ADL 3+, it might change the color within the vehicle and also reduces visibility from the outside for a less intrusive experience. The FIS suppresses vehicle speech outputs during high-workload manual driving or while in relax mode during automated driving. The FIS might detect motion sickness and provide counter-motion-sickness cues.

3.1.3 Control Transitions Planner (CTP)

The CTP plans the transitions between automated and manual driving and vice versa. Once the trip destination has been communicated to the FIS, the CTP plans a route that allows for the appropriate level of automated driving. The CTP tells the vehicle’s navigation controller to take a route that has more automated driving infrastructure so that it can drive at higher ADLs. On the other hand, if the driver is in a hurry or does not require automated driving at a high level, the CTP plans for a faster route at lower ADL. Furthermore, the CTP provides the FIS with a preview of the transition times, which are displayed and keep the driver up-to-date at what time new transitions are needed back to manual driving and at what time automated driving will be again available. The FIS integrates this information with the navigation and routing display so that the driver has also spatial information about the upcoming transitions.

3.1.4 Adaptive Tutoring Component (ATC)

Because the vehicle has many adaptable options for supporting the driver through various information assistants and automated driving assistants the driver has to get to know them. Therefore, the driver learns over time about these options and gets suggestions from the vehicle about how driving could be helped with the help of a tutoring system. The tutoring system supports the driver over time and adapts the tutoring sessions according to the driver’s knowledge of the system (therefore, preventing to show already learned tutoring sessions over and over again). Also, a special form of tutoring is available online or via virtual reality glasses. so that the driver can pass a test for using the ADL features. If the tutoring system detects that the driver is over-trusting the system (e.g., trying to use the system functionalities in unsuitable conditions) or if it detects that the driver has difficulties to engage or disengage the different system modes, it adjusts the tutoring sessions accordingly – e.g., by again showing a quick tutorial, which is suitable for the difficulties the driver experiences.

4 MOBILITY SCENARIOS AND INITIAL REQUIREMENTS

Altogether, we developed 10 mobility scenarios for three different personas: Harold, an elderly driver, Sven, a truck driver, and Florence, a business woman, who wants to work in her self-driving car. The methodological procedure for developing the scenarios is described in detail in section 5. In general, it was based on extensive literature research, the conduct of workshops, and iterations together with the project partners.

As outlined, the mobility scenarios describe how the HADRIAN innovative components are planned to be used. Table 2 provides an overview of the different mobility scenarios, which are described in detail in the following subsections.

Table 2. Overview of mobility scenarios

Scenario ID	Persona	Mission	HADRIAN Highlight	HADRIAN ADL
H1	Harold (elderly)	Countryside drive to visit daughter	Information assistant to support manual driving and suggestion for ADL 2E	2E
H2		Motorway drive to vacation	Information assistant to support manual driving and suggestion for ADL 3E	3E
H3		City drive to visit doctor	Auomated safety take-over /guarding angel	3E+
S1	Sven (truck)	Time pressure	Information assistant	2
S2		Boring drive in traffic	Short term automated driving	3
S3		Long-distance trip	Longer term automated driving	3+
F1	Florence (office)	Telecons	Manual driving support	2
F2		Light office work (e.g., email reading)	Short term automated driving	3
F3		Heavy office work (e.g., email	Long term automated driving	3+

		writing) or relaxing		
F4		Car Sharing	F1 – F3 in non-owned vehicle	2 – 3+

Each subsection is structured as follows: First, we introduce the respective persona, who represents the user group we are targeting. Then, we describe those persona's needs and typical situations they may face. Based on this, we outline the particularities for the main HADRIAN innovative components (i.e., ADL, FIS, CTP, Tutoring), which is followed by the detailed description of the mobility scenario and the identified initial requirements for each scenario segment (summarized in a table for each mobility scenario).

Thereby, the driver and environment sensing needs focus on what needs to be monitored of the driver and the environment in order to ensure an appropriate system reaction. The user-centered interaction needs describe what information should be provided by the system and what information needs to be put into the system from the perspective of the user. The safety hazards (Ericson, 2005) describe any real or potential condition that can cause injury, illness or death to people. A potentially unsafe condition is a result of failures, malfunctions, external events or a combination of all of them.

4.1 Harold Scenarios (Elderly)

Harold is a 78 years old man living in the suburbs of Paris. He used to drive his car for his whole life. Now he lives alone and his only daughter is about a 1-hour drive away on the country side. Harold is hesitant to use novel technologies. He has difficulties using fancy new technologies and even does not have a smart phone! Though, he liked the safety assistance features on his previous car.

He has recently received some driving restrictions because of following difficulties: Accordingly, he is not allowed to drive on highways anymore or more than 30 km around his home. This is a problem because he really wants to stay mobile! This is what the inspectors found:

- He cannot quickly focus on relevant aspects of complicated situations under time pressure
- This leads to problems at intersections
- He exhausts faster than before
- Difficulties to drive longer distances
- Has limited peripheral vision
- Difficulties at recognizing objects coming from the side
- However, he can drive without problems in uncomplicated situations such as straight roads with little traffic

Figure 2. Harold, the elderly driver

4.1.1 H1: Harold gets Adaptive Information Assistance

Harold want to visit his daughter in the countryside

This is challenging because, e.g., there are many country roads with small villages and narrow roads, where he has to negotiate oncoming traffic. While he has driven the road many times, seemingly every time there are new buildings or constructions that make it difficult to find the right way. Sometimes, deer and bicyclists and even pedestrians seem to be jumping out of nowhere.

Table 3. Particularities of the HADRIAN innovative components for mobility scenario H1

Automated Driving Level	This an extension to partial driving automation (**SAE** ADL **2**) here referred to as HADRIAN ADL 2E. Harold stays always in the loop of driving but is aided in his driving through an adaptive assistant. Only if safety cannot be assured anymore, a planned emergency stop is executed.
Fluid Interaction Support	**An adaptive Assistant (**Sensing system**)** gives situational information about the state of the environment and depending on the driver's Fit to Drive (F2D) value. It intelligently turns raw environmental information from the sensors into easy-to-process instructions and explanations for the driver. The adaptive assistant will always coordinate this information as much as possible with the driver without overloading him, as much as possible. The adaptive assistant is highly customizable and adjusts to the specific needs and constraints of the driver (e.g., visual or auditory, cognitive, motoric impairments) and of the environment (e.g., lighting condition).
Transition Planning Control	There is not much transition planning control needed because the driver is continuously in the loop. However, in cases when the driver wishes to, or the F2D value is too low, or if it is detected that the current and upcoming environmental or traffic complexity is too high, a suggestion is made to Harold stop driving.

Tutoring	Before the driver starts driving, the system explains itself to Harold, what it can do etc. The system may give recommendations, if the driver should even drive today and if he should plan in breaks to keep fit.

Table 4. Mobility Scenario H1 – Harold gets Adaptive Information Assistance

No	Scenario Segment	Driver and Environmental Sensing Needs	User-Centered Interaction Needs	Safety Hazards
1	*Before Harold starts his car to drive to his daughter on the countryside, he plans his trip by telling his car, that he "wants to visit his daughter".*	Sensing system continuously records a set of data which is forwarded to the "fluid" HMI, for example: • In-cabin noise levels to adapt auditory messages • In-cabin luminance to adapt contrast of visual information • Vibration level to adjust haptic feedback • Meteorological information to adapt cabin temperature	Entering destination Receiving confirmation of destination	None identified
2	*The car has already stored his daughter's address, so it can evaluate the trip to get there. It gives Harold information about how long the trip will take.*	Sensing system records traffic information on the way to his daughter	Receiving information about the trip (e.g., ETA, route, traffic jams, tolls, compulsory manual driving zones)	None identified
3	*The car assesses Harold's F2D score and based on his physical and mental state, it tells Harold how many breaks he will likely want to take and plans them for him and how much assistance he will get on his trip. If Harold were in a particularly bad condition, it would ask him "if he really wants to drive, because he does not seem to be so fit today".*	The system is using data about Harold's state to assess a F2D score (using his sleeping pattern, electrocardiographic [ECG] measures, electrodermal activity [EDA], attentional level and emotional state -eye movements and facial expression	Receiving information about the F2D score Requesting information about the trip, breaks, amount of assistance provided by the car, etc. Receiving information that the system can be overrun – probably needs not be presented once Harold knows how to do it	The system might not correctly recognize the state of the operator, and it might not properly support him.
4	*The first challenge Harold must face are various intersections with bus-stops, schools, kindergartens, etc. next to them. If Harold has a high enough F2D value, the car does not display anything*	Sensing system senses and interprets Harold's state, as well as the traffic and environment scenery to identify potential safety critical situations and to infer	Receiving guidance how to master the situation if needed Option to ask for another route to avoid the situation / Suggestion of other routes	The system might not accurately calculate the F2D value and distract the operator improperly causing unsafe driving.

	differently from a normal car. However, if Harold's F2D value were too low, well before arriving at such an intersection, the system already tells him about potential dangers he could face there, how fast he must drive, etc. An augmented reality display activates if needed to highlight critical information Harold should be aware of.	whether Harold needs more support (information). System senses whether Harold has seen the critical objects in the scenery (e.g. by means of eye-tracking)	(who initiates the information exchange?) If Harold has not seen a critical object, the system highlights this for him.	
5	*To drive out of his small town, Harold must cross a roundabout. The car now shows distance indicators for approaching objects, which could be dangerous, like bicycle riders.*	Sensing system senses and interprets the traffic and environment scenery in relation to Harold's driving behavior to identify potential safety critical situations (e.g. Harold comes too close to a car entering the roundabout) System senses whether Harold has seen the critical objects in the scenery (e.g. bicycle approaching from right side when Harold is exiting the roundabout) by sensing his eye-movements and whether he is acting accordingly (sensing of driving behavior in relation to environment)	Being made aware of vulnerable traffic participants, who Harold may not notice otherwise Enhancing available information for specific user limitations	The system might not recognize critical objects leading the operator to an accident.
6	*A color-coding system, like an internal traffic light in the car, tells Harold when it is safe for him to drive into the roundabout.*	Sensing system senses and interprets the traffic and environment scenery to determine when it is safe to enter the roundabout Sensing system senses Harold's driving behavior (e.g. whether he wants to drive into the roundabout too early)	Recognition of Harold's intention to enter the roundabout Receiving confirmation that it is ok to enter the roundabout	The in-vehicle traffic light might give wrong suggestions leading the operator to perform a hazardous maneuver.

7	*After leaving the town, Harold gets to a rural street, surrounded by forests. This makes it difficult for Harold to recognize potential hazards, like crossing wildlife or approaching overtaking cars. The car luckily realizes, based on Harold's physical and mental state, if he is safe to drive right now. If he is not safe to drive, the car suggests a stop.*	Sensing system senses and interprets the traffic and environment scenery to identify potential safety critical situations (e.g. overtaking cars which are difficult to see for Harold). Sensing system senses whether Harold has seen the critical objects in the scenery (e.g. overtaking cars, crossing wildlife) by means of eye-tracking (e.g. scanning behavior in relation to environment)	Possibility to change to automated driving mode if necessary: self-initiated or suggested by car Receiving information how to change the driving mode Receiving information about the current driving mode (driving authority indicator)	The system might distract the operator and cause unsafe driving.
8	*In a curve a large truck approaches. If Harold continues to drive at the same speed it will cause a deadlock scenario, where neither the truck nor Harold can continue to drive. Because of this, the car warns Harold about the danger of the deadlock scenario in time and tells him the rule, that "smaller vehicles must make room for larger vehicles". The system also guides him through the process by giving him instructions.*	Sensing system senses and interprets the traffic and environment scenery in relation to Harold's driving behavior to identify potential safety critical situations (e.g. Harold is not slowing down despite approaching truck) Sensing system evaluates whether Harold is attending to the information presented (recording of gaze) and whether he acts accordingly (e.g. deceleration)	Receiving a warning about the situation Receiving guidance how to master the situation Avoiding overload of Harold	The system might not recognize critical objects and/or the state of the operator, leading the operator to an accident by not supporting the driver properly.
9	*After some time, Harold comes to a small village with pedestrians, bicycles, etc. and a tractor slowly drives in front of him. Harold normally does not like to overtake, because it overwhelms him, but the car has a built-in overtaking-assistant, which suggests Harold two options. Either it can tell Harold when it is safe to overtake and give instructions, how exactly he should do it, or it can completely automatically overtake.*	Sensing system senses and interprets the traffic and environment scenery (e.g. pedestrians, tractor in front of him) and determines when it is safe to overtake.	Informing driver that it is possible to over-take Receiving support suggestions (fully automated, assisted manual) by the system Receiving confirmation if the system does over-take automated	The system might not recognize critical objects and/or the state of the operator, leading the operator to an accident by not supporting the driver properly.
	Some main Research Questions in this Scenario	Can Harolds information needs and transition needs be identified via physiological, behavioral and environmental sensing and if so how?	Will Harold find these information assistants and transition suggestions acceptable and will he be able to drive more safely and more comfortably than without them? In fact, can he drive	Do these information assistants and transition suggestions introduce new safety hazards?

			sufficiently safely to compensate for his driving restrictions?	

4.1.2 H2: Harold gets Adaptive Driving Assistance

Harold wants to make a vacation trip to the sea, where he has never been before.

This is challenging, e.g., because he needs to find the right motorway entrance, needs to be driving longer than he usually can do while staying attentive, needs help to navigate as he has never driven these roads and never been at this destination, or needs to merge on the motorway (looking backward, finding a gap to merge, then continue, while maintaining speed and distance).

Table 5. Particularities of the HADRIAN innovative components for mobility scenario H2

Automated Driving Level	This is an extension to conditional driving automation (SAE ADL 3), this is here referred to has HADRIAN ADL 3E: Assisted driving takes over when Harold seems to be coming close to not being able to complete the driving process (e.g., emergency braking or steering corrections), and actively suggests transitioning from manual to automated driving (level 3).
Fluid Interaction Support	FIS supports Harold by showing and highlighting critical traffic elements like street signs, cars in his blind spot, left turn options, highway entrances and exits, etc. The principle is that Harold is driving himself and the driving task is significantly simplified by projecting all the relevant information on a large HUD and providing essential assistants especially in critical situations. The system only provides Harold with visual information when it is needed and highlights or warns in case of critical information, so that Harold is less likely to be overwhelmed. If visual information seems not to be working, auditory information is played as necessary. It can also communicate with the destination and other surroundings to give Harold information for orientation and planning of the trip. The visual information should contain little text for simplicity reasons (This is the same as for HADRIAN ADL 2E). Driver monitoring looks for cues in the behavior of Harold for fatigue, stress, distraction and exhaustion and informs the information assistant about initiating appropriate messages, warnings, or driver assistance when needed.
Transition Planning Control	Transition to level 2 partial or level 3 conditional driving is suggested when needed. Also, conditional automated driving takes over when Harold seems to be coming close to not being able to complete the driving process (e.g., emergency braking or steering corrections), and assists in transitioning from automated to manual driving (level 3).
Tutoring	Harold learns beforehand and during the drive how the system is working, what to expect, and how to use it.

Table 6. Mobility Scenario H2 – Harold gets Adaptive Driving Assistance

No	Scenario Segment	Driver and Environmental Sensing Needs	User-Centered Interaction Needs	Safety Hazards
1	*Harold wants to go on vacation and sits in his car parked in his garage and talks to the car to inform it where he wants to go.*	Sensing system monitors Harold's voice features	Entering destination Receiving confirmation of destination	None identified
2	*The information assistant then asks him whether he would want to engage the built-in automated parking assistant to safely leave the narrow garage.*	Sensing system continuously records a set of data which is forwarded to the "fluid" HMI, for example: • In-cabin noise levels to adapt auditory messages • In-cabin luminance to adapt contrast of visual information • Vibration level to adjust haptic feedback Meteorological information to adapt cabin temperature	Receiving information that parking assistance is available	The system might be disenabled by the operator and the operator might not have the proper state of mind to drive.
3	*He agrees and therefore the driving assistant starts to unpark the car.*	Sensing system records traffic information (oncoming traffic), infrastructure information (parking spot) to infer safe maneuver	Selecting automated parking assistance Receiving confirmation that the system will do the parking maneuver	The system might not detect a critical situation or object and properly support the driver leading to an accident.
4	*After exiting from the garage, Harold takes over control and starts driving.*	Sensing system records driving behavior and senses that Harold took over control (e.g. Harold gives input to the gas pedal and steering wheel) The system is using data about Harold's state to continuously assess a F2D score (using his sleeping pattern, electrocardiographic [ECG] measures,	Receiving information that the maneuver is finished and driving is possible	The transition between automated and manual driving might not correctly done leading to an accident.

		electrodermal activity [EDA], attentional level and emotional state -eye movements and facial expression)		
5	*The information assistant tells him at this point that they will need additional fuel and tells him that there is a close-by fuel station.*	Sensing system records fuel status, infrastructure information (next fuel station)	Receiving information that more fuel is needed and where to get it Receiving navigational advice	The system might distract the operator leading to an unsafe driving.
6	*To access the fuel station a difficult left turn is required, so Harold's assistant watches out for oncoming traffic and signals Harold visually with a red cross and a green arrow when it is safe to make the turn.*	Sensing system senses and interprets traffic infrastructure information (left turn) and infers when it is safe to make the left turn	Receiving left-turn warning well in time Receiving left-turn assistance during maneuver	The system might suggest a wrong maneuver and/or not support the driving of the operator leading to an accident.
7	*After leaving the fuel station Harold arrives at a one-way street with various traffic signs confusing him. Luckily, his assistant again visually supports him by showing and highlighting the most important road signs.*	Sensing system senses the environmental scenery i (one-way street, type of traffic signs) Sensing system senses Harold's scanning patterns and his driving behavior (e.g. set speed) and infers that he is confused (e.g. uncoordinated scanning patterns, Harold slowing down because he is unsure which speed limit)	Receiving information about most relevant traffic rules in place Receiving assistance in case of violation of traffic rules as indicated by the signs	The system might suggest a wrong road sign and/or not support the driving of the operator leading to an accident.
8	*Afterwards, Harold is reaching the outer city ring with a lot of traffic. Since his knees are not the best anymore combined with a little slower reaction time, the driving assistant helps him with braking in the stop and go traffic.*	Sensing system senses traffic (heavy traffic) and environmental scenery (outer city ring). In relation to this context information and Harold's driving behavior (e.g. whether Harold has applied brakes strongly enough or not), the system infers whether support (e.g. additional braking) is needed.	Receiving information about active braking assistance (if above Harold's perception threshold)	The system might not support the driver leading to crash.
9	*The assistant suddenly shows Harold on a display that an emergency car is approaching from the backside and highlights the safest way to evade with clear arrows or special visual instructions as needed.*	Sensing system senses traffic (oncoming emergency car) and environmental scenery (to highlight safest way to evade). In relation to this context information, the sensing system senses Harold's state and driving behavior.	Receiving information about approaching emergency vehicle and how to best give way	The system might suggest a wrong maneuver and/or not support the driving of the operator leading to an accident.

		(does Harold brake and evade to the side?)		
10	*A few minutes later he approaches the highway entrance. The system shows Harold with a green arrow in which direction he has to drive to get on the right lane of the highway.*	Sensing system senses infrastructure information (highway entrance) in order to display information for supporting Harold (e.g. green arrow).	Receiving navigational hints	The system might suggest a wrong maneuver and/or not support the driving of the operator leading to an accident.
11	*Merging into the highway traffic is a challenge for Harold since there are vehicles in his blind spot, he must keep a safety distance and must increase speed. Luckily, his system visually indicates when another car is getting too close and if approaching cars are in his blind spot.*	Sensing system senses traffic (vehicles in blind spot) and Harold's driving behavior (system checks whether Harold is driving safely - e.g., keeps distance, drives with adequate speed, etc.)	Receiving assistance (i.e., enhancing manual control of vehicle) or car fully takes over because of highly critical situation	The system might not recognize correctly the vehicles or obstacles suggesting a wrong maneuver of the operator leading to an accident.
12	*In some highly critical situations, the system also intervenes and takes over certain actions (braking, corrective steering to merge).*	Sensing system senses and interprets the traffic situation and Harold's state and driving behavior in relation to that. The system infers whether Harold needs assistance in driving (e.g. braking, corrective steering)	Receiving information about system's active assistance (if above Harold's perception threshold)	The system might not recognize critical situations and support the driving of the operator leading to an accident.
13	*He made it on the highway and the car tells Harold that he can now let the car drive itself until it tells him again to get engaged (at level 3 Harold is not required to detect manual take-over needs himself but the system will alert him in time prior to a take-over).*	Sensing system senses and interprets traffic, infrastructure information (highway, full automation is available).	Receiving information that full automation is possible Confirming automation mode Receiving information about driver's responsibilities in that mode	The system might not be able to autonomously drive and might lead to an unexpected situation.
14	*Because there is not much to do in the car, Harold gets tired. The system detects this and advises him to have a break. He follows the advice and makes a short stop in a close touristic area.*	Sensing system senses Harold's state (e.g. by means of eye-tracking, EDA, ECG) and infers if Harold is getting tired.	Receiving break suggestion Possibility to confirm/decline suggestion Receiving navigational hints if suggestion confirmed	The system might not correctly recognize the state of the operator, and it might not properly support him.

15	*The system helps Harold to handle the dense traffic and many pedestrians with visual cues about his surrounding, warning systems about the traffic, kids, etc.*	Sensing system senses and interprets traffic situation, other road users (pedestrians, kids) Sensing system senses whether Harold has attended to the various hazards (e.g. pedestrians crossing the street) by means of eye-tracking and if he adapts his driving (e.g. reduced speed)	Receiving assistance when it is necessary (e.g., if Harold's gaze patterns suggests, he has overlooked something)	The system might not recognize critical situation and support the driving of the operator leading to an accident.
16	*It also provides Harold with scenic information, so he is not as tempted to be distracted by the landscape or other things.*	Sensing system senses environmental scenery ("scenic information")	Receiving scenic information	The system might distract the operator and cause unsafe driving.
17	*After continuing on the highway, he finally gets to the highway exit. Since the exit is on his right side and the sea (his actual goal) is in front of him he almost overlooked the exit, if the system had not showed him the actual route early enough. This gave Harold time to refocus on his track.*	Sensing system senses infrastructure information and GPS position (exit to destination) and infers that Harold is close to his exit Sensing system senses Harold's gaze patterns in relation to the context information (exit sign). It infers whether Harold has "overlooked" the exit	Receiving navigational hints in time Receiving information about system's active assistance (if above Harold's perception threshold)	The system might suggest a wrong maneuver and/or not correct the driving of the operator leading to an accident
18	*Since he gets close to his destination, the system starts communicating with Harold's hotel, so it can show him his check-in options, parking lots, etc. It also prepares the hotel workers for Harold's arrival.*	Sensing system senses and interprets infrastructure information and GPS position and infers that Harold is close to his destination	Receiving navigational hints where to park	The system might distract the operator and cause unsafe driving.
19	*Since Harold is exhausted after the long drive, the system activated a steering aid which makes slight steering corrections, thereby increasing Harold's latitudinal vehicle control.*	Sensing system re-assesses Harold's physical and mental state and assigns normative F2D score. It is able to sense that Harold is exhausted (recording of ECG, EDA, etc. - low arousal level, recording of steering behavior – e.g. uncoordinated, sudden steering reversals)	Receiving information about system's active assistance (if above Harold's perception threshold) Receiving suggestion to hand over to system Possibility to accept/decline suggestion (however, if declined – assisted driving mode)	The system might suggest a wrong maneuver and/or not support the driving of the operator leading to an accident

	Some main Research Questions in this Scenario	Can Harolds information needs and transition needs be identified via physiological, behavioral and environmental sensing and if so how?	Will Harold find these information assistants and transition suggestions acceptable and will he be able to drive more safely and more comfortably than without them? In fact, can he drive sufficiently safely to compensate for his driving restrictions?	Do these information assistants and transition suggestions introduce new safety hazards?

4.1.3 H3: Harold gets Guarding Angel Protection

Harold needs to visit his doctor in the city. .

This is challenging, e.g., because of lots of dense traffic, including cars, motorbikes, bicycles, pedestrians - they come from all directions! Furthermore, there are, e.g., confusing two-lane traffic circles, unforeseen road constructions and traffic redirections, or left-turns under time pressure

Table 7. Particularities of the HADRIAN innovative components for mobility scenario H3

Automated Driving Level	This is an extension of SAE ADLs 3 - 4 (conditional / high) driving automation, provided as self-enabling safety mechanism that protects Harold. This capability is here referred to as HADRIAN ADL 3+E. A guarding angel functionality provides safety protection against accidents and keeps the vehicle within safe operational boundaries while allowing Harold to actively maneuver the vehicle within those boundaries.
Fluid Interaction Support	A **personal digital assistant** supports Harold across different life situations to better be able to assess his driving state and facilitate interactions using a natural interaction format: Consists of an AI system that talks to Harold in various situations at home as well as in the car to understand his needs and provides interactive opportunities. Speaks in the voice of his daughter, thereby providing familiarity. Harold's active driving is needed by the system as input to be aware of Harolds driving skills and any deterioration. The car may provide an indication to other traffic participants that this is a self-driving car of the assistive kind and therefore allow others to appropriately respond to its behavior (should be clarified whether and how this could be done).
Transition Planning Control	All transition planning is done in real-time: Harold can only control the car within its safety boundaries, e.g., if he exceeded a speed limit the car is automatically reducing the speed to the appropriate speed limit while providing feedback to Harold about the speed (assumed to come directly from speed limit signage via direct connectivity to the vehicle). In situations where the car cannot resolve a situation by itself, Harold can take control within a sufficiently simple, clear, and slow transition process. This may require the car to be stopped.
Tutoring	Harold learns beforehand and during the drive how the system is working, what to expect, and how to use it.

Table 8. Mobility Scenario H3 – Harold gets Guarding Angel Protection

No	Scenario Segment	Driver and Environmental Sensing Needs	User-Centered Interaction Needs	Safety Hazards
1	*Harold´s digital assistant Frida reminds Harold that today he has an appointment with his doctor at the hospital in the city.*	No Requirements	Receiving information about an upcoming appointment	None identified
2	*Harold gets ready and gets in his car where Frida's voice welcomes him and engages in usual conversations that Harold appreciates to feel less isolated and alone.*	Sensing system is continuously asesing Harold's state to assign a F2D score: the system uses data on his sleeping pattern, electrocardiographic [ECG] measures, electrodermal activity [EDA], eye movements and voice [pitch])	Initiate conversation Possibility to stop the dialogue if wanted	None identified
3	*As Harold starts driving on the road with the guardian angel road infrastructure enabled, the road sensors detect a small row of ducks crossing the road not far away from Harold's home. This information is communicated to Harold's car and Frida advices Harold to slow down because of the crossing animals on the road.*	Sensing system senses and interprets the traffic and environment scenery and determines whether the detected row of ducks is a potential hazard	Receiving information about obstacle and assistance automatically activated (see beneath)	The system might not detect a critical situation leading to an accident
4	*The car supports Harold in stopping the car, just slightly adjusting the brakes as needed. As the ducks have passed, Harold continues.*	Sensing system senses and interprets the traffic, environment scenery and Harold's driving behavior in relation to that (e.g. how strongly is Harold braking, how much does the brake assist needs to apply brakes additionally)	Receiving information about active brake assistance (only if above Harold's perception threshold) Receiving information that obstacle is gone and it's safe to continue driving	The system might not detect a critical situation leading to an accident and might not properly support the operator
5	*They continue driving and then arrive behind a school bus that is stopped on the road. While at first, there are children getting out of the bus, soon all the children are gone and it becomes apparent that the bus is actually broken down. The bus driver gesticulates to Harold to continue driving and is looking*	Sensing system senses and interprets the traffic (bus), other road users (children crossing the street), environment scenery.	None (Harold recognized situation that the system could not)	The system might not recognize critical objects and so provide the correct information to the operator

	under the bus hood, apparently for some problem.			
6	*Harold tells Frida that he would like to continue driving and Frida disengages the guarding angel stopping functionality to give Harold active control.*		Enabling manual driving No overload with warnings	The system may be disabled and as result Harold may cause an accident.
7	*On the wind shield, guidance is displayed that allows Harold to safely pass the bus, indicating safe gaps in the oncoming traffic: even if he were to depress the accelerator pedal completely, the car would only accelerate at a rate that is considered safe and not exceed reasonable speed limits and it does not allow bumping into things.*	Sensing system senses and interprets the traffic (oncoming traffic) and environment scenery. The system senses Harold's driving behavior in relation to the context and infers whether Harold's driving input is adequate for the given situation (e.g. Harold wants to accelerator pedal completely which would not be appropriate for the given situation)	Receiving guidance to master the situation Receiving information about active assistance systems (if above Harold's perception threshold)	The system might not detect a critical situation and properly support the driver leading to an accident
8	*After passing the school bus, the trip continues and the system informs Harold that there is a construction site and therefore a detour is needed. The car automatically gently corrects the steering if Harold is not turning onto the new course.*	Sensing system senses whether Harold is turning onto the new course by himself (e.g. by means of steering wheel information) Sensing system senses and interprets traffic and environment and infers when it is necessary (construction site with significant delay) and safe to initiate the turn.	Receiving information that a detour is necessary Confirming the detour Receiving appropriate navigational hints in time	The system might not detect a critical situation and properly support the driver leading to an accident
	Some main Research Questions in this Scenario	Can the need for a safety take-over be identified via physiological, behavioral and environmental sensing in time for a safe transition and if so how?	Will Harold find these safety take-overs acceptable? Will they enable sufficiently safe driving to compensate for his driving restrictions?	Do these safety take-overs introduce new safety hazards?

4.2 Sven Scenarios (Truck)

Sven is a 42 years old long-distance truck driver living in Frankfurt. He has a wife and an 8-year-old daughter.

- He is a truck driver for 20 years
    - He is a really good and reliable driver - that’s why his boss wants to keep him at any rate, since truck drivers are hard to find nowadays
    - He has been almost everywhere in Europe and neighboring countries and is familiar with all important highways
- When he is on a tour, he has a lot of responsibilities
    - He is in regular contact with his dispatcher (to get to know about his next route, to communicate if there are any delays, …)
    - Whatever he is transporting, he must make sure that the load is secured
    - He also has to be aware of places with lots of criminal activity
    - He needs to take care about administrative stuff (e.g., filling in delivery forms) and must be aware of regulations when he is allowed to drive or not
- Truck driving gives him a feeling of independence
    - Whenever he is closing the door of this truck cabin, he feels like his own boss
    - Since the truck cabin is a sort of living room for him, he takes care of it and has arranged it for his own needs
- He really likes his job, although it’s not like in the past anymore
    - Nowadays everything is controlled
    - Some routes are really unpleasant to drive, because there is so much traffic and traffic jams
- His job is stressful, and he often has to fight upcoming fatigue on monotonous drives
    - Also, he often has to wait very long until he can load/unload, which can cause further delays
    - Although he likes to be independent, he also sometimes feels lonely
    - He misses his family, which he sometimes does not see for days - so whenever it is possible, he tries to talk to them over skype
    - He is tempted to even skype during boring, long driving stretches
- Over the years, he has got some health issues
    - He gained some weight, because of all the sitting in his truck and hardly any exercise
    - Also, he sometimes has problems with his back, and the quite uncomfortable bed in his truck doesn’t make it better

Figure 3. Sven, the long-distance truck driver

4.2.1 S1: Sven gets De-stressing Assistance

Sven needs to drive from Frankfurt to Hamburg (about 6-7 hours drive). However, he needed to wait for his truck to be loaded in Frankfurt for over one hour and now it's already 9:30. He must be at the customer in Hamburg before 16:00 o'clock – otherwise he won't be able to unload and start to return on the very same day. On this relatively short drive, Sven is delayed but must make his delivery in time.

Table 9. Particularities of the HADRIAN innovative components for mobility scenario S1

Automated Driving Level	The HADRIAN ADL 2 includes improved adaptive cruise control with merge protection to handle situations when a car squeezes in between his truck and the vehicle ahead. The system does not disengage in this case, it also allows for smaller distances behind a front truck because it excludes the need for the driver to immediately take over in cases of an unexpected brake maneuver of the front truck. The system may also provide active signaling to the "intruder" by flashing the lights. Usage of the improved Adaptive Cruise Control (ACC) in HADRIAN ADL 2 could be supported by his company and give Sven "bonus" points on his driving style score, which may make him suitable to receiving a bonus. Furthermore, a HADRIAN improved Lane Keep Assist system (also part of the HADRIAN ADL 2) with detailed digital mapping and infrastructure information allows for automated passing maneuvers
Fluid Interaction Support	As the FIS is aware that Sven is stressed, it gives him feedback that he may want to use HADRIAN ADL 2 for assistance. Sven is very aware of the automation mode he is in, as he is in a stressed situation and misunderstandings may occur. A driver monitoring system detects that Sven is stressed, according adaptations are made. For example, incoming calls could be blocked, music is played or something that is tailored to his preferences to reduce his stress. Moreover, the lighting of the truck cabin may change accordingly. Also, the truck may act as a kind of co-driver communicating with Sven to keep him calm and comforting him. Additionally, the truck could advice Sven about health-related issues.
Transition Planning Control	The system informs Sven when and why driving assistance functionality is not available at certain parts of the road. A trip management system aids Sven to reduce his stress and worries by supporting his planning. The trip management system shows him upcoming traffic and informs him about rest stops, regulatory information, provides trip management and updated information if detours are necessary. This system considers traffic and weather predictions and shows estimated arrival time based

	on all these information sources. The system actively proposes reroute options and facilitates Sven's decision making through easy-understandable display of information. Based on infrastructure information it shows Sven in advance for which parts of the trip the truck will be able to drive in which automated mode (e.g., as a color-coded navigation map), so that he can better plan on his own, when to do certain things.) Also, the system automatically informs the dispatcher about delays, so that a better planning is also possible for the dispatcher.
Tutoring	Sven learns beforehand and during the drive how the system is working, what to expect, and how to use it.

Table 10. Mobility Scenario S1 – Sven Gets De-Stressing Assistance

No	Scenario Segment	Driver and Environmental Sensing Needs	User-Centered Interaction Needs	Safety Hazards
1	*After waiting forever for his truck to be loaded, Sven is finally on his way to Hamburg.*	Sensing system continuously records a set of data which is forwarded to the “fluid” HMI, for example: • In-cabin noise levels to adapt auditory messages • In-cabin luminance to adapt contrast of visual information • Vibration level to adjust haptic feedback • Meteorological information to adapt cabin temperature Sensing system senses and interpretes the traffic (traffic jams, etc.) and the infrastructure information (Sven is on the highway on his way to Hamburg) Sensing system uses physiological, eye-tracking and data on driving behavior in order to infer Sven’s F2D score	Receiving information about expected trip time / delay, recommended stops, when automated mode is available	None identified
2	*As he is worrying, whether he will make it on time, he starts to drive a bit faster and with less distance to the truck in front of him. The system recognizes these changes in Sven’s behavior and senses his stress. Therefore, the truck gives Sven the feedback that he seems stressed and it may be a good idea to enable the Hadrian ADL 2 system.*	Sensing system senses traffic (truck in front of him) Sven’s driving behavior (acceleration, distance to truck in front of him) Sensing system senses Sven’s physiological state (ECG, EDA, etc.). Based on the data, the system infers that he is in a state of high arousal.	Receiving suggestion of ADL 2 Receiving information how to activate ADL 2 Possibility to accept/decline suggestion Receiving confirmation that ADL 2 is activated	The system might not correctly recognize the state of the operator leading to a missed suggestion or to a false suggestion to transition.

3	*This system requires Sven to stay sufficiently engaged to monitor the system while executing most standard maneuvers automatically such as lane changes and speed control. Also, the system makes clear to him, in which automation mode he is and monitors whether Sven is sufficiently "in the loop" while monitoring the truck.*	Sensing system receives information of current ADL Sensing system re-evaluates F2D constantly: It senses whether Harold is attending to the information presented (recording of gaze) and if he acts accordingly. For example byrecording of Sven's body posture to infer which type of activity Sven is engaged in, relating this information to the current ADL. Based on this, the system infers whether the sensed activity is adequate for the currently active ADL.	Receiving information that ADL 2 is active Receiving information about his responsibilities in this level Receiving warnings if he is out of the loop or doing things that are not allowed in ADL 2 Receiving ADL 2 status information (e.g., planned maneuvers, system perception)	The system might not correctly detect the engagement or state of the operator leading to an unproperly support.
4	*As Sven wants to be as fast as possible at the destination, he sets the maximum speed and the driving assistance system selects a proactive driving style, initiating more passing maneuvers and slightly reduced distances between trucks ahead to avoid too many squeeze-in maneuvers by other cars.*		Providing the system with personal settings about maximum speed, driving style Receiving confirmation of these settings Receiving information about these settings (e.g., what does proactive driving style mean) Possibility to change settings Receiving information if settings cannot be initiated and why	The system might not keep the right headway or speed or lateral distance according to the safety measured indicators and country regulation causing unsafe driving.
5	*At the same time, the truck relieves stress from Sven by creating a calming atmosphere in the truck, changing the interior lights and playing relaxing music.*	Sensing system senses Sven's physiological parameters (ECG, EDA, etc.) and based on this, infers whether the set action successfully helped Sven to reach an optimal level of activation	Possibility to adjust settings (light, music) for personal preferences Possibility to activate/deactivate "calming atmosphere option"	The system might not accurately measure the stress level of the operator leading to reverse effects such as higher stress level or fatigue.
6	*The trip management system displays the trip information on a large display, showing him exactly when he will arrive, taking into account all sorts of information about the environment, traffic jams, rest stops, regulations etc.*	Sensing system senses and interprets the traffic (traffic jams, etc.) & infrastructure information (rest stops, regulations on route, etc)	Receiving information about the trip, tailored to his needs (e.g., ETA, upcoming traffic jams, rerouting options, suggestions of rest stops, route sections which allow automated driving) Possibility to enter trip preferences (e.g., short ETA)	The system might distract the driver leading to an unsafe driving.

7	*As the trip management system detects an upcoming traffic jam, the system suggests a rerouting option to avoid further delays*	Sensing system senses and interprets the traffic (traffic jams, etc.) & infrastructure information (alternative route) and infers whether a rerouting is necessary	Receiving information about traffic jam, rerouting options and according ETA Selecting and confirming new route	The system might suggest a wrong retouring not in line with the regulation of the road.
	Some main Research Questions in this Scenario	Can Sven's stress level and contextual constraints be identified via physiological, behavioral, and environmental sensing and if so how?	Will Sven find these information assistants and transition suggestions acceptable and will he be able to drive more safely and more comfortably than without them?	Do these information assistants and transition suggestions introduce new safety hazards?

4.2.2 S2: Sven gets Bored-Driving Assistance

Sven is bored by driving in a convoy forever: He is currently on his way to Munich from Frankfurt. On the highway there is heavy traffic with a lot of other trucks and a lot of construction sites. So, Sven needs to drive in a convoy for 4 hours.

Table 11. Particularities of the HADRIAN innovative components for mobility scenario S2

Automated Driving Level	A HADRIAN ADL 3 automated driving function allows Sven to disengage from driving under the monotonous stop-and-go situations. This type of automated driving allows Sven to disengage from driving and use this period to engage in various non-driving activities that would help him complete his professional duties but also facilitate his wellbeing. Also, Sven could complete administrative tasks. Active transition support, see below, makes the duration of automated driving predictable for Sven.
Fluid Interaction Support	The FIS monitors Sven's activities to be compatible with this ADL 3 (e.g., Sven has to keep a sufficiently high level of arousal and not fall asleep). In case, Sven performs a task that is incompatible with the current HADRIAN ADL 3, appropriate warnings are provided to Sven. Near the end of the ADL 3 period, Sven is led early enough by appropriate cues to come back to the manual driving and his state is observed whether it is compatible with preparing to come back to manual driving. Automated driving related information is shown at the place where Sven is putting his attention, e.g., if he is reading something on a device, the alert pops up on the reading device
Transition Planning Control	The function offers itself when it foresees to be able to be continuously operated for a minimum of at least 5 minutes (duration to be determined) based on integrity information from the road infrastructure and informs Sven about the expected duration of the HADRIAN ADL 3 automated driving. Knowing the duration of ADL 3 driving allows Sven to actually disengage from driving and perform his non-driving tasks or short periods of rest. This is facilitated by HADRIAN ADL 3 integrity information that is sent from the road infrastructure to the vehicle. For example, at motorway entrances where vehicles join the motorway, the merging is facilitated by a centralized command and control unit that is planning gaps for the merging of vehicles and communicates the planned gaps to the automated vehicles and gives signals to the non-equipped ones. Also, road side video cameras are observing the state of the road and communicate unexpected events to Sven's HADRIAN ADL

	3 system so that early automated maneuvers can be initiated to avoid dropping unexpectedly the level 3 automated driving. If the system recognizes that Sven is bored or annoyed, it suggests him some exercises (e.g., breathing exercises, stretching), which are continuously monitored and he is provided with feedback about how he is doing. Also, Sven is reminded to do exercises and provides him, e.g., with a cycling option, and tasks that he can do with his hands (e.g., playing PlayStation, guitar playing, learning a new instrument, weight lifting laying down, playing chess / poker with other truck drivers, playing a game with his daughter, relaxation exercises). During the transition to manual control, the system monitors whether the driver is performing the transition appropriately.
Tutoring	Sven learns beforehand and during the drive how the system is working, what to expect, and how to use it.

Table 12. Mobility Scenario S2 – Sven gets Bored-Driving Assistance

No	Scenario Segment	Driver and Environmental Sensing Needs	User-Centered Interaction Needs	Safety Hazards
1	*As Sven is facing quite a lot of heavy traffic and stop-and-go, he is assisted by the HADRIAN ADL 3 function.*	Sensing system senses and interprets the traffic (stop and go) & infrastructure information and the current ADL. The system continuously assesses Sven's state by means of physiological sensors (EDA; ECG, etc.), type of engaged activity (sensing of body posture, active devices within the cabin, etc.) and assigns a F2D score. This information is used to e.g. adapt take-over requests (e.g. more time needed, when Sven is engaged in cognitively demanding activity) or to alert Sven when sensed activity is unsuitable for current ADL (details see below).	Receiving general information that the truck provides ADL 3 functionality and about Sven's responsibilities in ADL 3 (tutoring?)	The system might not properly receive the right information from the infrastructure leading to not activate the automated driving in advance or properly.
2	*Whenever the system foresees that it can operate fully automated for at least 5 minutes, it informs Sven that he can let the truck drive itself for the expected minimally guaranteed time and that he can do other things now.*	Sensing system senses and interprets traffic & infrastructure information and infers that "full automation is available"and for which amount of time	Receiving information that ADL 3 is possible and for which time interval Possibility to confirm/decline ADL 3 activation Receiving information that ADL 3 is activated and which activities are allowed/not allowed Receiving information about the left time in ADL 3 mode (and/or visualization in navigation map)	The system might not correctly recognize if it is able to activate automated, leading to unexpected takeovers with the operator distracted.
3	*There is a list of activities that Sven can do, he knows them, and the system reminds him of the permissible activities.*	Sensing system monitors the types of activities Sven is doing and infers whether these activities are suitable for the set ADL by sensing his body posture and which devices are in use).	Receiving information which activities are safe to do in this level Receiving warnings if he does something that is incompatible with this level	The system might not accurately estimate the amount of time needed to take over in the worst scenario leading to suggest improper activities.

4	*Sven has learned over time to use the ADL 3 system as it has provided him with tutoring about how to safely use it previously during breaks or monotonous driving stretches.*	Sensing system continuously checks whether Sven is using the automated driving functions as intended by recording usage patterns (e.g. engagement/disengagement) in relation to context, and his monitoring behavior while ADL engaged Sensing system checks whether Sven has been following the tutoring sessions by recording his gaze, driving behavior, interaction with automation (number of engagements, disengagements, duration of usage, etc.)	See line 3 Possibility to initiate tutoring if he wants to learn more	The system might have not correctly provided the operator all the required information enhancing unexpected events during driving.
5	*While driving at HADRIAN ADL 3, Sven's activities are monitored to make sure that he keeps within the permissible activities and that he maintains a sufficient level of arousal so that he will be able to take over again when the time comes.*	Sensing system senses the types of activities Sven is doing and checks whether these activities are suitable for the set ADL by sensing his body posture, active devices (e.g. cell phone) System senses Sven's gaze patterns and physiological and neurobehavioral signals and infers whether his arousal level is sufficient for take-over (F2D score)	Receiving warnings if he does something that is incompatible with this level/ receiving suggestions of what he could do instead / adapting of driving style Receiving information about estimated time to TOR	The system might not recognize the state of the operator increasing the chance to not have enough time to take over.
6	*Right now, Sven seems a bit bored – so the system suggests some health exercises he could do. As Sven is doing some stretching exercises, the system provides him with some feedback about how he is doing. After that, some further training is suggested to Sven – this time, he can train his arms with a cycling device.*	Sensing system senses Sven's physiological parameters (ECG, EDA) and infers that Sven is in a state of low arousal (F2D score)	Receiving suggestions for health exercises (taking into account available training time) Possibility to select certain exercise(s) Receiving feedback about recommended position and progress in exercise (during exercise, but also in comparison to earlier exercises)	The system might not accurately estimate the amount of time needed to take over in the worst scenario leading to suggest him improper activities.
7	*The system informs him in time, when he should start preparing for take-over, considering what he is currently doing. The system is always aware, where Sven's attention is, and provides cues for take-over in appropriate manner (haptic,*	Sensing system records traffic & infrastructure information and infers when take-over is imminent. System infers Sven's state and the type of activity he is currently engaged in by sensing his body posture and the	Getting informed about upcoming take-over in time Receiving information about the current driving situation and kind of take-over	The system might not correctly estimate the amount of time needed to take over in the worst scenario leading to collision.

	visual, auditory) so that it is ensured that Sven perceives the information in time. A video stream from the front vehicle further helps him to understand his environment, especially during the back-to-manual driving transition periods.	currently active devices; it senses Sven's attention level (eye movements) and based on this, it infers the needed time for take-over	Receiving information how to take over (tutoring?) Receiving information that (assisted) manual driving is activated / ADL 3 deactivated	
8	*The system detects an object blocking the vehicle way so that it cannot pass. Since Sven has not his full attention on the road, the system shows the situation and the time to take-over to make him aware. The system gives the control to Sven when take-over response (TOR) time has passed and Sven drives manually.*	*Sensing system records traffic (vehicle blocking street), Sven's point of attention (by recording his gaze)*	*Getting informed about take-over in time* *Receiving information about the situation and why take-over is necessary* *Receiving information how to take over (tutoring?)* *Receiving information that manual driving is activated*	The system might not estimate properly the amount of time needed to take-over and make aware the driver about the situation. A wrong estimation might provoke a collision.
	Some main Research Questions in this Scenario	*Can Sven's activities and states (e.g. boredeom) be sufficiently monitored via physiological and behavioral sensing and if so how? What kind of environmental sensing is needed?*	*Will Sven find the predictability of transitions to manual driving more acceptable than the baseline and will he be able to drive more safely with them?*	*Does the predictability of transitions introduce new safety hazards?*

4.2.3 S3: Sven gets Multi-Day Trip Assistance

Sven is on a long 4-day trip and away from family during this time. He needs to go from Frankfurt to Istanbul. Sven is allowed to drive up to about 9 hours a day and needs to rest (see truck driver rest requirements in section 5.2.2).

Table 13. Particularities of the HADRIAN innovative components for mobility scenario S3

Automated Driving Level	The automated driving at ADL 3+ allows continuous automated driving for at least 20 min and more. These stretches could be counted as resting periods for Sven if the monitoring system ensures that he can rest for at least 15 min a time. In this case Sven could keep in control of driving for up to 9 hours.
Fluid Interaction Support	The FIS monitors Sven to ensure he is engaging in rest-conform activities during these periods. If the driver monitoring system detects that Sven is stressed, Sven receives suggestions for how to relax. If this does not work, these periods would not be counted as resting time and Sven would get feedback to this extent. The system translates traffic signs and traffic related information (e.g., lane closure ahead or traffic ahead) into an understandable form such as through auditory or visual messages. This information may come from an onboard digital map, be translated in real time, or sent by infrastructure messages. Also, in periods of automated driving, Sven would be able to take a power nap. The FIS observes the power nap and determines whether it is good enough to count this as resting time. Also, if there is a proof that Sven has slept for a certain time without interruption, this could increase the driving time. Alternatively, during the phases of automated driving, Sven may occupy himself with other tasks, e.g., doing homework with his daughter, watching movies, playing games in multiplayer mode, socializing etc. This can help his well-being. The system monitors Sven's state in order to determine whether he gets in the wrong mood by a certain activity (e.g., aggressive driving) and informs Sven about this when detected. During the transition to manual control, the system monitors whether the driver is performing the transition appropriately.
Transition Planning Control	The TPC system gets information from the road infrastructure integrity assurance capability that HADRIAN ADL 3+ is available on some stretches on the trip. This information is appropriately displayed to Sven.

	Also, the truck proposes optimized rest periods based on observations of Svens behavior, physiological and neurobehavioral parameters as well as the traffic situation. Depending on the alertness level of Sven, the take-over requests would be adjusted, e.g., more time is given prior to the take-over if Sven is currently deeply engrossed in watching a movie.
Tutoring	Sven learns beforehand and during the drive how the system is working, what to expect, and how to use it.

Table 14. Mobility Scenario S3 – Sven gets Multi-Day Trip Assistance

No	Scenario Segment	Driver and Environmental Sensing Needs	User-Centered Interaction Needs	Safety Hazards
1	*On this long trip, Sven can hand over full control to the truck for several stretches when the truck is driving at HADRIAN ADL 3+. Hence, the truck can drive in fully automated mode for 20 minutes and more, allowing Sven to rest. The system monitors Sven in order to determine whether he is engaging in rest-conform activities. Right now, Sven is having a power nap for 16 minutes.*	Estimation of quality resting time based on a set of psychophysiological and neurobehavioral parameters (body movements, ECG, EDA, etc.) Sensing system is able to detect whether Sven engages in adequate activities for current ADL (recording of body posture in regard to ADL) Sensing system records traffic information (traffic jams, etc.), infrastructure information (“ADL 3+ available”)	Receiving information that ADL 3+ and hand over to the truck is possible Receiving information about permissible activities in ADL 3+ Receiving information for which time interval ADL 3+ / resting activities are possible Possibility to confirm/decline ADL 3+ activation Receiving information that ADL 3+ is activated Receiving suggestion to rest / how to best rest (what is allowed not allowed in terms of safety) / that resting is monitored (tutoring?)	The system might not accurately estimate the amount of time needed to take over in the worst scenario leading to collision.
2	*During normal driving or when Sven is not resting during HADRIAN ADL 3+ driving, if the monitoring system detects that Sven is stressed, it gives suggestions on how to relax.*	Sensing systemrecords Sven’s eye patterns and physiological parameters (ECG, EDA, etc.) and infers whether Sven is in a state of high arousal (F2D score)	Receiving suggestions for relaxation Possibility to communicate personal preferences and settings Possibility to reject automatic changes	The system might not accurately measure the stress level of the operator causing reverse effects such as higher stress level or fatigue.
3	*If Sven is not able to relax enough during periods of automated driving, the system makes suggestions where he could stop to have a break, considering the traffic situation and his state.*	Sensing system senses and interprets traffic and infrastructure ((suitable parking spot to take a break).	Receiving information where to stop to have a break and how it affects the further trip (e.g., changes of ETA, can traffic jams be avoided when taking a break now, etc.)	The system might not correctly recognize the state of the operator enhancing the possibility of the driver to fall asleep before the stop.
4	*In phases of manual driving, the system constantly monitors the environment.*	Sensing system senses driving behavior in context of traffic information and infrastructure	Receiving information about environment monitoring / automation perception	The system might not recognize the state of the operator and traffic conditions causing unsafe driving.

5	*Right now, there is a lot of sunshine and glare outside – so the system automatically adjusts the coating of the windshield, so that Sven does not get exhausted by all the glare.*	Sensing system senses the light condition inside and outside the car Change in Sven's gaze behavior, blink rate – system infers that Sven is blinded by the light	Possibility to override the system if automatic adjustment is not wanted / change it to personal preferences	The system might not be able to accurately detect the weather conditions and adjust the vehicle accordingly causing reverse effects to visibility.
6	*As he is driving inside of Turkey, a system inside translates variable traffic signs: therefore, he understands the "traffic ahead" warning that is displayed in Turkish at the overhead signs.*	Sensing system monitorsinfrastructure information (traffic signs).	Receiving information about traffic rules in place / meaning of traffic signs	The system might distract the driver.
7	*During the next period of HADRIAN ADL 3+ driving, Sven gets in contact with his daughter. Via videoconference, he helps her with her homework.*	Sensing system continuously senses Sven's state of activation (based on physiological parameters) and his type of activity based on body posture, currently active devices, focus of attention (eye-tracking) Sensing system senses vehicle information (current ADL)	See also line 1 Availability of means for video-conference (see also office mobility scenario) Initiating video conference (probably plus changes of vehicle interior for this task, e.g., reducing sun light from outside, see line 5) In case of critical event, receiving multimodal alert message Receiving information about the time until the next planned take-over	The system might not recognize the state of the operator not supporting him to unexpected events.
8	*After that, he starts playing a video game, by which he gets fully engrossed. The system senses this and therefore, the take-over request is initiated earlier to make sure that Sven's attention is with the driving task again, when he needs to take over.*	Sensing system senses and infers Sven's state, attention level and activation (e.g., eye movements, body movements) as well as his task (playing video game)	Receiving information for take-over in time Possibility to pause video game (self-initiated and/or by system) Receiving information about the current driving situation	The system might not accurately estimate the amount of time needed for Sven to take over in the worst scenario leading to collision.
9	*Sven reaches the destination to deliver the cargo in a factory. He requests to take control of the vehicle and the AD system makes the transition to manual driving. Sven drives inside the factory*	Sensing system senses Sven' state through a set of physiological and neurobehavioral parameters and re-asses his F2D score. This information is	Receiving information that he has reached the destination HMI mechanism for a driver-initiated take-over request	If it were to easy to take manual control for Sven, the system may inadvertently get into manual driving without Sven being aware ot it. This could cause an accident.

	toward the available docking station, which is displayed to him.	used to adjust the take-over message (timing, modality, etc.) Recording of infrastructure information, GPS (close to factory)	Safe and smooth control transition from automated to manual Receiving information of docking stations	
10	*Since Sven is behind schedule, he starts the self-parking function of the Hadrian ADL 3+ to park the truck quickly in the docking station. The HMI displays the trajectory of the maneuver and the vehicle status to keep Sven aware of the situation.*	Sensing systems senses Sven' state and infers whether Sven is still in the loop as required Recording of infrastructure and traffic information	HMI mechanism to start the self-parking function Receiving visual information of the self-parking maneuver	Sven may use the self-parking incorrectly and therefore cause a hazard (for example, he may erroneously think that the self-parking feature applies the brakes but in fact he has to do this himself).
	Some main Research Questions in this Scenario	Can Sven's resting times be sufficiently monitored via physiological and behavioral sensing and if so how? Can this be done reliably enough to count as official resting times?	Will Sven find the predictability of transitions to manual driving more acceptable than the baseline and will he be able to drive more safely with them?	Does the predictability of transitions introduce new safety hazards?

4.3 Florence Scenarios (Office)

Florence is a 27-year old businesswoman living in a suburb of Paris of the future (i.e., car sharing and intelligent traffic management are available)

- She is married and has two kids (10 months and 7 years old); her husband takes care of the kids at the moment
- Since a year she leads an IT start-up and has 10 co-workers
- Her office is in Paris – that's why she needs to commute daily
    - Depending on the daily traffic and time of the day, one drive lasts 20-35 minutes
- Currently, she needs to take care of basically everything in order to ensure the success of the company
    - She has a high responsibility that things run smooth – any shortfall could have severe consequences for the company
    - Accordingly, her workload is very high – so she tries to use every minute of her working time as efficient as possible, even the time she spends in her car
    - Sometimes, she is so stressed that she even forgets to eat or drink, and at the end of the day, she is usually quite exhausted
- Her daily tasks involve:
    - Communication and information sharing with her co-workers
    - Communication and meetings with important customers, contractors, producers
    - Organization and time scheduling
    - Office work (writing, reading, calculations, internet, social media, paper work ..)
- One further thing, you need to know about Florence
    - She sometimes has problems to read in a driving car, since it can make her dizzy and feeling nauseous after some time

Figure 4. Florence, the businesswoman

4.3.1 F1: Florence getsTelecon Assistance

Florence has planned a telecon with an important customer on her way to work.

Table 15. Particularities of the HADRIAN innovative components for mobility scenario F1

Automated Driving Level	HADRIAN ADL 2 supports Florence with driving assistance while she can engage in phone conversations. Florence has to stay sufficiently in the loop of driving, she cannot engage in other tasks such as checking or writing emails while in this mode. ADL 2 supports are lower level maneuvers such as following the lane, keeping distance in stop-and-go-traffic, and even selecting the appropriate lanes for upcoming turns.
Fluid Interaction Support	The FIS monitors her driving behavior and puts the call on hold when there are safety critical events happening to facilitate Florence to transition back to manual driving. The car also determines whether Florence's non-driving activities seem suitable for this ADL and provides appropriate interventions when a discrepancy is detected. The privacy of the information on the displays are ensured so that they cannot be send from the outside. The car provides appropriate interventions to either make her aware, suggest transitions to higher ADL, or help get her in a state to continue driving at ADL 2. If a call comes in, the car displays the caller information on a secondary display (close to but not within the primary field of vision) and provides all previous interactions and important information about this caller to help Florence prepare for that call. Alternative modes of interaction that minimize visual attention are offered.
Transition Planning Control	There is a task selection display that allows Florence to select what activity she wants to engage in during the drive. The CPT will route the vehicle such that Florence can be perform her desired tasks as much as possible. The CTP uses information from the infrastructure to perform these route planning.
Tutoring	Florence learns beforehand and during the drive how the system is working, what to expect, and how to use it.

Table 16. Mobility Scenario F1 – Florence gets Telecon Assistance

No	Scenario Segment	Driver and Environmental Sensing Needs	User-Centered Interaction Needs	Safety Hazards
1	*Florence's schedule has a teleconference call with an important customer scheduled during her drive to work. Florence likes to do that because she can easily speak while driving and the car helps to manage her distraction by supporting all lower level maneuvers such as following the lane, keeping distance in stop-and-go-traffic, and even selecting the appropriate lanes for upcoming turns.*	Sensing system senses Florence's gaze, other physiological and neurobehavioral parameters and her driving behavior (steering wheel reversals, set speed, etc.) in relation to the driving context she is currently in. Based on this information, the system infers a F2D score	HMI/Tutoring: Getting to know which support functionalities the car provides / which responsibilities she has Initiating phone call (incl. redialing in case connection was lost, looking up numbers, etc. w/o physical interaction necessary) Adaptive volume control (depending on outside noise) so that Florence does not constantly need to readjust volume	The system might disengage some feature of AD causing a dangerous driving situation (e.g., a collision). The system might not correctly recognize the state of the operator, and it might not properly support her
2	*However, Florence stays involved during the whole drive and needs to make the decisions concerning strategic movements. The car monitors her driving behavior and puts the call on hold when there are safety critical events happening to facilitate Florence to transition back to manual driving.*	Sensing system senses and interprets the traffic (other road users, etc.) and infers if safety critical situations arise Sensing system senses Florence's driving behavior and take-over performance (time headway, lateral deviance etc.)	Receiving indication that call is on hold since attention is needed for driving Possibility to put call on hold / continue call Information for conversation partner that Florence is in vehicle and that calls might be put on hold w/o prior notice. Fluid transition from automated to manual Indication, when call can be resumed	The system might not correctly identify the traffic environment and give her a wrong support.
3	*The car also determines whether Florence's non-driving activities seem suitable for this ADL and provides appropriate interventions when a discrepancy is detected.*	Sensing system monitors Florence's activities by sensing body posture, type of devices active in cabin, focus of attention – gaze Sensing system infers Inference whether these activities are adequate for current ADL	Receiving multimodal feedback / information about permitted activities to ensure safe driving depending on Florence's attention focus	The system might not correctly identify the traffic environment and give her a wrong support.

4	*Similarly, if Florence appears physiologically not fit to drive, it provides appropriate interventions to either make her aware, suggest transitions to higher ADL, or help get her in a state to continue driving at ADL 2.*	Continuous re-assessment of F2D score: Sensing system senses Florence's gaze, other physiological and neurobehavioral parameters and her driving behavior (steering wheel reversals, set speed, etc.) in relation to the driving context she is currently in. Based on this information, the system infers a F2D score Sensing system senses whether warnings have been adhered to by sensing Florence's eye movements.	Receiving multimodal feedback / suggestions for another ADL Possibility to accept / decline suggestions Information about consequences if suggestion is declined If no higher ADL possible and no improvement of driver state: standard low-risk maneuver Automatic adaptations of car interior to facilitate an optimal physiological state	The system might not correctly recognize the state of the operator, and it might not properly support her.
5	*After Florence finishes the first call, soon after she receives a phone call from another important customer. The car displays the caller information on a secondary display (close to but not within the primary field of vision) and provides all previous interactions and important information about this caller to help Florence prepare for that call. Alternative modes of interaction that minimize visual attention are offered.*		Receiving customized caller info in order to keep cognitive involvement low and to allow Florence to prepare in time before taking the call Receiving information about ETA in order to calibrate call duration and decision to answer Possibility to accept call, reject call + message (currently not available, please call again today/tomorrow/etc.)	The system might distract the operator, leading to unsafe driving.
6	*The call is only put through if the car determines itself not surrounded by high-level time-critical safety hazards and actively steers and maneuvers foreseeable obstacles but keeps Florence's active participation.*	Sensing system senses and interprets the traffic and environmental scenery and infers whether time critical hazards arise	Informing Florence that a call is not allowed Informing Florence that the call will/will not be put through due to the surrounding traffic situation Asking her to keep the hands always in the steering wheel ETA when calling is possible again	The system might make wrong measurements about the possible obstacles, thus leading to a dangerous driving situation.
	Some main Research Questions in this Scenario	*Can Florence's unsafe driving behavior detected sufficiently early and how? Can the suitability of her actions be determined appropriately via sensing?*	*Will Florence be able to drive safely while teleconferencing in acceptable ways?*	*Does the safety of driving while performing the non-driving activities improve over the baseline?*

		How can the environmental complexity be determined?		

4.3.2 F2: Florence gets Light Office Work Assistance

Florence is checking emails on her way to work.

Table 17. Particularities of the HADRIAN innovative components for mobility scenario F2

Automated Driving Level	HADRIAN ADL 3 allows Florence to completely delegate all the driving tasks to the vehicle. She is given sufficient time to come back to manual driving and therefore can only perform such non-driving related tasks that allow her to come back to manual driving within short time, e.g., she can check emails but should not write any and cannot nap or take things in her hands, or move away from the front seat position. ADL 3 is offered only when it can upheld for at least 10 min (?) and at least 20 sec (?) time are given to Florence to transition back to manual driving.
Fluid Interaction Support	The FIS monitors what Florence is doing and provides certain alerts when she is engaging in activities that are outside what can be performed during this ADL 3. The car observes Florence physiological and neurobehavioral signals to determine whether motion sickness may be developing. If this is determined, strong accelerations and braking maneuvers are avoided when she is reading / writing e-mails. The privacy of the information on the displays are ensured so that they cannot be send from the outside. Also, Florence's immersion in the task is measured for preparation of the take-over, e.g., by showing transition messages where she is currently looking at or using in-car ambient lighting to announce a transition. During the transition to manual control, the system monitors whether the driver is performing the transition appropriately.
Transition Planning Control	There is a task selection display that allows Florence to select what activity she wants to engage in during the drive. The CTP will route the vehicle such that Florence can be perform her desired tasks as much as possible. The CPTCTP uses information from the infrastructure to perform these route planning and plans the transitions to ensure that Florence has enough transition time. It then gives the appropriate signal to Florence when it is time to transition back (via the FIS).
Tutoring	Florence learns beforehand and during the drive how the system is working, what to expect, and how to use it.

Table 18. Mobility Scenario F2 – Florence gets Light Office Work Assistance

No	Scenario Segment	Driver and Environmental Sensing Needs	User-Centered Interaction Needs	Safety Hazards
1	*Before starting the drive to work, Florence tells the vehicle that she wants to do low urgency office work such as checking emails. That means that Florence accepts to be occasionally interrupted during her work while getting faster to work. Therefore, the car selects a short route to drive to work that requires several transitions from automated to manual driving.*	Sensing system continuously records a set of data which is forwarded to the "fluid" HMI, for example: • In-cabin noise levels to adapt auditory messages • In-cabin luminance to adapt contrast of visual information • Vibration level to adjust haptic feedback • Meteorological information to adapt cabin temperature Sensing system senses and infers the traffic (traffic jams, etc.), infrastructure information (possible stretches of ADL, routing)	HMI/Tutoring: Getting to know that she can inform the system about what she wants to do and how this will affect the behavior of the car (e.g., the car will select an appropriate route) Default panel options to select between low-medium-high urgency work modality Receiving route suggestion(s) and information (e.g., ETA, mean/total duration of automated driving periods, number of automated driving periods) based on her choice Possibility to choose route / accept / decline suggestions	None identified
2	*While driving in manual mode for the first couple of kilometers, the navigation display shows Florence when automated driving can start.*	Sensing system senses Florence's gaze, other physiological and neurobehavioral parameters and her driving behavior (steering wheel reversals, set speed, etc.) in relation to the driving context she is currently in. Based on this information, the system infers a F2D score	Receiving spatial/time-based information when which level of automated driving will be possible Receiving current automation status of vehicle (constant display of current status + possible level to transition to)	The system might distract or irritate the operator leading to a dangerous driving situation (e.g., a collision)
3	*Once she reaches that point, the car also provides other transition messages and makes it clear that she can give control to the vehicle.*	Sensing system senses whether Florence is handing back control to the vehicle (e.g. Florence gives no input to gas pedal or steering wheel; ADL system engaged)	Receiving information that she can hand over to the car Receiving information how she can hand over Indication of successful handover Receiving information about the kind of activities allowed and Florence's	The system might not correctly identify the hazards that it can handle or provide unclear and distracting messages

			responsibilities (e.g., takeover in <20s) in the current ADL	
4	*After transitioning to ADL 3, Florence starts reading her emails on the large HUD that is dimmed and mostly blocking the outside front-view such that she can easily read her emails but without inducing motion sickness.*	Sensing system senses Florence's activities: body posture, type of devices active in cabin, focus of attention – eye movements) It infers whether these activities are adequate for current ADL	Receiving indication that ADL 3 is active (and for how long) Easy access to emails and documents (either via laptop or vehicle interfaces) Possibility for individual adjustments of HUD / font size, dimming, etc. for her needs Easy-to use device to move along the emails	The system might not handle the situations correctly, and the operator may not be able to take over due to the obscured view or some motion sickness.
5	*The car monitors her physiological state to determine whether Florence is getting upset, seemingly tired, or starts engaging in activities that may prevent her to transition within a relative short period of time (i.e., activities that are not suitable for ADL 3 but would require ADL 3+). If such a case is detected, the car alerts Florence with an appropriate proposal on what would be best to do, depending on the situation.*	Continuous re-evaluation of F2D score based on physiological sensors (EDA, ECG, etc.) and eye-tracking data (e.g. number of blinks) to infer whether Florence is starting to experience motion sickness Sensing system senses Florence's activities: body posture, type of devices active in cabin, focus of attention (eye movements) It infers whether these activities are adequate for current ADL	Receiving alert that her activity/state is not appropriate for the current level of automation Receiving suggestions what to change in order to meet requirements of current automation level (and/or automatic adaptations of car interior) Possibility to check if activities can be done at a later point in time (when ADL 3+ is available) or suggestion provided by system to do it later when ADL 3+ is available	The system might not correctly recognize the state of the operator and might not properly support her.
6	*Florence sees a timer on the display telling her when to again transition back to manual driving. This timer gives her an opportunity to prioritize her tasks. As she gets closer to that manual driving transition point, the HUD starts to undim (unblocking the front view) and Florence gets additional cues that manual driving approaches.*	Sensing system senses whether Florence has attended to the transition alert (recording of gaze position)	Receiving multimodal alert that transition to manual driving is approaching and how much time is left in automated mode Receiving a gentle message that she can continue reading the emails later, so she does not feel annoyed by the system Option to regain manual control before the timer gets to zero (initiated by the driver) Timer present at all times so that Florence can schedule her work	The system might not give a good estimation of the time needed to take over leading to a dangerous driving situation (e.g., an accident).

7	*The cues are adapted to the current situation and can change in modality accordingly – e.g., if Florence is using her laptop for checking emails, a visual transition message is shown on this device; if Florence is listening to music, the volume of the music playing is reduced and the message is presented instead (similar to traffic information on the radio). The system gives Florence the most important information about the current driving situation in order to support her transitioning back to manual control.*	Sensing system senses which device is currently in use, sensing of ambient noise levels, vibration levels to adjust warning Sensing of traffic situation and infrastructure information (current speed level, etc.) to provide information to Florence	Receiving multimodal alert that transition to manual driving is approaching depending on Florence's focus of attention Receiving relevant information (e.g., current speed limit, right of way) about the current driving situation Receiving information how to take over Performing a fluid control transition from automated to manual If the hand over is done before the critical time the system helps to regain her driving performance	The system might not recognize the state of the operator and might give her wrong cues, leading to an unexpected situation.
8	*After she transitions to manual driving, the vehicle asks her whether she wants her email to continue to be read to her out loud as Florence is alone in the vehicle. She agrees and the system continues reading to her from where she had left off reading before.*	Sensing system monitors Florence's take-over performance (sensing of driving behavior in context of traffic and infrastructure information) Continuous re-evaluation of F2D score: sensing of physiological parameters (ECG, EDA, etc.) and neurobehavioral data (e.g. scanning patterns) in context of driving environment, in order to infer if Florence's workload is not exceeding adequate levels. Sensing and interpretation of traffic information and environmental scenery.	Receiving indication that ADL 3 is inactive (manual mode active) Possibility to continue with work verbally (initiated by Florence) Possibility to adjust sound settings if necessary Receiving information on how long she needs to wait until ADL3 is available again Option to restart reading from beginning instead of midway, in case Florence forgot in-between (depends on time between transitions + cognitive involvement)	The system might distract or irritate the driver causing a dangerous driving scenario (e.g., an accident).
	Some main Research Questions in this Scenario	**Can Florence's activities and states be sufficiently monitored via physiological and behavioral sensing to determine transition needs and if so how? What kind of environmental sensing is needed?**	**Will Florence find the predictability of transitions to manual driving more acceptable than the baseline and will she be able to drive more safely with them?**	**Does the predictability of transitions introduce new safety hazards?**

4.3.3 F3: Florence gets Heavy Office Work Assistance

Florence is using her computer and performs conventional office work on her way to work. She writes and checks email, opens and reads excel and PowerPoint files. Also, in the evening, she wants to take a nap when driving home.

Table 19. Particularities of the HADRIAN innovative components for mobility scenario F3

Automated Driving Level	HADRIAN ADL 3+ allows Florence to completely delegate all the driving tasks to the vehicle and can stay in such non-driving mode for extended periods of time (at least 30 min). She is then given extended time to come back to manual driving to account that her mind was away from driving for longer time and it may take longer for her to reengage. During ADL 3+ driving she can perform most non-driving related tasks e.g., she can write emails, nap, or handle papers and folders with her hands. Also, her seating position may turn away from the front. Florence is given at least 60 sec (?) time to transition back to manual driving.
Fluid Interaction Support	The FIS monitors what Florence is doing and her physiological and neurobehavioral signals to determine whether motion sickness may be developing. If this is determined, strong accelerations and braking maneuvers are avoided when she is reading / writing e-mails. The privacy of the information on the displays are ensured so that they cannot be send from the outside. Also, Florence's immersion in the task is measured for preparation of the take-over, e.g., by showing transition messages where she is currently looking at or using in-car ambient lighting to announce a transition. During the transition to manual control, the system monitors whether the driver is performing the transition appropriately.
Transition Planning Control	There is a task selection display that allows Florence to select what activity she wants to engage in during the drive. The CPTCTP will route the vehicle such that Florence can be perform her desired tasks as much as possible. The CPTCTP uses information from the infrastructure to perform these route planning and plans the transitions to ensure that Florence has enough transition time. It then gives the appropriate signal to Florence when it is time to transition back (via the FIS).
Tutoring	Florence learns beforehand and during the drive how the system is working, what to expect, and how to use it.

Table 20. Mobility Scenario F3 – Florence gets Heavy Office Work Assistance

No	Scenario Segment	Driver and Environmental Sensing Needs	User-Centered Interaction Needs	Safety Hazards
1	*Florence tells the vehicle that she wants to work intensively while on her way to work.*	Sensing system continuously records a set of data which is forwarded to the "fluid" HMI, for example: • In-cabin noise levels to adapt auditory messages • In-cabin luminance to adapt contrast of visual information • Vibration level to adjust haptic feedback • Meteorological information to adapt cabin temperature Sensing system senses and interprets the traffic (traffic jams, etc.), infrastructure information (possible stretches of ADL, routing)	HMI/Tutoring: Getting to know that she can inform the system about what she wants to do and how this will affect the behavior of the car (e.g., the car will select an appropriate route) Information about consequences related to choose ADL 3+ and route (e.g., vehicle might need to take detour in order to be able to support ADL 3+ over longer period) Informing the system what she wants to do Receiving information if this is possible or not	None identified
2	*This means that she will want to use paper files, pens, etc. in addition to her computer display, similar to a real office. Therefore, the car understands that Florence cannot be interrupted frequently and that she will have to take extra time to transition back to manual driving. Therefore, the vehicle selects a route with extensive infrastructure support for automated driving.*	Sensing system senses and interprets the traffic (traffic jams, etc.) and infrastructure information to select possible stretches of ADL and routing Sensing system senses Florence's state through a set of physiological and neurobehavioral parameters and her driving behavior (e.g., eye movements, sleep parameters, electrocardiographic measures, electrodermal activity, steering wheel reversals, set speed, etc.) in relation to the driving context she is currently in. Based on this information, the system infers a F2D level	Receiving route suggestion(s) and information (e.g., ETA, mean/total duration of automated driving periods, number of automated driving periods) based on her choice Receiving overview of actions for entire ride (travel phases: e.g., 5 mins. manual, 30 minutes L3+, 10min. L3, etc.) Possibility to choose route / accept / decline suggestions Receiving information that she needs to start the travel manually	None identified

3	*Once she has started to drive manually and reaches the automated driving initiation point, the car provides an auditory transition message and makes it clear that she can give control to the vehicle.*	Sensing system checks whether Florence is handing back control to the vehicle by sensing if Florence has engaged the automated driving system and gives no input to the gas pedal and steering wheel.	Receiving spatial/time-based information when which level of automated driving will be possible Receiving information that she can hand over to the car Receiving information how she can hand over Receiving information about the time until the next planned takeover. Receiving current automation status of vehicle and possible non-driving tasks	The system might correctly provide wrong messages leading to a dangerous driving scenario (e.g., an accident)
4	*Florence extends the vehicle-built-in keyboard and control inputs so that she can type and control the cursor. The large HUD is dimmed and mostly blocking the outside front-view such that she can easily view the display and the display is big enough to accommodate multiple pages of text, similar to the display in her office. Also, a folded tray extends that allows her to put her paper files, pens on it and fix it so it does not move around when driving. This allows her to sign and read while at the same time working on the keyboard and computer.*	Monitoring of Florence's state as well as body activities: body posture, type of devices active in cabin, focus of attention – eye-movements. Based on this information, inference whether these activities are adequate for current ADL	Receiving indication that ADL 3+ is active (and for how long) Initiating the heavy work task Possibility for individual adjustments of tray position, keyboard position, HUD / font size etc. for her needs Automatic adjustment of seat position for the writing task Automatic adjustment of the light environment to facilitate reading/writing in paper	The system might not be able to handle the driving situations properly and the operator may not be able to take over due to the obscured view. The presence of the folded tray might restrict the driving capability.
5	*She sees a timer on the display telling her when to transition back to manual driving.*	Sensing System checks whether Florence has attended to the transition information (recording of gaze position) and if Florence is starting to get ready for the manual take-over by sensing change in body posture and scanning behavior (scanning of important aspects in driving context)	Receiving multimodal information how much time is left in automated mode depending on her focus of attention Timer present at all times so that Florence can schedule her work	The system might not give an appropriate estimate of the time needed for take over leading to a dangerous driving scenario (e.g., an accident).
6	*The car observes Florence's physiological state for any signs of stress or motion sickness. As it detects that Florence has signs of motion sickness it tells Florence that she may*	Sensing system senses physiological parameters (e.g. EDA) and facial expressions (e.g. jawing) to infer	Receiving suggestion: do you want to look outside? Should I reroute (+ how much longer it would take)? etc.	The system might not correctly recognize the state of the operator and might not properly support her.

	want to take a short break from working and look outside, for which, upon Florence's approval, dims the HUD.	whether Florence is showing signs of motion sickness (F2D score)	Initiating unobstructed view outside if wanted Reroute/adapt driving behavior of vehicle (more straight roads to reduce probability of motion sickness)	
7	*The car also slows slightly down its speed to alleviate the first signs of motion sickness before they get more intense and searches for opportunities to safely stop if Florence is not getting better quickly. After Florence physiological state seems to get better again, the vehicle adjusts the system back to the working mode and she starts working again.*	Continuous re-assessment of F2D score to check whether set actions by fluid HMI were successful. Assessment see above. Sensing of traffic and infrastructure information (place to safely stop)	Receiving information about where to stop and impact on ETA if stopping Choosing to either stop or dim all interfaces for short time period in order to alleviate motion sickness Receiving recommendations to avoid motion sickness Possibility to inform system that she feels better Initiating of work task (system-initiated or self-initiated)	The system might not correctly recognize the state of the operator, and it might not properly support her.
8	*As she gets closer to the manual driving transition point, the HUD starts to undim (unblocking the front view) and Florence gets additional cues that manual driving approaches so that she can transition in time.*	Sensing System senses whether Florence has attended to the transition information (recording of gaze position) and if Florence is starting to get ready for the manual take-over by sensing change in body posture and scanning behavior (scanning of important aspects in driving context)	Receiving multimodal alert that transition to manual driving is approaching and how much time is left in automated mode Receiving information/messages to stow away office equipment (put your laptop in x, pens, in y, etc.) Receiving relevant information (e.g., current speed limit, right of way) about the current driving situation Receiving information how to take over Option to transfer to manual before the critical time (initiated by driver) Perform a fluid control transition from automated to manual If the hand over is done before the critical time the system helps to regain her driving performance	The system might not correctly identify the environment and give wrong cues. The time needed to undim the HUD might take longer than planned, and lead to obstructed view and unsafe driving

9	*After she transitions to manual driving, the vehicle provides her with information at what point she can get back to working in the vehicle again. The same ADL is used when Florence wants to nap or eat breakfast, except no office support is being offered. The screens dim to increase Florence's privacy by blocking the view from the outside.*	Checking of take-over performance (sensing of driving behavior in context of traffic and infrastructure information, e.g. set speed, lane keeping performance, deceleration/acceleration, time headway to vehicle in front) Continuous re-evaluation of F2D score: sensing of scanning behavior, physiological parameters (ECG, EDA) to infer workload	Receiving indication that ADL 3+ is inactive (manual mode active) Option to continue less demanding work once in manual mode Receiving spatial/time-based information when which level of automated driving will be possible Choosing between tasks in ADL 3+ quickly via standard options (work, breakfast, nap etc.)	The system might have issues with the I2V connections and not drive safely. The system might not correctly recognize the state of the operator, and it might not properly support her.
	Some main Research Questions in this Scenario	Can Florences activities and states be sufficiently monitored via physiological and behavioral sensing and if so how? What kind of environmental sensing is needed?	Will Florence find the predictability of transitions to manual driving more acceptable than the baseline and will he be able to drive more safely with them?	Does the predictability of transitions introduce new safety hazards?

4.3.4 F4: Florence gets Car Sharing Tutoring

Florence has a car sharing contract with a local car-sharing provider. The car comes to her location and she can use the various automated driving features to get her office work done on her way to work.

Table 21. Particularities of the HADRIAN innovative components for mobility scenario F4

Automated Driving Level	The car allows the ADLs 2, 3, and 3+ and comes appropriately equipped for a specific ride.
Fluid Interaction Support	See scenarios F1 – F3 for the appropriate level. In addition, the interaction support is made appropriate for multi-user usage.
Transition Planning Control	See scenarios F1 – F3 for the appropriate level. In addition, transition planning is made appropriate for multi-user usage.
Tutoring	Florence is required to perform a tutoring lesson prior to using the car for the first time. The tutoring lessons are adapted to Florence's learning history and avoid repeating old materials. She learns about how to order the right car for her trip and how to use the on-board systems.

Table 22. Mobility Scenario F4 – Florence gets Car Sharing Tutoring

No	Scenario Segment	Driver and Environmental Sensing Needs	User-Centered Interaction Needs	Safety Hazards
1	*Florence orders an office car for her commute to work. She has a selection of several different vehicle types that depend on the type of work she plans to be doing.*	Pre-driving assessment of Florence's state (Time after wakening, Sleep quality)	HMI for selecting vehicle depending on her needs (search, filter function) Overview of supported tasks, intended application areas of vehicle, and device support (connectors in docking station)	None identified
2	*In order to sign up for the car-sharing, she had to complete several pre-driving tutorials and even complete a test in a simulator to show that she understands the limitations and possibilities of the vehicle.*		Receiving tutorials about core support functionalities / ADL Practicing specific situations (e.g., how to activate/deactivate certain systems / ADL, practicing of transitions) in simulator drives Refresher tests/tutorial (for single functions or scenarios in case vehicle has not been used by Florence for some time) Help function to look up information on-demand	None identified
3	*Some tutorials are also given in the car when it is possible for Florence to safely view and study them if she has not yet passed them. Specifically, the usage of the timer and preparations for transitions back to manual driving were practiced in that session.*	Tutoring during drive: sensing system checks Florence's learning curve during the tutoring sessions by sensing her interaction patterns with the system (e.g. number of engagement/disengagement), take-over performance during "tutoring take-overs" (planned take-over maneuvers), eye movements (focus of attention, scanning patterns during take-over scenarios), etc. Information of traffic and environment is sensed in order to contextualize her	Receiving information about preparation for transition to manual driving Evaluate Florence performance during tutorial / after take-over	The tutorial might not cover all the different situations leading to misinformation of the operator

		performance and to infer when and what tutoring session should be issued		
4	*Once completed, Florence orders the car she needs, it comes to her location to pick her up. She can leave the car on the side of the road - it finds itself a parking spot.*	Sensing system senses traffic and environmental scenery, Florence's GPS coordinates to a) find Florence, b) find itself a parking spot	Receiving information that automated parking is possible Receiving information how to safely leave the car Receiving information (e.g., on mobile phone) that the car is parked and location of the parking spot	The system might not be fully supported by the I2V and it might not be able to park alone
5	*The car company has a profile for Florence, knowing how often she has driven a specific car and provide appropriate tutoring. Therefore, if Florence is using a new car, the tutoring sessions focus on explaining the most important differences between the current, "new" car and previous cars Florence has used recently (or most often).*	Tutoring during drive: sensing system checks Florence's learning curve during the tutoring sessions by sensing her interaction patterns with the system (e.g. number of engagement/disengagement), take-over performance during "tutoring take-overs" (planned take-over maneuvers), eye movements (focus of attention, scanning patterns during take-over scenarios), etc. Information of traffic and environment is sensed in order to contextualize her performance and to infer when and what tutoring session should be issued	Receiving information about the new / other functionalities of the car and limitations Possibility to request certain information or skip parts of the tutorial Possibility to choose full tutorial (e.g., in case time has passed since Florence used an older model) Allow scheduling of tutoring sessions along with ADLS and entire trip	The tutorial might not give a fully knowhow of the system, leading the operator to unexpected events

5 MOBILITY SCENARIO DEVELOPMENT PROCESS

This section describes the development process of the mobility scenarios and administration of the workshops. Also, additional information about the scenarios and discussions within the workshops is summarized here.

In general, the development process was organized as follows for each of the three user groups targeted in HADRIAN:

1. **Getting to know the users:** In order to identify constraints, needs, daily work routines etc. of the respective user group, we did an extensive literature research. Furthermore, we talked to experts and identified future mobility scenarios. All HADRIAN project partners were provided with a summary of these results prior to the respective workshop in the consortium telcos.
2. **Creating the persona:** In order to create a common understanding of the user group and its specifities, we created representative personas, who comprise the most relevant characteristics of the respective user group. We developed Harold as a respresentative of elderly drivers, Sven as a representative of truck drivers, and Florence as a representantive of business people, who want to do office work in their car.
3. **Preparing and conducting workshops with selected HADRIAN project partners:** In preparation for the workshops we identified typical situations the persona might face based on her/his needs. These served as discussion basis within the workshops. General aim of each workshop was to identify problems and challenges related to the situations, and to collect and discuss first ideas how to solve those issues within HADRIAN. The workshop for Harold was conducted face-to-face in Munich. The workshops for Sven and Florence were done remotely due to the corona virus outbreak.
4. **Summary of workshop results and development of mobility scenarios:** After each workshop, the workshop notes were summarized and structured based on the underlying solution concepts. This structured summary then served as basis to generate the mobility scenarios, i.e., the storyline was developed considering how these concepts could be used in real driving situations.
5. **Iteration and collection of initial requirements:** The summary and derived mobility scenarios were then sent to the project partners for feedback and iteration. A consolidated version served as basis to identify the initial requirements. These were collected, discussed, and iterated under the guidance of the responsible work package leaders (i.e., WP2 focused on driver-environmental sensing, WP3 on user-centered interaction needs, and WP5 on safety hazards).

The following subsections are structured as follows: First, we provide an overview of the literature relevant for developing the respective persona and identification of typical situations. We then outline the workshop conduct, and provide an overview of the workshop results and additional discussions.

5.1 Harold Scenarios (Elderly)

5.1.1 Summary of Research in Elderly Mobility Needs

The next section gives an introduction to critical needs and impairments of older drivers. It particularly focuses on physiological and psychological limitations, and their impacts on driving performance. Also, some approaches to support elderly in compensating their issues are presented.

5.1.1.1 Elderly Driving Performance

5.1.1.1.1 Elderly Impairments

In the course of their life, people develop a multitude of impairments, especially in the age of about 60-70 years. These can interfere with the driving capabilities of those elderly people. A case control study by Vaa (2003) with 298 cases yields the relative risks of some of those impairments. The risk was calculated by comparing the number of accidents involving drivers with condition with the number of accidents involving drivers without condition. Both numbers were controlled for the kilometers the people were driving. Particularly dangerous are cognitive impairments, followed by cardiovascular diseases and hearing, locomotor and vision impairments. The table beneath shows the exact relative risks of the study.

Table 23. Relative risk of elderly impairments

Impairment category	Additional relative risk of accidents
Visual	1.09 (9%)
Arthritis/Locomotory	1.17 (17%)
Hearing	1.19 (19%)
Cardiovascular diseases	1.23 (23%)
Diabetes mellitus	1.56 (56%)
Mental disorders	1.72 (72%)
Neurological	1.75 (75%)
Alcoholism (for reference)	2.00 (100%)

Even though it seems little, visual impairments do play a role of driver's safety to be concerned with. Because the vision of older people generally decreases, and they are slower to identify and substitute the missing visual cues, they are prone to accidents. Wood (2002) analyzed proposed critical visual impairments of older people and looked into five aspects in literature. a) Reduced visual acuity was in some studies found to decrease driving performance, but the effect is questioned by a controversial effect of a large study with 17.000 drivers which found no effect. b) Loss of visual field and peripheral vision is greatly associated with increased accident rate. Drivers with reduced visual field have crash rates twice as high as healthy drivers. c) Reduced dynamic visual acuity is the ability to resolve details in moving objects.

This reduced vision of moving targets also increases chances of accidents. d) Loss of binocular vision was not found to greatly reduce driving capabilities. e) Decreased color vision is more controversial in literature. Some studies found great effects, while others found none. However, it has be mentioned, that it has not been greatly researched yet.

5.1.1.1.2 Impairment Self-Assessment and Compensation

Besides those impairments, older people generally seem to have little self-assessment capabilities of their own driving critical abilities. A paper by Horswill et al. (2011) shows, that elderly drivers have poor insight in their own hazard perception capabilities. They tend to overestimate their specific driving relevant capabilities. This can be a great safety critical impact in traffic. On the other hand, they are in able to self-assess their general driving capability and restrict their driving behavior based on that.

This insight in their general driving capabilities makes it possible for older drivers to compensate for some of their psychological and physiological losses. A study by Andrews & Westerman (2012) for example found, that elderly drivers compensate by adopting longer headways to decrease chance of collision. They also found, that older drivers with lower cognitive ability generally anticipated traffic events less frequently, which speaks for a successful, intuitive assessment of their capabilities. Also, older drivers with a lot of experience were able to rely on that knowledge concerning maintaining lane position, even though they showed decreased spatial ability. However, compensation for age-related cognitive ability impairments seems to require an investment of additional resources. This leads to less of those resources for other critical task in traffic. The fact, that older people avoid driving solely because of self-regulation is criticized, however. Molnar et al. (2013) found, that elderly drivers often change and restrict their driving behavior because of lifestyle changes and preferences, as opposed to self-regulation. They identified three groups of reasons drivers give for deciding if they strategically participate a traffic situation (e.g., driving during rush hours, driving in unfamiliar areas, plan the route ahead of time, etc.) or tactically do certain actions while driving (e.g., eating while driving, chatting with passengers, reading a road map while driving, talking on phone while driving , etc.). a) Non-modifiers, b) self-regulators, c) others, which includes for example the fact, that they don’t need to participate in risky behavior while driving.

The general consensus agrees, that elderly drivers are able to compensate a variety of different impairments, especially if they are still relatively fit in complementary issues. For example, it is possible for people with peripheral impairments to turn their heads more and substitute for their impairment. The most critical safety issues arise, when this is not possible anymore and multiple systems of a person are impaired. Especially problematic are decreased cognitive capabilities, which can generally hinder the ability to compensate. Specific cognitive impairment types are reduced divided and selective attention, speed of processing information and less decision-making performance and performing tasks consciously (Davidse, 2006). This is validated by the fact that the most occurring accident types involving elderly people are complex situations like intersections (Wood, 2002).

5.1.1.2 Elderly Mobility Needs

5.1.1.2.1 Travel Needs

Musselwhite and Haddad (2018) proposed a model for the travel needs of elderly drivers. They developed a model consisting of three hierarchical categories. a) Primary mobility needs are purely the practical basis of mobility. The primary mobility need of the person is simply to get from A to B as safely, reliably, cheaply and comfortably as possible. b) Secondary mobility needs are embedded in the social context of a driver. They represent the need for independence, control and to be seen as normal. They are linked to status, roles, identity, self-esteem and impression management. c) Tertiary mobility needs are of aesthetic nature. The authors divided the aesthetic needs in three different topics: Kinesthetic mobility, which is mobility for its own sake, the feeling of movement and of being mobile. Immersive mobility, which is the need to visit and immerse in beauty (e.g., beautiful sceneries and locations). Imaginative mobility, which is thinking in mobile possibilities, observing movement, reminiscing and discussing movement. The authors believe that this model might correspond as well to younger drivers. However, they only assessed and constructed the model based on older drivers.

5.1.1.2.2 Acceptance

Diepold et al. (2017) investigated the general acceptance of older people towards automated vehicles. They found, that about 75% of elderly drivers are not willing to ride with automated vehicles due to uncertainty and distrust in the technology. The rest (25%) are curious about the new technology and would like to try it once at least. The main reason indicated was to “enjoy the environment passing by”. Controversial to the general acceptance of automated vehicles, older people do actually seem to see their benefits in increased mobility and greater independence (Schmargendorf et al., 2018) found. However, they are also concerned about certain topics, like security and privacy of those cars. Son et al. (2015) did another research on the effect of age on acceptance and effectiveness of ADAS, focusing on forward collision warning and lane departure warning systems. They found no significant effect for acceptance of ADAS between younger (30-45 years) and older (60-75 years) drivers. Older drivers however, profit more of ADAS than younger drivers do, concerning safe driving behavior.

5.1.1.2.3 Interface Design

Concerning the interface of an automated vehicle, it seems that older people have special needs. A study by Kim et al. (2012) investigated the impact of multimodal, in-vehicle navigation systems. They found that, while young drivers benefit from multi-modal navigation systems, older people are oftentimes overwhelmed because of their already high workload and issues concerning selective attention. Thus, such interfaces must be personalized for elderly people and best restricted to less modalities. An interview-study by Li et al. focuses on the general design of an age-friendly highly automated vehicle. Older drivers specified, that they are positive towards highly automated driving, but they want to retain potential control over the vehicle. They especially require an information and a monitoring system, where they can control the behavior and the reasons of the automated vehicle. They need the takeover requests of an automated vehicle to be adjustable and explanatory. The driving style should be imitative, such that it imitates the standard driving style of the driver, and corrective, such that it corrects bad and dangerous driving behavior of the driver, in the same time.

5.1.1.3 Improvements for Elderly Drivers

5.1.1.3.1 Advanced Driving Assistance Systems

There are already some concepts and ideas for assisting older drivers in traffic. A variety of those is summarized by (Davidse, 2006). He searched the most critical aspects of elderly driver’s accident rate and suggested certain assistance ideas. The idea is, that an advanced driving assistant system should support the relative weaknesses of the driver. It should not take over tasks the driver already is good at. The author differentiated the impairment in a) vision and hearing (peripheral vision, nighttime visual acuity, sensitivity to glare, contrast sensitivity, colour vision, motion perception, hearing), b) cognitive processing and decision making (divided attention, selective attention, speed of processing information and making decisions, performing tasks consciously), c) physical changes (flexibility of head and neck, manual dexterity and strength) and d) interaction with other road users (performance under pressure of time, insight in the behavior of other road users). Some assistance needs and ADAS ideas for the most important impairments concerning crash rate are listed in Table 24.

Table 24. Suggested ADAS for elderly drivers (Davidse, 2006)

Impairment category	Assistance needed	ADAS
Peripheral vision Flexibility of head and neck	Signaling objects that are located in the driver's blind spot	Automatic lane changing and merging systems Blind spot and obstacle detection systems
Motion perception	Draw attention to approaching traffic	Collision warning systems aimed at intersections Automated lane changing and merging systems
Selective attention	Assist driver in directing attention to relevant information	In-vehicle signaling systems Special intelligent cruise control
Speed of information processing and decision making Performance under pressure of time	Provide prior knowledge on the next traffic situation	Systems that give information on the characteristics of complex intersections the driver is about to cross

Since older people are overrepresented in accidents at intersections because of their decreased divided attention and their issues at decision making under time pressure, Dotzauer et al. (2013) tested an intersection assistant in their study. They found, that it significantly increased the focus on relevant aspects of the situation, like the center of the street. This resulted in saver intersection crossings in shorter times. Another study by Becic et al. (2013) showed that additional cognitive load by distraction led to a more conservative driving style in younger and older drivers, when crossing an intersection and when they used an intersection-crossing assistant. Older drivers showed even more conservative driving styles and relied more on the in-vehicle intersection-crossing assistant than younger drivers. The intersection-crossing assistant was a sign in the vehicle indicating if the way to cross the intersection is free or if crossing cars are approaching.

Li et al. (2019) focused on age friendly highly automated vehicles, especially on take-over situation performance. Results indicate, that informing the driver about the state of the vehicle together with giving reasons for the manual driving takeover request led to better takeover performance, lower perceived workload and more positive attitudes towards the vehicle for every age group. Also, verbal signals about the takeover-related states of the car are helpful. Purely signaling the reasons for a takeover request without giving specific information about the situation led to less positive effects in takeover performance and perceived workload for older people.

A research by Emmerson et al. (2013) focuses on the impact of navigation systems on elder's driving behavior. They showed increased confidence with navigational systems than without. The system acts also as a form of companionship and an element of pleasure in driving. Older drivers who don't use navigation systems are more often involved in unsafe navigating behavior, like printing the navigation instructions on paper and glimpsing on those while driving.

5.1.2 Workshop Conduct

The workshop took place on the 11th of February 2020 in Munich with representatives of CEA, NVT, PLUS, UGR, VDI/VDE-IT, and VIF. The total number of workshop participants was 11.

In the beginning, all participants were introduced to the workshop aims and were provided some general advice about the workshop process. This was followed by a short presentation of Harold and his mobility needs. The participants were then divided in three teams, each assigned to one of the three mobility needs. Thereby, each team consisted of members of different partner institutions to ensure a diversity of viewpoints.

Each group got the task to envision the respective trip from Harold's home to the destination, and to think about challenges Harold may face on his trip. Each group draw the trip on a big sheet paper and made notes about possible challenges. After this initial problem identification, participants were asked to brainstorm individually about possible vehicle solutions for the identified challenges in their group and to write down these ideas. Afterwards, the respective group discussed their solutions and decided on the best ideas. The results of each group were then presented to all workshop participants and were further discussed (for the collected workshop material, see Figure 5, Figure 7, and Figure 6). Based on the feedback, each group refined their solutions and worked out the main concept elements. In short final presentations, these elements were presented to all participants. All presentations were video recorded to ensure a comprehensible documentation of the results. The workshop was concluded with a discussion on the gained insights and suggestions for further workshop procedures.

5.1.3 Additional Scenario Discussions and Workshop Material

5.1.3.1 Harold Scenario H1

- If Harold makes too many errors or does not appear to be fit to drive, the vehicle can take over in many scenarios (like acceleration/deceleration or lane assist). If it does it will always ask Harold if it should and tell him the reason why.
- A safe overtaking maneuver for example can be different for everybody, based on the speed one is mentally able to accelerate in such a situation. The vehicle must be customizable in such a way, that Harold feels safe.

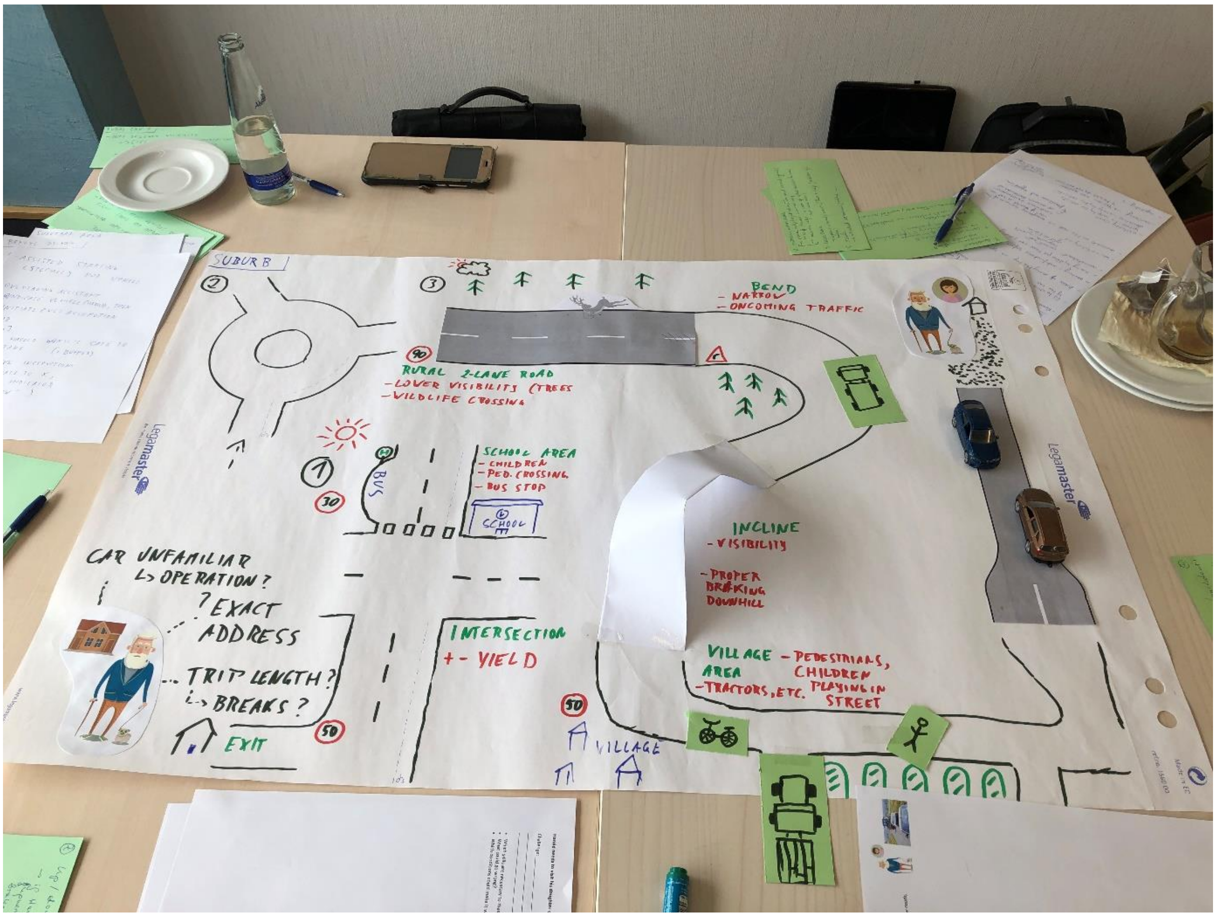

Figure 5. Workshop material for mobility scenario H1

5.1.3.2 Harold Scenario H2

- System tells Harold what fuel to use at the fuel station
- The system actively supports in traffic jams with distance keeping, and an emergency breaking assistant
- When approaching a toll station, the system shows Harold how close to the toll booth he must get for the transaction
- Since the sun can blind at in the evening an adaptive front screen compensates for the light
- It also shows him selected information about surroundings for Harold's enjoyment while Harold is driving with very low workload or has stopped.

Figure 6. Workshop material for mobility scenario H2

5.1.3.3 Harold Scenario H3

- Stopped vehicle on the road that is unloading material, requiring Harold to pass.
- A left turn without traffic light, where Harold has to wait for oncoming traffic to pass before turning left
- An emergency vehicle behind Harold that is detected by Harold's car, the acoustic signaling reflects where the emergency vehicle is coming from. Harold's vehicle is automatically implementing the safe maneuver and informs him about doing so.
- Self-parking at the hospital based on a simple mechanism that allows Harold also to call the car again for pick-up.

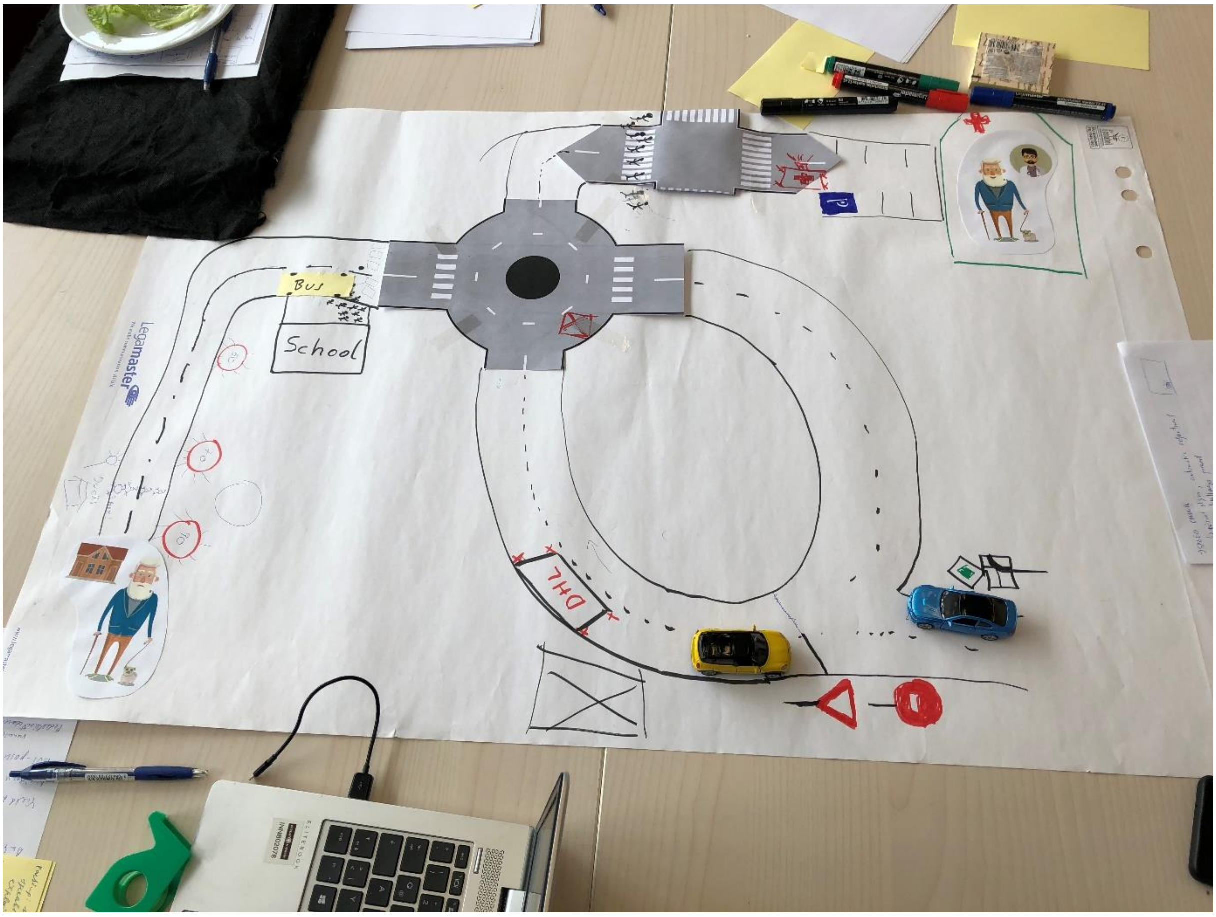

Figure 7. Workshop material for mobility scenario H3

5.2 Sven Scenarios (Truck)

5.2.1 Summary of Research in Truck Mobility Constraints

The following sections give an understanding of different aspects of truck drivers. Besides depicturing the current situation of truck accidents in Germany, the sections focus on truck drivers' constraints and legal issues. Last, there are a few related projects and studies listed.

5.2.1.1 Truck Accidents

To understand which aspects of truck driving must be considered in order to increase driving safety, we must first understand the characteristics of truck driving and which situations are problematic. The following chapters represent our research into this topic.

Trucks are involved in about 4% of German traffic accidents. With annual external financial damages of about 393 million Euros, they are responsible for 9-16% of financial damage on German streets. Percentagewise the highest financial loss happens on motorways (Bundesanstalt für Straßenwesen, 2005). Those high costs of accidents are caused by the greater value of each truck in addition to the potential loss of wares and the accumulated costs of an inactive truck. Truck accidents are mostly triggered by insufficient distance to surrounding vehicles and unadapted speeds of those vehicles. Often, vehicles are cutting in in front of a truck on motorways and causing it to either brake too rapidly and damaging vehicles behind the truck, or by directly crashing into the vehicle cutting in. Incorrect lane changes are another issue in truck driving. When changing lanes on motorways, it is more likely that truck drivers overlook incoming vehicles and bumping into those. Changing lanes can be problematic without additional traffic participants too, since the size of a truck facilitates that truck drivers lose control in this maneuver and crash into the guard rail. Truck accidents also often happen at intersections. Especially vulnerable traffic participants like, e.g., bicyclists are problematic here, since those can be overlooked even easier (Panwinkler, 2018; Trabert et al., 2018).

The above-mentioned accident situations mostly have two main reasons: violations, where a (truck) driver intentionally breaks certain driving rules and shows problematic behavior while driving, and errors, where a driver causes an accident unintentionally because of physiological issues or distraction (Sullman et al., 2002). The following chapters will look further into this and portray critical circumstances.

5.2.1.2 Truck Driver Constraints

When looking into reasons why safety impairing behavior in truck drivers occurs, a reasonable approach is to investigate the work-life of truckers since the situation in which the driver works has an impact on his safety-critical behavior. The following chapter depict important legal issues, actual work routines of truck drivers, and their thoughts on their work situation.

The work of truck drivers consists of driving and sitting in their vehicles for many hours. Hence, they often suffer from an inadequate diet, sedentary habits, and mostly do not have the time to do sports. Also, dense schedules, long work weeks, a constant feeling of being monitored of the drivers, breaks, etc. and the responsibility for the truck and its goods are very straining conditions. Consequently, many truck drivers have too little sleep and are exhausted while driving (Williams & George, 2014). Many start their work-day tired. Some drivers even stated in interviews, that they use long, straight roads for short naps to regenerate a bit. Because of their demanding work routines, truck drivers are a high-risk group for health conditions, like cardiovascular diseases, obesity, sleep apnoea and stress (Greenfield et al., 2016). However, they do know that their unhealthy lifestyle has consequences in the long run and would like to change their lifestyle and health if the conditions would allow for that. (Greenfield et al., 2016) suggest, that health improvement ideas should be aligned with the unique working conditions of truck drivers.

The already mentioned issues of rule violation and error manifests itself in distractions like cell phone usage while driving. This is obviously a huge risk, however it happens fairly often because of boredom. Also, too dense driving schedules may force truck drivers to do administrative tasks and route planning while driving (Claveria et al., 2019). The safety impact of distracting secondary tasks is influenced by three dimensions: a) The frequency of a secondary task, b) its duration, and c) its visual demand (Hanowski et al., 2005). Especially high visually demanding tasks, like the use of mobile phones when texting or browsing the internet and navigating with purely visual navigation systems, carry the highest risk. It is important to note however, that not only visual tasks reduce visual attention on the street. A mainly auditory stimulus does not imply, that drivers will not look away from the street (Hanowski et al., 2005).

Not only the usage of one’s mobile phone poses a safety risk. Secondary tasks unrelated to driving can be categorized in three groups: a) work-environment related necessities, like getting food from the in-cabin refrigerator, eating, drinking, etc., b) interacting with one’s phone and c) administrative tasks, like schedule planning, filling in logbooks, etc. Since truck drivers are prone to the issue of boredom, they are compensating it by doing secondary tasks and initiating social interaction via phone calls or skype while driving (Iseland et al., 2018).

5.2.1.3 Obstacles for Highly Automated Trucks

To design an automated system reducing safety critical incidents, it is important to understand, which obstacles are already revealed by previous research. With this knowledge we are able to consider those hurdles early on.

5.2.1.3.1 Acceptance

When implementing a new system in a workflow, it is important that potential operators and stakeholders can accept it. Concerning automated trucks, research found that, while many drivers are skeptical of the concept of high-tech automation in vehicles, there is a huge variance between people in their level of acceptance. The attitudes spread so much especially because of different views on topics like ease of use of a system, design quality of the cabin, and if the system can successfully improve workflow. Trust in road safety, reliability, and the likelihood of workflow improvement however, are less influential on acceptance than expected (Fröhlich et al., 2018). Drivers specifically also worry about the comfort of such a system, potentially reduced driving pleasure and the feeling of getting redundant and replaced by a machine (Richardson et al., 2017). In summary, the general consensus is that hedonistic aspects of an automated truck, like comfort and better quality of work-life, are most influential on acceptance.

To design for an acceptable system for trucks, it is also critical to consider that many truck drivers already struggle with today's driving assistance technology. This causes a certain mistrust in such systems by drivers. Trösterer et al. (2017) found in a contextual inquiry study that truck decision makers and drivers have an understanding that highly automated trucks may increase driving safety. The most important benefit for decision makers is that it could make the profession of a truck driver more attractive, since there is a constant lack of personnel in this area. However, both groups have ambivalent opinions of how reliable automatic trucks would function. It is also difficult for truck drivers to imagine automation technology in their trucks, which increases mistrust. The availability of information about how much time is left approximately until a takeover situation could have a positive effect on acceptance, since this would allow truck drivers to engage more deeply in secondary tasks and plan them better when driving autonomously.

5.2.1.3.2 Take-Over Situations

Because it is a very safety-critical situation, take-over requests are important to consider. When an automated truck hands over the control to the driver, he must be ready to drive as quickly as a given situation requires him to prevent potential calamities. In general, truck drivers have a slightly better take-over reaction time than unprofessional drivers, possibly because of their profound experience on the roadway. Applicable to professional and private drivers is, that more complex and less prematurely visible situations, where a take-over is required, take more time for the driver to process, which leads to longer reaction times. The visual attention also has an impact, since drivers, who look away from the roadway when a take-over request is called, also take longer to react. However, the general take-over reaction time of a driver gets shorter by every call, which implies a learning effect (Lotz et al., 2019).

Furthermore, not only the current situation and behavior of the driver has an impact on take-over time, but also the design of human-machine interfaces preparing the drivers for take-overs. Telling the driver how much time or how much distance it approximately takes until the next foreseeable take-over has positive effects on reaction time. Also, more information about the take-over situation leads to more sympathy towards using an automated system, less stress, and more feeling of control over the situation. The greatest positive influence on reaction time has time-based information, where the system tells the driver how much time is left until the next take-over (Richardson et al., 2018).

5.2.1.4 Truck Automation Legal Regulations

Understanding the public legal situation of mandatory automated systems and assistance systems for trucks can help to design more in line with the latest technologies. It allows to purposefully either improve existing and upcoming technology, or to investigate which novel technologies need to be introduced.

Table 25 shows a selected list of relevant assistance systems for trucks, which will be made obligatory in the European Union in the near future between 2022 and 2024 (ADAC e.V., 2019). The new regulations are especially supposed to decrease accidents at intersections, turnings, and accidents by distracted drivers. Most of the systems must follow certain requirements when implemented in a truck. For example, is it mandatory that they can only be turned off when the driver performs a series of actions, to prevent an accidental shut-down of the systems; but it must be easy to turn off acoustic warning signals, if the driver feels distracted by those; the system also must be always activated automatically when the truck is started.

Obligatory automation systems for trucks, as well as other vehicles, in the near future include systems, which can take vehicle control from the driver, which monitor state and environment of the vehicle, and which monitor if the driver is ready to retake control of the vehicle if necessary. Those systems are only described on a very abstract and fundamental level by the General German Automobile-Club (ADAC).

Table 25. Future mandatory automation & assistance systems for EU trucks

System	Description
Intelligent speed adaption	Assists drivers in complying with the legal speed limits. Drivers will be made aware by various modalities when exceeding speed limits. However, it must be possible to be turned off at any given moment, since the responsible agencies currently do not believe it to be reliable enough to work without such an option. It only provides information and must not interfere with driving.
Advanced emergency braking system with detection of moving vehicles, pedestrians and bikes.	Is able to brake and reduce speed independently when an immediate accident is detected. According to the ADAC it is the most important near future system to reduce accident rates in trucks.
Lane-keeping system	Automatically keeps the truck in the proper lane when driving.
Turning assistant	Detects pedestrians and bicyclists in front and next to the truck and warns the truck driver of these as potential accident objects.
Driver drowsiness and attention warning	Detects tiredness of a driver and warns him if his state gets too bad to continue driving. It must not store information because of data protection.
Advanced driver distraction warning	Detects the level of distraction of the driver. The system can warn him about this and tell him to return his focus on the street.

5.2.1.5 Other Relevant Projects and Publicatins for Highly Automated Truck Driving

A couple of projects are already at the start working on different automated truck concepts. We must look into those to separate the HADRIAN project from already existing ones, prevent redundancy and create valuable scientific and technological contributions.

An especially interesting project is the German TANGO project (Robert Bosch GmbH, n.d.). It focuses on automation level and drivers secondary task availability based on the driver's psychophysiological state. The truck monitors the driver's state while it drives in autonomous mode and combines this information with the state of the vehicle and the environment. The truck then checks for secondary activities the driver can safely perform at a given moment. If the truck drives in fully automated mode in a less complex environment, e.g., on a straight motorway, it gives the driver the possibility to perform more complex tasks than in more complex situations, when it might need the driver's attention more probably. Possible tasks are also generated based on the demands on the driver. The system will offer easier tasks in situations where it detects high stress levels of the driver. The whole system is an approach to realize more adapted and safe take-over situations, more acceptable automation systems, and more efficient use of automated trucks.

Other approaches focus on the possibilities automated trucks might offer to the driver. For example, (Richardson et al., 2015) investigated the health issue of truck drivers and created a driver seat, which is adaptable for the drivers' current movement and sport's needs. In automated mode of the truck, it allows the driver to stand up and do exercises while safely being strapped in the seatbelt.

More projects exist, which take different approaches on automated trucks. Some are centered on trucks, like adaptive information given to the driver for platooning operations to increase selective situational awareness of the truck driver to more effectively detect safety-issues (Tarkiainen et al., 2019). Some projects by private companies and the European Union can be found under the following links:

- TANGO – https://projekt-tango-trucks.com
- A list of different EU projects – https://ec.europa.eu/transport/road_safety/specialist/projects_en
- MAN – https://www.truck.man.eu/de/en/Automation.html
- Volvo – https://www.volvotrucks.com/en-en/about-us/automation.html

5.2.2 Description of Resting Requirements for Truck Drivers (AETR-Agreement)

The European Agreement concerning the Work of Crews of Vehicles engaged in International Road Transport (AETR-Agreement) from the year 2006 consists of cross-country regulations for mandatory breaks and resting time of professional truck drivers carrying goods. It only applies to drivers of vehicles exceeding 3.5 tons. It is, however, not necessary to be loaded for the regulations to come into effect. It covers the EU as well as a list of other countries, like Albania, Norway, Russia, Serbia, Turkey, Ukraine, etc. It distinguishes different kinds of regulations for breaks and driving limits, which will be summarized in the following chapter.

5.2.2.1 Breaks

Breaks are short rests after a certain period of continuous driving. During a break, the driver must not carry out any work including driving. The break may be taken in a moving vehicle. After driving for 4.5 hours, a truck driver has to do a break of at least 45 minutes. Alternatively, a driver can split up the break in two smaller ones. One break of at least 15 minutes is carried out during the 4.5 hours driving period. After the driving period, he then must carry out another break of at least 30 minutes.

In summary, there are two types of breaks:

1. Regular breaks (45 minutes after 4.5 hours driving)
2. Split breaks (2 breaks during 4.5 hours driving, second one must be 30 minutes)

5.2.2.2 Daily driving limit

The daily driving limit describes how long a truck driver is allowed to drive per day. It includes only driving time, and not breaks or rests. The maximum daily driving time is 9 hours. Twice a week the maximum daily driving time can be increased to 10 hours.

In summary, there are two types of daily driving limits:

1. 9 hours
2. 10 hours (twice a week)

5.2.2.3 Weekly driving limit

The weekly driving limit regulated how long a truck driver is allowed to drive in a week in total. It limits the weekly driving time to 56 hours, applied to a fixed week from Monday 00.00 am till Sunday 12.00 pm. The limit over a two-week period is 90 hours. For example, if one drives for 56 hours in week 1, he is allowed to only drive 34 hours in week 2.

5.2.2.4 Daily rest periods

A daily rest period is an uninterrupted period where a driver may freely dispose of their time. The employer is not allowed to give a driver any kind of task during this time. The normal daily rest time is at least 11 hours after working. A driver can, however, split up the daily resting period in two smaller periods of at least 3 hours each. When splitting the daily resting time, it must be 12 hours in total, instead of 11 hours. A driver can also reduce the daily rest period to 9 continuous hours three times between any 2 weekly rest periods. No compensation for this reduction is required afterwards. A daily rest can be taken in a vehicle, as long as it has suitable sleeping facilities and is stationary.

In summary, there are three types of daily rest periods:

1. Regular daily rest (11 hours)
2. Split daily rest (2 times at least 3 hours, 12 hours in total)
3. Reduced daily rest (minimum 9 hours every two weeks)

5.2.2.5 Weekly rest periods

Weekly rest periods describe the mandatory resting time for a truck driver for each week. A weekly rest must start after a maximum of six consecutive 24-hour periods from the end of the last weekly rest period. A weekly rest period is at least 45 hours consecutive hours long. A driver can take a reduced weekly rest period of a minimum of 24 hours. If a reduction is taken, it must be compensated for by the difference of the taken rest and the regular rest period of 45 hours. This compensation must be done at least after 3 weeks. For example, if a truck driver is resting for 33 hours in one week (12 hours less than regularly), a rest of 45 + 12 hours must be taken after at least three following weeks.

In summary, there are three types of weekly rest periods:

1. Regular weekly rest (45 hours after six days)

2. Reduced (24 hours after six days with compensation after 3 weeks)
3. Compensated weekly rest (compensation for reduced rest)

5.2.2.6 Multi manning

Multi manning is the situation, when at least two drivers are present in the vehicle in each driving period. When multiple drivers are present, each driver must only have a daily rest period of 9 continuous hours per 30 hours instead of an 11-hour rest per 24 hours. The truck must stand still during this resting period. This change of resting time is titled the “multi-manning concession”. Its purpose is that two drivers can take turns in driving for 4.5 hours and taking a break. The rest periods of 9 hours cannot be counted as regular daily rests, but are counted as reduced daily rest, which is only allowed three times in any two-week interval.

Sources:

Driver and Vehicle Standards Agency. (2016) Drivers’ hours and tachographs: good vehicles. Retrieved from https://www.gov.uk/guidance/drivers-hours-goods-vehicles/1-eu-and-aetr-rules-on-drivers-hours

5.2.3 Workshop Conduct

The remote workshop took place on the 11th of March 2020 with representatives of ASF, CEA, FORD, NTUA, NVT, PLUS, TEC, UGR, USR, VDI/VDE-IT, and VIF. It was originally planned as face-to-face meeting in Frankfurt, which needed to be cancelled due to the corona virus outbreak. The total number of workshop participants was 17.

In the beginning, all participants were introduced to the workshop aims and were provided some general advice about the workshop process. This was followed by a short presentation of Sven and the three scenarios. Also, participants were introduced to the AETR-agreement on resting times of Truck Drivers in Europe. After that, the three situations were discussed successively. The procedure was the same for each situation:

First, participants were asked to imagine that Sven currently drives a truck with SAE ADL 2 features, i.e., it has a lane departure warning system and emergency braking assistance. Based on this assumption, it was discussed which challenges may come up for Sven, how the situation could affect Sven and his behavior, and which conditions would make it worse. The comments of the participants were written down in a Word document, that was shared online and was visible for each participant. To trigger the discussion, the participants were also asked to look at some pictures showing specific situations.

Second, it was discussed how the situation would change if Sven was provided with a highly automated truck. Specifically, it was discussed, what the truck should provide in order to help Sven, what is particularly helpful for Sven, what he could do now that he could not do before, and which new problems may arise. Again, participants’ comments were written down in the Word document.

The workshop was concluded with suggestions for further remote workshop procedures.

5.2.4 Mobility Scenario Considerations during the Workshop

5.2.4.1 Short Trip and Stressed by Delay

For this situation, several factors were identified that could further stress Sven. On the one hand, there may be environmental factors that cannot be controlled by Sven, e.g., bad or extreme weather conditions, unexpected traffic jams, necessary detours because of an accident, getting pulled over by the police, crowded rest stops, or a flat tire. Also, cognitive distractions may complicate the situation, e.g., like getting a phone call that his daughter is sick. According to the AETR resting requirements, Sven can continuously drive up to 4.5 hours but then needs to do a break for about 15 min, and he needs to take at least one break on his 6-7 hours drive. This needs to be planned optimally in order to avoid any further delay. Also, even if he makes it in time to Hamburg, the unloading may take longer than expected.

The stress could impact Sven’s behavior in different ways. He may drive faster than the speed limit and probably with less distance to the trucks in front. He may be tempted to overtake trucks in risky situations. Also, he may initiate secondary tasks while driving, since there is no other time to do them (e.g., eating, attending to bureaucracy, planning for alternative routes, communication with dispatcher, daughter). While slightly fatigued and stressed, Sven has some experience handling these states as he did many times. Nevertheless, he experiences this situation as uncomfortable and would like to avoid having to experience it again.

5.2.4.1.1 What could help Sven?

The main objective is to reduce the stress for Sven, and these options were identified:

Direct alleviation of stress inside the cabin: A driver monitoring system detects that Sven is stressed, according adaptations are made. For example, incoming calls could be blocked, music is played or something that is tailored to his preferences to reduce his stress. Moreover, the lighting of the truck cabin may change accordingly. Also, the truck may act as a kind of co-driver communicating with Sven to keep him calm and comforting him. Additionally, the truck could advice Sven about health-related issues.

Actively offering Driving Assistance at SAEADL 2 (i.e., HADRIAN ADL 2) if Sven is stressed: As the driver monitoring system is aware that Sven is stressed, it gives him feedback that he may want to use HADRIAN ADL 2 for assistance. The HADRIAN ADL 2 includes improved adaptive cruise control with merge protection to handle situations when a car squeezes in between his truck and the vehicle ahead. The system does not disengage in this case, it also allows for smaller distances behind a front truck because it excludes the need for the driver to immediately take over in cases of an unexpected brake maneuver of the front truck. The system may also provide active signaling to the “intruder” by flashing the lights. Usage of the improved Adaptive Cruise Control (ACC) in HADRIAN ADL 2 could be supported by his company and give Sven “bonus” points on his driving style score, which may make him suitable to receiving a bonus. Sven is very aware of the automation mode he is in, as he is in a stressed situation and misunderstandings may occur. Furthermore, a HADRIAN improved Lane Keep Assist system (also part of the HADRIAN ADL 2) with detailed digital mapping and infrastructure information allows for automated passing maneuvers and informs the driver when and why driving assistance functionality is not available at certain parts of the road.

Allowing Sven to better anticipate and plan the situation: A trip management system aids Sven to reduce his stress and worries by supporting his planning. The trip management system shows him upcoming traffic and informs him about rest stops, regulatory information, provides trip management and updated information if detours are necessary. This system considers traffic and weather predictions and shows estimated arrival time based on all these information sources. The system actively proposes reroute options and facilitates Sven’s decision making through easy-understandable display of information. (Based on infrastructure information it may also be possible to show Sven in advance for which parts of the trip the truck will be able to drive in which automated mode (e.g., as a color-coded navigation map), so that he can better plan on his own, when to do certain things.) Also, the system automatically informs the dispatcher about delays, so that a better planning is also possible for the dispatcher.

Other options considered: In less stressful situations, the truck could show more ecological behavior. This could be motivated by possible regulatory guidance for truck companies to show that a truck company has to exhibit efficient driving at least for 30 % of driven kilometers to get tax benefits.

5.2.4.2 Medium Trip and Driving in a Convoy forever

In this situation, it is likely to happen that Sven occupies himself with a non-driving related task because of the monotony of driving in continuous stop-and-go. However, even if there is a certain time to do a secondary task, it is continuously interrupted, i.e., Sven is constantly in and out of the loop, which may make him less effective in both tasks. The construction sites may cause road narrowing. Narrow lanes, however, may not be recognized by the lane departure system especially if old and new lane markings are overlaid in different colors. Therefore, the lane departure warning system may not give warning or warnings all the time. Whenever there is a merging of lanes, Sven needs to negotiate with other traffic participants who goes first. This requires his attention and may get tiring and frustrating over the time. Also, being stuck in a convoy, comes with additional problems: fuel consumption may be higher, e.g., if it is summer and there is the need to increase the AC, and Sven may need fuel sooner. The distance to the truck in front of Sven may also impact the fuel consumption, but keeping distance is taxing and may be safety critical. Also, the fumes and smell of the other trucks may be uncomfortable. In wet weather conditions, braking behavior may be impacted. Driving behind other trucks further limits the view, and what Sven can see and process to prepare for maneuvers. Additionally, it may happen in such a situation that an emergency lane needs to be built in case the traffic jam was caused by an accident and ambulance must pass between the vehicles. To keep Sven sufficiently engaged, a video stream of the front vehicles could be displayed to give Sven better situation awareness of his surrounding and upcoming exits or road events.

5.2.4.2.1 What could help Sven?

Automated Driving at HADRIAN ADL 3 with transition protection: Sven could be helped by an automated driving function that allows him to disengage from driving under these monotonous stop-and-go situations. The function offers itself when it foresees to be able to be continuously operated for a minimum of at least 5 minutes (duration to be determined) based on integrity information from the road infrastructure and informs Sven about the expected duration of the HADRIAN ADL 3 automated driving. Knowing the duration of ADL 3 driving allows Sven to actually disengage from driving and use this period to engage in various non-driving activities that would help him complete his professional duties but also facilitate his wellbeing. Also, Sven could complete administrative tasks. This is facilitated by HADRIAN ADL 3 integrity information that is sent from the road infrastructure to the vehicle. For example, at motorway entrances where vehicles join the motorway, the merging is facilitated by a centralized command and control unit that is planning gaps for the merging of vehicles and communicates the planned gaps to the automated vehicles and gives signals to the non-equipped ones. Also, road side video cameras are observing the state of the road and communicate unexpected events to Sven's HADRIAN ADL 3 system so that early automated maneuvers can be initiated to avoid dropping unexpectedly the level 3 automated driving.

The truck monitors Sven's activities to be compatible with this ADL 3 (e.g., Sven has to keep a sufficiently high level of arousal and not fall asleep). In case, Sven performs a task that is incompatible with the current HADRIAN ADL 3, appropriate warnings are provided to Sven. Near the end of the ADL 3 period, Sven is led early enough by appropriate cues to come back to the manual driving and his state is observed whether it is compatible with preparing to come back to manual driving.

Automated driving related information is shown at the place where Sven is putting his attention, e.g., if he is reading something on a device, the alert pops up on the reading device if he was using one.

Use the time for training / health exercises: If the system recognizes that Sven is bored or annoyed, it suggests him some exercises (e.g., breathing exercises, stretching), which are continuously monitored and he is provided with feedback about how he is doing. Also, Sven is reminded to do exercises and provides him, e.g., with a cycling option, and tasks that he can do with his hands (e.g., playing playstation, guitar playing, learning a new instrument, weight lifting laying down, playing chess / poker with other truck drivers, playing a game with his daughter, relaxation exercises).

5.2.4.3 Long away from family due to 4-day trip

This situation comes with several challenges. Since Sven passes different countries on his way, there is a change of languages, in signage, there may be different traffic signs. He may get problems to understand the signs, also variable messaging may be difficult to understand. Road conditions may differ, different road markings (lane marking colors, style differences) may be used, there are time zone changes and law changes, or changes in speed limits in each country. Also, weather conditions may strongly differ, and it could get even harder to extract relevant information when it is dark or wet. Sven will also need to deal with customs and weigh stations. Due to these differences, Sven may need to get assistance (e.g., in case there is a problem with his truck) on how to communicate. If he gets ill on the trip, he is may be even forced to continue driving even with medication that impacts his driving abilities.

Another challenge is that he may feel lonely because he is separated from his family for such a long time while driving alone. So, keeping contact to his family or talking to / socializing with other truck drivers is important. However, sudden calls from his family may also interrupt him while driving and could cause distraction.

Also, Sven needs to rest several times and needs to sleep in his truck to meet the required resting requirements. However, resting times may not be really relaxing for him because of the uncomfortable bed and noises at the rest areas. So, he cannot sleep well, which also means that his physical condition becomes worse over his trip. Additionally, at rest areas that are not monitored, this may make him feel unsafe and he cannot sleep as well. Since he has a responsibility for his expensive truck load, it may also be important to stay alert.

Apart from that, he also might need to deal with delays or convoy driving, which could stress him. Also, he may have already planned where to rest, but delays could interrupt these plans.

5.2.4.3.1 What could help Sven?

Automated driving at HADRIAN ADL 3+ with transition protection: On some stretches on the trip, HADRIAN ADL 3+ gets information from the road infrastructure integrity assurance capability that continuous automated driving at HADRIAN ADL 3+ are available for at least 20 min and more. These stretches of driving in HADRIAN ADL 3+ could be counted as resting periods if Sven can rest for at least 15 min a time. In this case Sven could keep in control of driving for up to 9 hours. The truck inherent monitoring system would monitor Sven to ensure he is engaging in rest-conform activities during these periods. If the driver monitoring system detects that Sven is stressed, Sven would receive suggestions for how to relax. If this does not work, these periods would not be counted as resting time and Sven would get feedback to this extent.

Make it easier for him to deal with incomprehensible signs in different countries: Translate traffic signs and traffic related information (e.g., lane closure ahead or traffic ahead) into an understandable form such as through auditory or visual messages. This information may come from an onboard digital map, be translated in realt time, or sent by infrastructure messages.

Optimized resting / avoiding exhaustion: By monitoring Sven and the traffic situation, the truck could propose optimized rest periods. Also, in periods of automated driving, Sven could have a power nap. The truck observes the power nap and determines whether it is good enough to count this as resting time. Also, if there is a proof that Sven has slept for a certain time without interruption, this could increase the driving time.

The truck could also monitor the sound level and inform Sven if the noise level were too high for extended periods of time and that he should consider engaging the cab's noise cancellation system. This system actively observes Sven's head position and sends out time-shifted acoustic waves that cancel the noise. Also, the windshield coating receives a darker shade of tinting when the sun glare is too bright.

Appropriate duration of automated driving periods and appropriate activities: In phases of automated driving, Sven may occupy himself with other tasks, e.g., doing homework with his daughter, watching movies, playing games in multiplayer mode, socializing etc. This can help his well-being. The system monitors Sven's state in order to determine whether he gets in the wrong mood by a certain activity (e.g., aggressive driving) and informs Sven about this when detected. Depending on the alert level of Sven, the take-over requests would be adjusted, e.g., more time is given prior to the take-over if Sven is currently deeply engrossed in watching a movie.

5.3 Florence Scenarios (Office)

Due to an increase in urbanization, globalization as well as in wealth, the average mobility demand is constantly increasing. The global demand of passenger mobility in urbanized areas is set to double by 2050. Meanwhile, the number of individual journeys taken on a daily basis has grown massively, thereby putting increased pressure on existing mobility systems. Even larger growth is expected in the field of goods mobility, especially in dense urban areas, due to the growing importance of e-commerce and the accompanying boom in demand for last-mile delivery (Little D. Arthur, 2018).

Smart cities are emerging and a rise of digitalization (internet of things, big data) is expected in the near future. Additionally, further societal drivers, such as environmental regulations, safety and security concerns as well as restructuring of working arrangements are slowly changing the future mobility.

There are several mobility concepts developed in order to face the challenges ahead, Most of them rely on the interplay of electrification, automation and sharing services to assure a seamless mobility. ((National Association of City Transport Officials, 2019; Simpson, 2019)). This means clean sharing meets autonomy, where the boundaries between private, shared, and public transport are getting blurred. Hereby, smart connected traffic management plays a major role to realize an efficient traffic system (Mobility4EU, 2016).

With respect to the describe future mobility trends, Florence is driving in her private automated vehicle connected within a smart traffic management. However, she might also be using an automated shared vehicle. Additional needs related to the sharing service are described after the general considerations of the office scenario.

5.3.1 Summary of Research in Office Mobility

To improve the situation and needs of office workers, this chapter gives an overview of relevant literature. . It summarizes which secondary activities are expected to be performed by office workers on work-related trips in their car. It also provides an introduction about motion sickness, an issue linked to tasks in autonomously moving vehicles.

5.3.1.1 Secondary Tasks in Automated Vehicles

When designing for secondary activities drivers probably want to perform inside of their vehicle, we must consider various driving relevant properties of those activities. This knowledge helps considering how the vehicle should behave in various situations and how the attention of the driver should be guided most efficiently to increase safety and usability of such a system.

Table 26 lists some important secondary activities together with driving critical properties. The three properties are: a) Interruptibility, which means how much attention a task takes for the driver. This is important because it can have an influence on the take-over reaction time in case the vehicle cannot handle a certain situation. b) Duration describes how long a single secondary task normally approximately takes. This must be considered to make engaging in a certain activity comfortable and in some way recommendable by the vehicle. If the next planned take-over takes a certain time, it can for example recommend certain activities the driver can perform without early interruptions. c) Hindrances describe physical demands of an activity on the driver.

Table 26. Description of secondary activities while driving

Task/Activity	Interruptibility	Duration	Hindrances
Checking / writing emails	Little disruptive	Short to mid (< 1 min to > 1 min)	Using a laptop
Working on a PowerPoint presentation	Very disruptive	Mid to long (> 5 min)	Using a laptop
Making and receiving phone calls	Very disruptive	Depends on topic and partners	Using a hands-free phone device, phone or laptop
Eating breakfast	Very disruptive	Mid	Both hands are occupied eating
Relaxing	Very disruptive	Long	Engaging in a more comfortable seating position
Signing / handling / reading papers	Very disruptive	Long	Piles of paper and occupied hands

Secondary activities do not seem to have a great impact on take-over reaction time, in case of unforeseen circumstances the vehicle cannot handle anymore. However, they do have an impact on the quality of the take-over maneuver. Drivers have a greater deviation from the center of their lane, when being distracted by a secondary task in a vehicle (Zeeb et al., 2016). However, there is not enough research to allow a clear definition of acceptable tasks for different levels and modes of automation.

5.3.1.2 Motion Sickness

A lot of the formerly mentioned secondary activities come with an obstacle, which is motion sickness (kinetosis). Many people engaging in visually demanding secondary tasks while moving in a car, train, ship, etc. start to feel sick and dizzy after some time. A design goal of an automated vehicle where one can perform other tasks besides driving must therefore be to minimize this effect in some way.

Motion sickness can occur, if the perceived motion of an object a person visually focuses does not correspond with the sensation of motion and acceleration by the vestibular system when inside of a moving environment. Since the central nervous system expects congruent motion-information in a healthy person, it responds with an emergency routine similar to an illness or intoxication. This response is perceived as physical discomfort, drowsiness, exhaustion and nausea (Diels & Bos, 2016). Relevant for automatic vehicles is, that the probability and severity of motion sickness increases when the driver is in reduced control of the vehicle’s movement (Rolnick & Lubow, 1991).

Another influence on the severity of motion sickness is the specific secondary activity a driver is performing. Reading text has the worst influence, followed by watching movies or TV and texting. Playing video games has the least severe impact on motion sickness (Sivak & Schoettle, 2015).

The issue can be reduced by the vehicle design. Research found for example, that display position in automated vehicles can help. Drivers using heads up displays, where they look straight ahead into the screen, for secondary tasks show significantly less symptoms of motion sickness, than drivers using heads down displays, where they have to look slightly down (Diels et al., 2016). Besides the direction of one’s glance, it also has a benefitting effect to watch the road (Sivak & Schoettle, 2015).

5.3.1.3 Planned Interface Concepts for Automated Vehicles

Looking for concept of other institutions is a way to gather some insight in the design statements of those. It can be helpful to know certain aspects of those concepts. This chapter lists various concepts and their main premises.

Most concepts aim at reducing motion sickness and increasing riding comfort (Pretto et al., 2019). To reduce motion sickness, they utilize adapted virtual reality devices; to increase working comfort, they enlarge the room size of the driver’s cab, increase the mobility of the driver’s seat, install multiple screens inside of the vehicle or install movable parts to offer the driver small desks and repositories for working. Table 27 describes some selected concepts of different car manufacturers.

Table 27. Examples for current interface concepts for automated vehicles

Concept Name	Addressed Issues	Description
Volvo “Concept 26”	Comfort of working in a vehicle	A driver’s seat adopted to automated driving. It is able to engage in three stances (driving, creating, relaxing) differing by seating position and the driver’s distance to the steering wheel. There also is a large touchscreen on the glove compartment.
BMW “I inside Future”	Comfort of working in a vehicle	Vehicle has an enlarged interior for more space to work and relax while driving. The vehicle also acts as a smart assistant, for example reminding of appointments. Work-relevant information can be projected onto the dashboard for easy availability of such information.

Regus & Rinspeed "Xchange"	Comfort of working in a vehicle Motion sickness reduction	Completely designed for office work. It consists of a shiftable steering wheel to make more room on the front space for paper laptops, etc. It offers fully turnable and tiltable seats for small conferences and meetings in the car. A touchscreen is attached to the glove compartment and a large display is located at the back of the car for presentations. Small desklike contraptions can be folded onto the lap of every passenger to use laptops or sign documents. The movable seats could be used to reduce motion sickness via glance direction and seating position as well.
Audi "Experience Ride"	Motion sickness reduction	It consists of a virtual reality device which offers content moving corresponding to the motion of the vehicle, to reduce motion sickness.

5.3.2 Description of Mobility Needs and Constraints

For the workshop, six different tasks Florence would like to do during conditional automated driving (i.e., having to take back control occasionally), were identified in order to facilitate the identification of needs, challenges, and problems that Florence might have. This served as a basis to identify HADRIAN solutions that could help Florence. The tasks are depicted in Table 28. Prior to the workshop, we classified each task regarding interruptibility, approximate duration, and problems that may occur when doing the task while driving in a conditional automated car.

Table 28. Tasks, Florence would like to do during conditional automated driving

Task	Interruptibility	Duration	Problems
1. Checking / writing e-mails	Little disruptive	**Short** (<1min) to **mid** (>1min) (writing vs. checking)	# potentially manually occupied # motion sickness? # reading & entering text in moving vehicle (+glare, motion, etc.)
2. Working on a PowerPoint presentation ("navigation" element included)	Very disruptive	**Mid – long** (>5min)	# motion sickness # cognitive demand # reading text in moving vehicle (+glare, motion, etc.)

3. Making and receiving phone calls from important customers, while checking files (e.g., offer)	Very disruptive	Dependent on others (**short** to **long)**	# decision to take the call yes/no # once answered, little control about duration & attention demand (difficult/important call) # possibly interrupted call # multi-tasking: looking up information while on the phone
4. Eating breakfast	Very disruptive	**mid**	# manually occupied # eating & vehicle motion # motion "secure" storage (e.g., cup-holder) needed for number of different things # possibly smeared hands
5. Relaxing (eyes closed for longer periods of time)	Very disruptive	**long**	# unsuitable seating position # take-over readiness # possible interfering factors: lighting, noise
6. Signing / handling / reading papers	Very disruptive	**long**	# motion sickness? # reading & entering text in moving vehicle (+ glare, motion, etc.) # motion "secure" storage (e.g., cup-holder) for papers # manually occupied (piles of paper...)

5.3.3 Workshop Conduct

The remote workshop took place on the 14th of April 2020 with representatives of ASF, CEA, IKA, NTUA, NVT, PLUS, TEC, TUD, UGR, VDI/VDE-IT, and VIF. The total number of workshop participants was 23.

In the beginning, all participants were introduced to the workshop aims and were provided some general advice about the workshop process. This was followed by a short presentation of Florence and the tasks she would like to do during conditional automated driving on her daily commutes but also during other drives (e.g., within the city of Paris). Also, it was outlined that Florence lives in a suburb of Paris of the future, where carsharing and intelligent traffic management are available.

In the first part of the workshop, the six tasks were discussed successively (it was assumed that Florence is alone in her car). The procedure was the same for each task:

First, participants were asked to think about other problems that may occur when doing the respective task in a highly automated car. Second, it was discussed how the car could support Florence to address the identified problems. The comments of the participants were written down in a Word document, that was shared online and was visible for each participant.

In the second part of the workshop, it was discussed with the participants, what would change if Florence would like to use car sharing for the commute instead of her own car, and how such a car could cover Florence's needs, and what Florence would need to know about the car. Again, the comments of the participants were collected in a Word document.

The workshop was concluded with a short discussion about other ideas that might have not been covered throughout the workshop.

5.3.4 Mobility Scenario Considerations during the Workshop

In the following, the main concept elements in order to support Florence doing the different tasks during conditional automated driving are summarized as they were discussed in the workshop.

5.3.4.1 Checking / Writing E-mails

For this task, several factors were identified, which may have an impact on Florence:

Lack of interruptibility of the task: Especially, when writing an e-mail, it's probably frustrating for Florence to be interrupted, since she wants to continue her task. So, she may continue to work even after a take-over, which would impact driving safety. Having a sufficient prewarning time may be helpful for Florence (10 seconds may be too low; 30-60 seconds would be better). This also depends on the traffic situation, the current interaction modality, and Florence's state (i.e., cognitive, emotional involvement, see beneath).

Input device used for the task: It makes a difference how Florence can handle the task depending on which input modality she is using. She may use her smartphone, a laptop, or an extra keyboard with a screen in front. It also might be the case that she switches between devices depending on what she wants to do. For checking e-mails, the smartphone may be sufficient, for writing longer e-mails, she probably would rather do that with a keyboard or laptop.

Which device is appropriate may also depend on the traffic situation. For example, in stop & go traffic or in situations with a lot of acceleration and braking, it may be very difficult to hit little keys on a smartphone or tablet (touchscreen). Also, the positioning of a certain device needs to be considered, since it must be ensured that Florence can take-over in time - especially, if the time to take-over is short.

Another option would be to use speech recognition for writing e-mails. However, there might be also some problems here. It could be problematic if Florence is not alone in the car (privacy issue) or she probably does not want to use speech recognition for important business e-mails. If she is not familiar with speech recognition, she also may need to learn certain commands for editing. If she knows what she wants to say, speech recognition may be faster for entering text, however, if she needs to think a lot or edit text, an input via keyboard may be more feasible. The recognition of dialect may also difficult for such a system or the differentiation between commands (probably directed to the car) and actual text.

Output device used for the task: If messages are presented in an auditory way only, Florence may mishear something due to the noise in the car, she may not be able to remember everything. Also, the pace of interaction is given and is not self-determined. Also, the speech output system may know nothing about the complexity of the current traffic situation or in which driving mode Florence currently is. For a visual display, the time of day could be problematic in terms of readability. During the night, it might be too bright. During the day, it might not be bright enough or glare might impact readability.

Manual, cognitive, emotional distraction: Florence may be emotionally occupied (e.g., upset, stressed, happy) when she is reading or writing certain e-mails, which could cause distraction when she needs to take over. She may also be cognitively distracted when she is diving into e-mails or she is writing e-mails in a foreign language – a take-over request could be interfering here. Also, the amount of e-mails and frequency of e-mailing is important.

General physical state and motion sickness: Florence might also have problems to do the task because she is tired or has not slept well due to the baby at home. Another factor could be upcoming motion sickness, if she has her head down while reading/writing e-mails. Especially, if she already got motion sick, it will be difficult to get out of it.

Interruptions caused by the environment: It may happen that connectivity gets lost along a route – this could interrupt Florence's work.

Mode and situation awareness: It's important that Florence knows, in which driving mode she is and whether she can do the task safely. The interface for the task and the interface for driving should be separated to avoid confusion. On the other hand, it may be necessary to keep up her situation awareness while she is working on her e-mails so that she can handle take-over situations better.

5.3.4.1.1 How could Florence be supported?

Preparing Florence for take-over: If Florence is supposed to take over while writing an important e-mail, she could maybe switch to speech input in order to keep writing or finish her thoughts without being visually distracted. However, cognitive distraction is likely to be an issue here. Maybe it needs to be timed, that after a certain time after the take-over, she could use speech input. Taking over could be very cognitively demanding, therefore the system should allow Florence to really get focused on what is going on outside of the vehicle, give her time to process and only after some time allow her to go back to the task. A solution may be that the last sentence is read out loud so that she can go back to the writing task using verbal input.

When Florence is detected to be stressed, the time before a forced take-over could be increased in order to ensure a safe take-over. Maybe the support for take-over could be increased when she is being stressed: once going to manual, she may drive erratically, car maintains steering control longer when she is detected to be stressed. Also, the driving style could be adapted, e.g., the car drives slower when Florence is getting stressed (though it is not clear to what extent this would be acceptable to Florence.

Taking into account the current driving mode and traffic situation: The system could push messages only when there is time, but not during manual driving or high workload situations (e.g., complex traffic situation, Florence's state or while she is occupied with eating her breakfast).

Taking into account whether Florence is checking or writing e-mails: Florence may be able to handle more take-overs when she is only checking e-mails, but less when she is writing important e-mails (1-2 interruptions in 30 minutes?). While checking e-mails, she could mark those that she wants to work on later, when less interruptions of the task are foreseeable.

Supporting prioritizing / planning and route selection: The car might offer a planning display, which allows Florence to better plan when to read or write e-mails. She would know in advance when and where she has time to do what. For example, it could be color coded how likely it is that a transition will take place for a certain part of the route or how long the interruption-free interval is going to be.

Also, there could be a route selection display that allows Florence to select certain routes depending on what she wants to do (e.g., rather take a longer, smooth route if she needs to write a lot of e-mails). Furthermore, the car could adapt its driving style to the task Florence is doing by avoiding strong accelerations and brakes when she is reading / writing e-mails. This may also help to avoid motion sickness.

Avoiding motion sickness: In order to avoid motion sickness from the outset, the car may adjust speed and reduce lane changes. Sensors could be available that sense if Florence is getting motion sick and that automatically initiate countermeasures (i.e., warning to stop working for a while – maybe she even should take over and drive manually to help to reduce motion sickness?, hints to look outside, or initiating of interface designs that mitigate motion sickness, providing peripheral cues, or use sounds in order to allow Florence to better anticipate movements and turns of the car).

Also, using a head-up display can help to avoid motion sickness, since Florence would be able to still look outside. For highly automated driving such a display (see-through) could appear automatically. It also could provide a hint in time if a take-over is necessary and disappear automatically.

Ensuring privacy, if other people are in the car: With more people in the car, it might be good to have screen filters. The privacy of HUDs may be questionable. Make display direction addressable: so the display displays different angles dependent on from where you look avoiding that other people can view what Florence looks at from a different viewing point.

5.3.4.2 Working on a PowerPoint Presentation

The main difference with respect to the task of reading/writing e-mails is that working on a PowerPoint presentation will most likely require Florence to work with a laptop or a keyboard/screen combination, since it would be difficult to do this task on smaller devices like a smartphone.

Also, an extra device (mouse, touchpad) is needed for navigation between slides, maybe switching between documents, selecting and manipulating objects on-screen etc.

Another issue is connectivity and access to her files, which must be ensured. Using cloud-based storage, files could be automatically up-/downloaded if connectivity is given. Another option could be a hard drive / USB that is inserted into the vehicle.

5.3.4.2.1 How could Florence be supported?

Preparing Florence for take-over: Florence could get an alert on the computer display that a take-over is coming soon, with some planning horizon. Instructions could be given to her what to do, e.g., take hands on the steering wheel, provide her some information about the traffic situation to increase her awareness, or some information that she can come back to her current task after a few minutes in order to help her planning.

Another option could be to measure Florence's immersion in the task by using gaze tracking and use the gaze information for preparation of the take-over, e.g., by showing transition messages where she is currently looking at or using in-car ambient lighting to announce a transition.

Supporting planning by route selection: The vehicle could support her planning by providing information which routes would allow driving in automated mode for longer time intervals.

Supporting Florence with appropriate devices and optimal mounting of devices: A laptop or keyboard/screen combination should be optimally mounted in the car. Maybe also the windshield could be used as a screen (HUD). Florence could also be supported by providing her haptic control or using voice commands for writing, or to select and move slides.

There could be a compartment below the steering wheel to put the laptop for easier storage. Also, if she could only use a keyboard on her lap, it would be easier to store. All movable solutions should be wireless for easier storage. Also, the system may prevent usage if devices are not securely stored.

A virtual keyboard could be used, where the keys are projected on a surface. It could be easily hidden or stored away (however, it needs to be considered that a lack of haptic feedback may impact the usability).

Changing the seating position: While working, it might be more comfortable for Florence, if her seating position changes, e.g., the seat rotates towards the laptop or the seat moves backwards. However, this may have an impact on take-over time (may be longer because the seating position needs to be changed back to the normal driving position before taking over). It also needs to be considered that strong changes in seating position may have an impact on safety measures and motion sickness. A question is, if the seating position could be manipulated to improve the take-over?

5.3.4.3 Making and Receiving Phone Calls from Important Customers (while Checking Files)

A major problem when doing this task could be unforeseeable interruptions, e.g., caused by lost connectivity, take-over requests initiated by the car, complex traffic situations that require Florence's full attention etc. Also, mode awareness could be a problem during a phone call. If the automation mode changes, this may be difficult to notice for Florence or she might be less aware about the mode she is currently in since she is occupied with the call. Another general problem could be the surrounding noise in the car.

5.3.4.3.1 How could Florence be supported?

Automatically informing the caller that Florence is in mobile office: When receiving a phone call, the system could tell the caller that Florence is not in the office but in the car (to help the stage and facilitate Florence to manage the call). Also, the call could be interrupted by the system if it detects a transition need and tell the caller that Florence cannot talk now. A policy could be established with the company on how to use the car: the car knows this policy and facilitates this (i.e., reject calls or explain delays – this information could be automatically transferred to people who are waiting for her).

Enabling safe calls: An app on the phone could check with the car, whether it is safe to take the call. Incoming calls should be prevented during take-over maneuvers.

Reducing her stress: If surrounding noise is a problem and disturbing the call, the car could inform Florence where she could pull over. Another solution could be to go into defensive driving mode or drive slowly. A caller filter could filter out all other calls, while she is in one call with an important customer, or the system could already recognize the caller and provide Florence with the information she needs (i.e., information which the caller might be asking about).

***GENERAL REMARK: Automatically informing the environment and infrastructure about take-overs:** Maybe it could be shown to other people that the driver is taking over at this moment, so that, e.g., other drivers may keep more distance. Also, the infrastructure could be provided with this information and disseminate this information to other cars – especially to automated cars. It could also help identifying the weaknesses in the infrastructure (many take-overs take place in specific areas) and allows to better plan the trip to avoid too many take-overs.

5.3.4.4 Eating Breakfast

In general, strong accelerations or decelerations while drinking or eating could be cumbersome, uncomfortable, or even unsafe when, e.g., hot coffee is spilled.

Furthermore, take-over times may be longer, since Florence probably needs time to clean her hands or needs to put aside a tray with food. Also, she might have troubles to find a space where to safely put the food. It could also happen that she drops food.

Issues when multitasking: If Florence is eating / drinking while working, e.g., on her laptop this might cause problems, since it must be ensured that no food or liquid is spilled on the device. At the same time, if Florence would use voice commands for work, the recognition may be impacted if she is speaking with a full mouth. Also, while eating she could get a call from an important client (should the system not transfer calls while she is eating?).

5.3.4.4.1 How could Florence be supported?

Adjusting driving style and route: The car could adjust the driving style to accommodate eating, i.e., less strong accelerations and braking, no sharp turning, while still keeping the schedule. If the trip may take longer because of changes in the driving style, Florence should be informed or warned that she will be late.

Another option could be that the system recommends a route that would allow her to eat and drink in time (faster way to go). It could also suggest an alternative breakfast place. The car could also choose a route with a minimal number of necessary take-overs.

Stopping for eating: While eating or when she, e.g., has dropped some food, Florence could do a voice-initiated stop (that is safe). Also, Florence might not know that a stop is possible, and the car could remind her about that. Areas could be created where automated vehicles can safely stop (part of the infrastructure to enable automated driving; there may not be sufficient space in cities for that, but should be considered in areas where it could be possible).

Appropriate devices and storage: There could be a waterproof keyboard and a special eating tray to keep food from the computer. The tray could automatically stabilize vibrations coming from the vehicle in order to avoid spilling. One tray might be used for the laptop, one for the food. It must be possible to easily store food away (e.g., in a food container) in case of a take-over request. A self-cleaning utensil could further help. The system could detect hand positions to appropriately calculate take-over times.

Preordering of food/coffee: Since Florence may not have time to prepare her own breakfast, the system could preorder the food at a shop along the route. When ordering the breakfast, the coffee comes in spill-preventing cups or is automatically ordered in shops that allow to fill up Florence's own spill-preventing coffee cup. Also, if the system recognizes that Florence is getting tired, it could suggest a cup of coffee and order it automatically if Florence agrees.

Further ideas: Enable a safe take-over with one hand instead of two.

5.3.4.5 Relaxing

If Florence wants to relax while in conditional automation, one of the most obvious problems arise – she could easily fall asleep, which will be a problem if she has to take-over in a few seconds. On the other hand, Florence might not be able to relax when she does not know how long she can relax – e.g., when the next take-over would be likely initiated. Another disturbing factor could be an unsuitable seating position or other interfering factors, such as bright light or noise. On a similar note, incoming phone calls and messages could disturb her. While relaxing, it is likely that Florence is closing her eyes for several seconds at a time, which would make solely visual warnings ineffective. If Florence must take over, she may have a very low or non-existent situation awareness of the current driving situation.

5.3.4.5.1 How could Florence be supported?

Preparing Florence for take-over: Knowing when the relaxation happens will help to better detect when she is falling asleep and therefore adjust the take-over time in a better way or even trying to prevent her from falling asleep with appropriate warnings. Warnings in general need to be adapted, as visual warnings are not effective in this situation. The HMI could, therefore, issue auditory or haptic warning signals instead. Ambient cabin light might not be effective. As the seating position might be switched, the car could readjust the seat to driving position (also as a motion cue). Similarly, the car could decrease the temperature slightly, increase the ambient lighting in the cabin to get Florence back to driving.

Situation Awareness: The system could via HUD (head-up display) or acoustic signals give her information about the current situation and what she may need to do, support her to regain situation awareness.

Support relaxing: the car could give an estimated relax time, indicating how long it is until the next takeover is likely to be issued. Incoming calls could be blocked during relaxing time (system has a "relax mode" which can be enabled). Important calls from specific people could be specified beforehand, which will go through, even though "relax mode" is enabled. Regarding noise, a noise cancellation system could filter out most of the noise. Although, traffic relevant warnings may be blocked as well – therefore, the system may actively only suppress non-safety relevant signals. In order to reduce brightness, a put-on mask (maybe not recommended) or electronically dimmed windows could provide some support. In a similar way, the seating position could be adjusted accordingly.

5.3.4.6 Signing / Handling / Reading Papers

When Florence is handling papers, she might not see visual warnings presented, e.g., on the dashboard. Also, visual warnings cannot be projected onto the paper. She might be manually occupied as well – meaning, before a take-over, Florence would need to put away all the papers first. These aspects might influence her take-over time significantly. If monitoring her task would be one mitigation strategy (e.g., for adjusting take-over time), the system might have difficulties to detect that Florence is looking at papers specifically.

With handling papers in the car, there comes a number of additional problems: papers might fly around if the windows are open or because of a strong a/c stream; in case of an emergency breaking, papers might also fly around and could, in extreme situations, block Florence's vision. Also, reading and writing on paper while driving can be difficult if the vehicle motions are abrupt/intense, or because of glare/bright lightning conditions.

Similarly, to the other tasks, Florence might prefer a different seating position, as for example, she might need more space. Although, altered seating positions need to be evaluated - in terms of safety - in an event of an accident (airbags, etc.).

Lastly, motion sickness might easily occur when reading in a moving vehicle.

5.3.4.6.1 How could Florence be supported?

Preparing Florence for take-over: A scanner and display combination presents the paper so that she can read it in head-up mode – this could address a number of problems: it could make it easier for Florence to maintain situation awareness, as she can quickly check the driving environment; visual warnings (e.g., for take-over) could be displayed as well; Florence would not need to put away all her papers, leaving her hands free – in combination, these aspects could reduce take-over time and, additionally, this solution could reduce motion sickness.

In general, it could be beneficial to detect that Florence is working with papers. In case the mentioned solution above is not feasible, a dedicated tray, on which Florence can put the papers, could make it easier for the system to detect that specific task. And therefore, adjusting take-over time appropriately.

Suitable storage / physical solutions: Handling papers in a moving vehicle might be problematic, as described above. A physical solution could be to have dedicated tray that keeps the papers safe: e.g., through a sucking valve or clip board, keeping the papers from flying around. This dedicated tray could also be the foreseen place to put the papers when a take-over is initiated. Also, writing on paper while driving can be difficult - a stabilizing tray and possibly also stabilizing seat could mitigate this.

Seating position: Similarly, as described within other tasks, the seating position could be adapted so Florence has more space to work.

5.3.4.7 Car Sharing

Florence would like to use car-sharing for the commute instead of having to own her own car. As Florence could get a different car every time she uses the car-sharing service, she may not be familiar with the car and might have a hard time to figure out how the car with all it's functionality works. For example, Florence might not know how and when to engage the automated driving functionality and similarly, Florence might not be aware of the specific system limitations. In general, it might be difficult for her to construct a correct mental model of the car and its functions, which could impair her ability to adequately calibrate her level of trust to this specific car. Another important question for Florence could be, how she could adapt the car for her to be able to work effectively. Would the car need to know about what Florence will want to work on?

Privacy could be an issue in general, as the car company could potentially acquire a wealth of information from its customers. There might be differences in handling of secure information between a car-sharing and a private car. For example, it could be forbidden to store sensitive data on a publicly used car-sharing vehicle. Similarly, Florence may not be comfortable speaking on the phone about sensitive issues in a car-sharing vehicle because she is being monitored. This problem might be especially prominent during ride-sharing when there are multiple passengers in the vehicle. On a more general note, voice commands in the car could be especially difficult if more than one passenger is in the car (e.g., during ride-sharing).

In general, how could a car that is designed for a car-sharing service cover Florence's needs?

5.3.4.7.1 How could Florence be supported?

The simplest solution would be to only send one car type to Florence, so she gets familiar with this one car model. She could get a specific training that familiarizes her with this vehicle. But this may not be a good business model to only have one car type for her. Still, if she would need to transition to another car, for whatever reason, this could be difficult for her.

Cars could offer a very similar user interface on all vehicles e.g., iphone versus android to simplify transfer between vehicles. But, OEMs might want to differentiate themselves by offering specific user interfaces, which make it possible to “recognize” the brand based on it's interface. Meaning, a high level of standardization might not be realistic. Nevertheless, there is a need to ensure that the safety critical functions are as standardized as possible.

A tutoring system could explain the most important features, e.g., via voice. The car sharing service could have a profile for Florence, knowing how often she has driven what car specifically and provide appropriate tutoring only to prevent bothering Florence with repeating, uninteresting lessons. Also, the tutoring could point out the most important differences in functionality & system limitations in comparison to the cars she has driven before. The system could quickly explain the most important functions using training or explanation videos and single parts of the explanations can be skipped by Florence if the information is not of interest for her.

Florence could be concerned about her privacy, so the car-sharing company could offer a “secret mode” where she can go undetected to any place. But, in this way she would not get many of the features that she would otherwise get (e.g., no tutoring, no seat adjustments, no automatic destination setting and especially no or reduced Fit2Drive algorithm - in general, no ability to provide strong automation). Also, a solution could be to have a “secure cloud”, where the data is stored.

5.3.4.8 Other Ideas

Florence could be rewarded for doing “good” take-overs: the insurance company could offer a premium and the system could allow Florence to do more workload-intensive secondary tasks. The tutoring system could support this approach (e.g., by gradually offering the complete functionality of the car, when Florence became already familiar with the “lower-complexity” functionality).

Long distance commute: seat could be turned more prominently, if the time in automated mode is prolonged. Florence would also have more time to schedule and plan the work. For example, in the beginning she would only do emailing but within longer periods of automated driving she could concentrate on more cognitive intensive tasks, like working on a power point presentation.

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