ART-04-2016 - Safety and end-user acceptance aspects of road automation in the transition period

H2020-ART-2016-2017

Improved Trustworthiness and Weather-Independence of Conditionally Automated Vehicles in Mixed Traffic Scenarios

D2.2

Specification of Traffic Scenarios and Questionnaires

This report is part of a project that has received funding from European Union's Horizon 2020 research and innovation programme under grant agreement No 723324.

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Editors	Micaela Troglia Gamba (CISC), Ahu Ece Hartavi Karci (US), Kübra Zehra Kasikci (US)
Authors	Micaela Troglia Gamba (CISC), Kübra Zehra Kasikci (US), Ahu Ece Hartavi Karci (US), Pamela Innerwinkler (VIF), Philipp Clement (AVL), Johan Zaya (VCC)
Responsible person	Micaela Troglia Gamba (CISC)
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List of Abbreviations

ADAS	Advanced Driver Assistance Systems
AVL VSM™	AVL Vehicle Dynamics Simulation Software
CP	Collision Point
CRG	Curved Regular Grid
DiL	Driver in the Loop
FMI	Functional Mock-up Interface
FMU	Functional Mock-up Unit
HiL	Hardware in the Loop
HMI	Human-Machine Interaction
L3AD	Level 3 Autonomous Driving
NEPCE	Nearly Energy Preserving Coupling Element
NHTSA	National Highway Traffic Safety Administration
OEMs	Original Equipment Manufacturer
SAE	Society of Automotive Engineers
SAE Level 3	Conditional Automation of Vehicles
SAE Level5	Full Automation of Vehicles
SiL	Software in the Loop
SPSS	Statistical Package for the Social Sciences
ViL	Vehicle in the Loop
VTD	Virtual Test Drive
VRU	Vulnerable Road Users
WP	Work Package

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Executive Summary

Automated vehicle technology has the potential to be a game changer on the roads, altering the face of driving as experienced today. Many vehicles are already capable of some level of automation while higher automated prototype vehicles are continuously tested on public roads. System and human driver uncertainty, however, pose a significant challenge in the development of trustable and fault-tolerant automated driving controllers, especially for conditional automation (SAE level 3) in mixed traffic scenarios under unexpected/harsh weather conditions.

This report aims to serve as an intermediate report between the analysis of traffic road injuries and the selection of traffic scenarios and the field study preparation of the TrustVehicle project. The first section consists of an introduction into the report. In section 2, an overview of Questionnaire I (QI) is given, which has been constructed to collect quantitative and qualitative data on the concerns and opinions of the public regarding automated driving. The method, procedure, sample, and ethical process underlying QI are discussed, and followed by a critical reflection of its potential limitations. This section also describes the focus group and interview activities undertaken to gain a deeper understanding of the public's views on automated driving and their degree of acceptance. Section 3 outlines broadly the focus areas of automated driving scenarios based on the four main groups of road users as from the business of the OEMs involved in the TrustVehicle. It is structured into subsections dealing with: i) truck and commercial vehicle based scenarios (3.1), ii) public transportation based scenarios (3.2), iii) passenger vehicle based scenarios (3.3), iv) scenarios involving vulnerable road users (3.4). Section 4 consequently advances with the description of the driving simulator that will be used to run TrustVehicle scenarios, paying attention to the components and software that will be engaged with, and is followed by concluding remarks on future directions.

Key Words: Level 3 automated driving, user acceptance, quantitative research, critical driving scenarios, Driving simulator

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1 Introduction

1.1 Background

Automated vehicle technology has the potential to be a game changer on the roads, altering the face of driving as experienced today. Many benefits are expected, ranging from improved safety, reduced congestion and lower stress for car occupants, social inclusion, lower emissions, and better road utilization due to optimal integration of private and public transport. Many cars sold today are already capable of some level of automation while higher automated prototype vehicles are continuously tested on public roads especially in the United States, Europe, and Japan. Automated vehicle technology has arrived rapidly on the market and the deployment is expected to accelerate over the next years. As a matter of fact, most of the core technologies required for fully automated driving (SAE level 5) are available today, however, reliability, robustness, and finally, trustworthiness should be significantly improved to achieve end-user acceptance. System and human driver uncertainty pose a significant challenge in the development of trustable and fault-tolerant automated driving controllers, especially for conditional automation (SAE level 3) in mixed traffic scenarios under unexpected weather conditions

Since the main target of the TrustVehicle project is to adopt a user-centric approach in developing solutions that will significantly increase reliability and trustworthiness of L3AD vehicles a mixed research methodology [1] is utilized in the initial phase of the project to assess public opinion on autonomous and self-driving vehicles

Therefore, this is an intermediate report between the analysis of traffic road injuries and the selection of traffic scenarios and the field study preparation.

In deliverable 2.1 (D2.1), results have shown that:

1. Men are more frequently involved in injuries than women and usually they are drivers and riders.
2. Women are more involved in injuries as passengers and pedestrians.
3. Most victims, aged below 18 years, are passengers.
4. The more representative age group in fatalities is between 25 – 49 years old.
5. 61% of all fatalities occurs outside urban areas, primarily in daylight conditions.
6. The highest percentage of junction fatalities is reported on urban roads and nearly 55% of people died at junctions refers to vulnerable road users.

In addition, the most frequent critical accident grounds are over speed, premature action, no action, late action, incorrect direction and inadequate planning. However, distraction, psychotropic substances, tiredness and handheld mobile telephone usage are also significant factors [2].

Finally, deliverable 2.1 underlined that nearly 30% of all road fatalities is covered by pedestrians (21%) and by cyclists (8%) and that elderly represent an unexpected high risk category.

Automated vehicle technology is expected to improve safety and to contribute to the mitigation of road fatalities. As reported in a study conducted by The University of California Davis [3], whenever a new technology comes to the market, a learning process, consisting of three phases, occurs.

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The first is called “Discovery” when users first learn about the new technology. The second is named “Translation” i.e. when people shape their own opinions about the new findings. The last is called “Applications” and it means that users apply the new findings into the daily routine. Studies on opinion about autonomous and self-driving vehicle conducted in the U.S.A. showed that the perceived lack of safety, the uselessness of autonomous driving systems, and the high cost are negative features. The reduced environmental impact and the greater efficiency of the vehicle are considered attractive features.

High levels of concern were expressed about riding in self – driving vehicles, security issues related to self-driving vehicles, and self- driving vehicle not performing as well as actual drivers. Females noticeably expressed higher levels of concern in comparison with males and their expectations of benefits related to autonomous driving were lower.

As one of the main objectives of the TrustVehicle project is to analyse user requirements, as well as expectations and concerns related to the use of automated driving systems, plans were made to collect opinions from people about automated vehicles. The next section will describe the methodology used to reach this objective.

1.2 Structure of the Report

This report is divided into three main sections. The first refers to the questionnaire, the second is related to the specification of the traffic scenarios offered by the OEMs, and the third concerns the field test/ simulator.

The first section describes the process used to create the first version of the questionnaire. This questionnaire is a response to the TrustVehicle’s goal to explore what people think about automated vehicles and how comfortable they feel with this new technology.

The second section gives a broad overview of critical driving scenarios developed through the TrustVehicle project and focuses on four main road users as related to the businesses of the OEMs involved in this project.

The third section focuses on outlining the characteristics of the simulator that will be used for the TrustVehicle project.

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2 Questionnaire

The initial stage highlighted existing literature. Since autonomous cars have not been introduced to the market there is not much existing data on the public's opinion. Studies on opinions about autonomous and self-driving vehicles were analysed. Most of them were conducted in the U.S.A., and particularly at the University of Michigan [4] and Worcester in Massachusetts [5].

The researchers of the University of Michigan investigated the familiarity with and the general opinion about self-driving vehicles, which benefits were expected using this new technology and which were the concerns. They referred to NHTSA concerning levels of automation.

The Faculty of Worcester decided to explore six key influences that could affect the desirability of autonomous cars. These were related to safety, cost, legislation, productivity, efficiency and environment.

As one of the main objectives of the TrustVehicle project is to analyse user requirements, expectations and concerns related to the use of automated driving systems, the TrustVehicle group decided to start to collect opinions from people about automated vehicle. One of the most efficient methods to reach large number of people is the questionnaire.

2.1 Methodology

A research approach consisting of a series of steps to collect and analyse information was adopted. To increase understanding of users´ acceptance of automated vehicles, a quantitative non-experimental research that uses a survey approach and describes the trends for users was adopted.

In the first phase, a qualitative method will be used to identify the topic, followed by a quantitative method to measure the answers for the identified topics. The focus will be on the procedures used to create the questionnaire that will be annexed to the deliverable and that will be distributed among all in the consortium and sent to the contact list that each partner will prepare.

2.2 Procedures

Firstly, as mentioned in the background, literature was reviewed, and two questionnaires were found that could be adapted to the concept of TrustVehicle. Using an existing questionnaire has the advantage that the questions have already been validated, but ad hoc procedures will be used to develop the questionnaire. Two draft questionnaires were uploaded to the internal website and the project partners were invited to give feedback and comments on questions. In the meantime, psychologists from CISC organized interviews and focus groups in Klagenfurt and Villach.

Participants were volunteers and could be divided in two groups. The first one was made up of colleagues and the second was made up of people coming from several countries. During the networking sessions, the TrustVehicle project was presented and the emails of the persons who would be interested in attending the focus group or the interviews were collected. As the attendance was a

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voluntary feature, we arranged the appointments according to the preferences of the participants. There were no special inclusion criteria or requirements apart from being more than 18 years old.

Four interviews and three focus groups were conducted. A total of twelve people, seven women and five men, were involved. Participants were from Argentina, UK, South Korea, Iraq, Italy and Austria. They were between 24 and 49 years old and they had a high level of education (6 and 7 according to the international classification of education).

At the end of the focus groups and the interviews, data was collected and integrated with the feedback from the partners, so the first questionnaire could be created. The first version of the questionnaire was pretested and then revised. After that, the final version was delivered to the TrustVehicle consortium.

2.3 Techniques

A hybrid methodology that combines qualitative methods with quantitative ones is used in the TrustVehicle project to assess user acceptance. Therefore, user forum, focus groups, in-depth interviews, which are primarily qualitative methods are used with quantitative questionnaires.

Focus groups [6] are a data collection method. Data is collected through a semi-structured group interview process. Focus groups are moderated by a group leader. The moderator creates a permissive and nurturing environment that encourages different perceptions and points of view, without pressuring participants to vote, plan or reach consensus. Focus groups are generally used to collect data and to understand how or why people hold certain beliefs about a specific topic or program of interest.

The method used for conducting the interview was a semi-structured interview. It means that there is a list of questions and topics that need to be covered during the interview. The interviewer follows the guide, but he is also able to follow typical trajectories in the conversation that could stray from the guide. At the same time the informant is free to express his/her view in his/her own term.

Finally, the questionnaire enables to collect large amounts of information from large number of people in a short period of time. When data has been quantified, it can be used to compare other research and to measure change.

2.4 Selection of Sample Size & Respondents

The size of the sample plays a crucial role in a survey. When using focus groups or interviews in a qualitative survey the sample needed will be smaller with respect to the case when quantitative-only data are collected.

Larger samples give a better estimate of the population, but this does not guarantee to obtain an adequate number of responses. Participants recruited by mail usually tend to have a lower response-rate than participants personally recruited. To reduce this shortcoming, an ad-hoc invitation for the people to join the research will be designed and several reminders will be send.

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2.5 Focus group and Interviews

In October 2017, four interviews and three focus groups were conducted in Austria. At the beginning, psychologists from CISC presented the project, its main goals and the TrustVehicle consortium. Then the current level of automation was explained. Each participant received papers with a brief description of these subjects. The main questions asked during the focus groups and the interviews were:

- *Had you ever heard of autonomous and/or self-driving vehicles?*
- *What is your general opinion regarding autonomous and self-driving vehicles?*
- *Do you have a car? Do you know if your car is equipped with any autonomous-vehicle technologies?*
- *Using a completely self - driving vehicles, what do you think are the benefits? And issues?*
- *Have you ever tested a car with any autonomous technologies?*
- *With completely self-driving vehicles there any possible scenarios about whom you are concerned?*
- *Would you be interested in having a complete self-driving vehicle? Why?*
- *Have you even heard about the current law regarding the testing, operation and safe of autonomous cars?*
- *How do you imagine spending your time travelling in an autonomous vehicle?*

2.6 The output

Even though some responses will be outlined in this section, a more detailed analysis will be provided when results are gathered from the questionnaires.

2.6.1 Benefit

Concerning the benefit of this technology and whether it is experienced as comfortable and useful for long distances, especially when driving on motorway and during the night:

1. It "*can avoid human mistakes, when you are tired*."
2. "It could work for older people, for the disabled."
3. "*In public transport, when driving in intercity, or on highways, it can improve the traffic. Also for trucks on motorway, you can plane the trips*".

A list with benefits as expressed in direct quotes is outlined as follows:

1. "*It can save penalties, for instance if the care don´t allow you to over speed.*"
2. *"A car that give you some sign, alarm, alert; in most of the accidents people did not see what happens."*
3. *"Or when the car can recognize you, for instance if you are drunk and therefore you are not allowed to drive."*

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4. *"Can improve in reducing accidents."*
5. *"Being artificial intelligence, the vehicle can calculate the decision for you. The machine can adapt and learn. 1 second for detection, 1 for reaction."*
6. *"It should be an option for people who cannot drive anymore."*
7. *"Car can have tools to know if driver reacts or if he/she is felt into sleep."*
8. *"Car can limit the speed in a dangerous situation (i.e, ice, fog, rain, wind according to weather conditions)."*
9. *"Car will be connected with other car and so knowing if an accident occurred."*

2.6.2 Issue

The main issues were related to the question of responsibility when an accident occurs:

"*Who is responsible for accident? Manufactory and software, if you keep the steer there is a driver. This is the point*".

Moreover, what could happen when, for instance, the computer shuts down? How could the driver get in control?

"*As all is electronic staff, something maybe is not working".*

"For feeling comfortable you must have always the possibility to keep driving". "Machine can help but not substitute human".

"*You have to trust in the car, you put your life and the life of other passengers in the car*".

"Driving in USA is different, here in Europe there are narrow streets".

Age could play a role in driving different opinions. "*It depends if you like to drive. Older generation, for instance they don't like technologies. People who are more than 80 could be afraid of this".*

2.6.3 Scenario Concerned

For what concern the scenario, the most dangerous is in the city, when children are moving. They were afraid of the "*interactions with pedestrians and cyclists, they jump unexpectedly*".

"*If all cars are automated, human behaviour is not predictable*".

An important question was asked: "*what is the time for the devices? Hardware need to transfer the data".*

"*Only driving at 50 km, you see the person crossing in front of you. In this case is helpful, but what happen if the break does not work and the car is not responding?". Nothing is perfect*.

The role of the decision making is crucial.

"*Yes, the decision making. Which is the priority in case of risk of crashing? The passengers, the driver or the other people who is involved?*

For instance, when a cat is crossing the street usually human try to avoid knocking down it. Maybe the car chooses to run down the cat instead of turn immediately or having a crash. But what happen

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when there is other people and when, for instance, human does not agree with the car decision and can not to anything? (because he or she is not allowed?)"

2.6.4 Spending Time

At the end, when respondents were asked how they would think to spend their time when riding in a completely self-driving vehicle, the answers were:

- *In short distance: looking outside*
- *In long distance, reading, watching movie, like in a plane*
- *Enjoy the music, not reading, watching movie, seeing outside.*
- *As a train or a long journey: reading, sleeping and looking out of the window.*
- *"At the beginning, I would stay concentrate on the paying attention at what is happening, I would be not sure. Later reading something, or watching out the window".*

2.7 Data Collection

The survey will be delivered through an online questionnaire. The survey will be arranged by CISC in an anonymous way. CISC, represented by Dr. Micaela Troglia, will have access to the data. She will also be responsible for the processing of data in the Trust Vehicle project.

Selected researchers from the University of Surrey and authorised by a signed form, will have access to data. The data could be accessed by any third party only in an anonymous and aggregated way.

A cover letter will specify the purpose of the research and how data will be treated. No personal information, names, email addresses and IP addresses will be related to the survey results. All data collection and processing will be carried out according to EU and national legislation.

2.8 Data Analysis

For data collection, an online questionnaire development cloud-based software, SurveyMonkey, is used. Representative participation is one of the main steps of the good analysis, which is followed by the careful interpretation of the data to produce actionable results. Therefore, the process shown in Figure 2-1 will be followed for analysing the gathered data. It will start with a quick review of the results, which will be used to find any flaws in response population, and to identify what areas to focus on for detailed analysis. In data cleaning phase incomplete and duplicate responses will be found and deleted. Moreover, responses will be discarded if the respondent did not complete enough of the survey to be meaningful. Also, special care will be given when editing survey data so that it is not altered. In the data analysis phase, rather than basic analysis using charts, cross tabulations, and filters, a more complex statistical analysis will be carried out using high powered analytical tools such as SPSS and Excel. In the graphical analysis phase, the data will be displayed in a variety of visual formats that make it easy to see patterns and identify differences among the results set.

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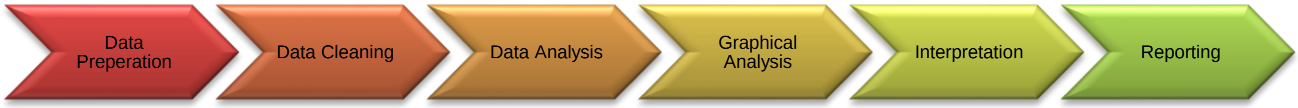

Figure 2.1 Process of data analysis

After analysing the data, a report will be written to present the findings of the questionnaire. It is important to note that even though the process is clearly defined, the number of the questions and the number of the responses influence the expected timeline of the analysis.

2.9 Ethics

The research will be carried out in a rigorous and ethical manner. The research will be voluntary; therefore, no participant will be forced to take part in the research. The right of participants will be respected and the research will be reported fully and honestly.

It is imperative to apply for ethics approval for the integrity of the research that is going to be conducted. This can either be done through the University of Surrey or any other institution that has the authority to grant ethics approval before the commencement of research with human participants.

The recruitment process for the questionnaire is compliant with the guidelines of the Research Ethics Committee of Faculty of Health and Medical Sciences at the University of Surrey.

2.10 Limitations

Due to ever-increasing technological advances, researchers have been able to design and develop their own online questionnaires to gather data from the target group(s) at a fraction of the cost and time it would have taken to develop them in the past. Other than these advantages, the online questionnaire has other benefits such as automatic storage of the data, and flexible response time which allows the respondents to answer questions on their schedule, and at their pace. Even though the methods and instruments to assess the public opinion about autonomous and self-driving vehicles, was carefully defined, TrustVehicle partners are still aware of the limitations of the selected instrument, and the methodology. These are:

First, it could be hard to secure a high response rate with online questionnaire. So, the TrustVehicle partners also take part in the distribution process of the questionnaire in their own institutions.

Second, often the respondents who will be more motivated to return the questionnaire are those who have a positive/ negative viewpoint. Such a response bias would influence the responses of participants away from an accurate response. To minimize the effect of response bias sensitivity analyses can be used to evaluate the extent of it.

Third, throughout the analysis ambiguities, in which several interpretations are plausible, can be recognized. People may read differently into each question and therefore reply based on their own

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interpretation of the question. To minimise its effect special attention was given to the wording and questionnaire has been tested before.

2.11 The Questionnaire

The aim of this questionnaire (pls see Annex) is to collect general opinion and issues regarding automated vehicles. It is not related to specific scenarios, even if possible scenarios are described.

The questionnaire starts with an explanation of the level of automation, according to 2014 SAE international. For every level of automation, the question asks how much people are concerned with this level of technology and if their vehicle is equipped with the current level of technology.

There are questions on benefits and issues regarding completely self- driving vehicles. Respondents are also asked to rank topics on laws, costs, and safety.

The final part of the questionnaire aims to collect some basic background information on gender, age, education, employment, the most often used vehicle, and offers the opportunity to add comments.

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3 Scenarios

While addressing the widest possible overview of critical driving scenarios, the TrustVehicle project developed with the aim to exploit the technologies for future production vehicles, and focus is placed on four main groups of road users as from the business of the OEM involved in the project.

3.1 Trucks and Commercial Vehicles

3.1.1 Docking Station, Back Parking

Figure 3-1 Docking Station Back Parking

A loading dock is a recessed bay in a building, where trucks are loaded and unloaded. Loading docks are commonly found at manufacturing plants, warehouses and other industrial buildings. They are the primary location of the movement of product, coming in and out of a facility. Back parking is a frequent activity of a truck driver going in and out of a docking station. In a busy environment the parking process needs special care considering other vehicles and pedestrians in the field. Autonomous back parking scenario starts with the selection of the available docking platform and initial positioning of the vehicle. With the initiation of the self-parking feature, the truck will approach the desired position giving proper actuation and perceiving the environment for any dangerous situation without any driver intervention.

3.1.2 Construction Site, Back Approach

Especially the construction sites along crowded city roads need a huge effort of the drivers while going in and out of the site. Serious manoeuvring with special attention to other vehicles and pedestrians is needed. Autonomous back approach feature will primarily detect the situation of the road and manoeuvre possibilities. The driver will observe the recommended manoeuvre and initiate the approach. This scenario calls for a simultaneous perception of the situation as well as the ability to update the manoeuvre accordingly. The manoeuvre will finish with the entry of the truck in the site and final approach to the loading position. Possible handover cases will be considered for the scenario regarding changing road restrictions and immediate attention to the danger present in situations.

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Figure 3-2 Construction Site Back Approach

3.2 Public Transportation

3.2.1 Automated Driving to Electric Charging Point on a Bus Stop

The electric bus under consideration should drive automatically towards electric charging points at the bus stop. In this scenario, the bus is approaching the bus stop and charging spot on manual driving mode and then it will be switched to an automated driving mode. The system will then provide instructions for the driver. The automated driving system calculates the driving path and checks possible obstacles.The charging event can be done automatically after the system has parked under the charging spot. After the charging event, the bus will drive automated to the border of the automated driving area.

When the bus is approaching the bus stop on manual driving mode, the system provides driving instructions (e.g. speed and distance to automated driving enabled area) to the driver. Then when the bus enters the automated driving area, the preconditions for automated driving are checked, e.g. current speed, position, heading and angle of the steering wheel as well as sensor capabilities and weather restrictions. Then the automated driving system calculates the driving path and checks possible obstacles. If automated driving can be activated, it is offered to the driver via HMI. The driver turns the automated driving ON or acknowledges the transition from manual driving to automatic driving. The system is now in transition mode. It confirms that automated driving mode is activated (HMI). While driving on automated driving mode, the system shows to the driver only relevant information, e.g. the current location of the bus, planned driving path, obstacles, destination and distance to the destination. At the destination (under the charging point) the system shows to the driver when the bus has been parked and the charging can be activated. Automated driving mode is deactivated (shown in HMI).

Exceptions to the success scenario are when the automated driving mode cannot be activated when the bus is entering the area, due to too high speed of the bus, position of the steering angle, obstacles on the route. Furthermore, when an obstacle moves on (or too near) the planned driving path, which is a non-critical situation. When the obstacle emerges in front of the bus within the safety margin it is a critical situation.

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3.2.2 Automated Driving from the Bus Stop after the Charging

In this scenario the electric bus is switched to automated driving mode in order drive the bus out of the bus stop after charging.

When the bus is parked in the bus stop and it is ready to leave, the system offers manual driving mode (default) and the automated driving and automated driving mode to the driver shown on HMI. The availability of the automated driving mode depends on possible obstacles on the pre-planned route and on sensor capabilities /weather conditions. If the driver selects the automated driving mode, the system confirms that the automated driving mode is activated (HMI). While driving on automated driving mode, the system shows to the driver only relevant information, e.g. the current location of the bus, panned driving path, obstacles, destination and distance to the destination. The destination is the pre-planned transition area near the border of the area where automated driving is possible. When the bus enters the transition area the preconditions for changing to automated driving are checked (position, possible obstacles etc.) The driver is advised to take control of the vehicle. The system is now in transition mode (shown on HMI). If the manual mode can be activated, the system confirms that the manual driving mode is activated (HMI).
Reasons the automated driving mode cannot be activated are the position of the steering angle, obstacles on the route, weather or problem with sensors. The manual driving mode cannot be activated e.g. when there is a lack of driver attention.

3.3 Passenger Cars

For automated driving scenarios with passenger vehicles, the focus will be on degraded sensor functionality and sensor data output. In order to conduct safe automated vehicle maneuverers, vehicle controllers are highly dependent on trustworthy data from the vehicle sensors. The sensor output must ensure that lines, objects, VRU's and so on within the driving path are detected and reported. However ensuring 100 % detection rate is unlikely and much of this due to external disturbance and not necessarily sensor performance. Degradation of the sensor output can result in false detections, late detections or even missed detections which may lead to crashes. The degradation of sensor output also impacts the availability of the intended function, i.e. the automated driving function is availably much less than expected. The use cases for potential sensor output degradation are split in the below listed scenarios.

Scenario 1: Functional behaviour – sensor faults already reported by diagnostics

Scenario 2: Environmental conditions – harsh weather that may reduce sensor visibility

Scenario 3: Misalignment – changes in sensor position or reduced calibration accuracy

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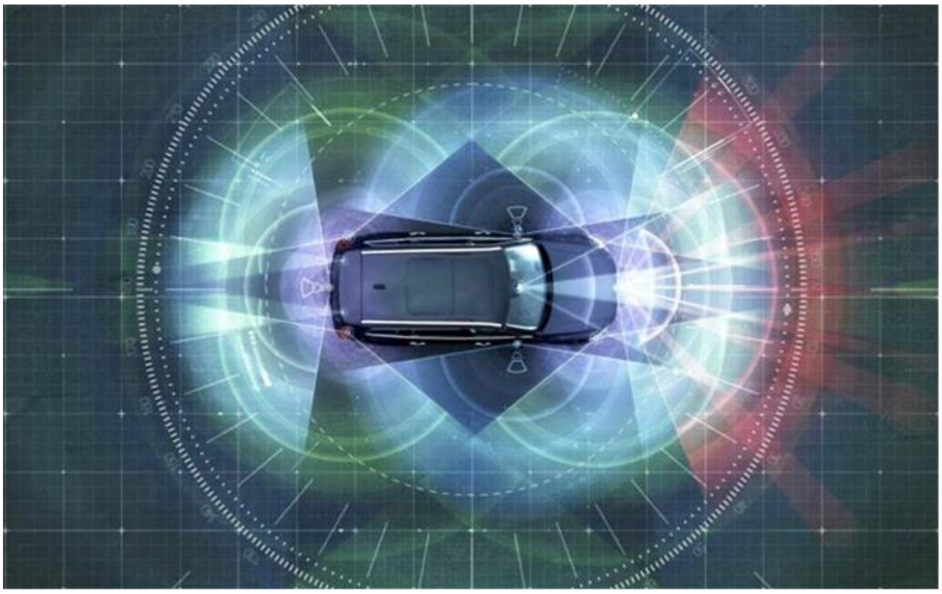

Figure 3-3 Volvo sensor setup

3.4 Vulnerable Road Users

3.4.1 Pedestrian between Parked Cars

Pedestrians formed 21% of all road fatalities in the EU in 2014 [7]. Critical scenarios involving VRUs often occur when the VRU is hidden by obstacles blocking the ego-vehicle’s view. This could happen if other vehicles are parked along the road. The scenario depicted in Figure 3-4 involves a pedestrian stepping out between two parked cars on the passenger’s side of the ego-vehicle. In order to avoid collision at the collision point (CP), the ego-vehicle has to react accordingly as soon as the pedestrian is detected.

A related scenario would be if there was an oncoming vehicle on the next lane, which would force the ego-vehicle to do an emergency brake rather than swerve to the oncoming lane.

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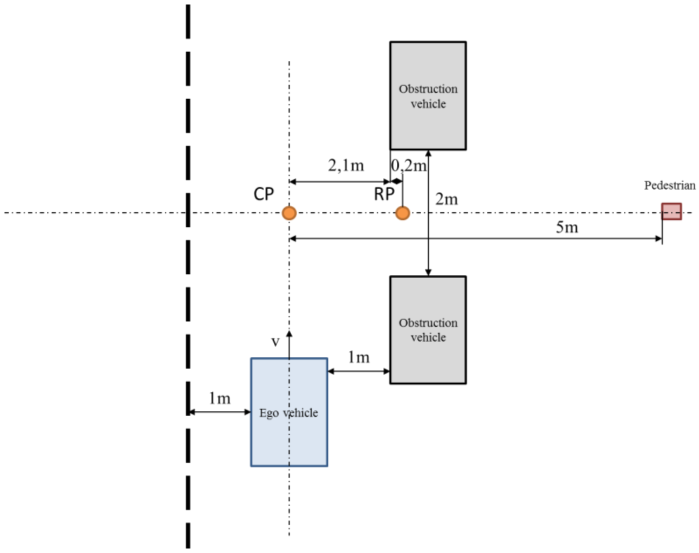

Figure 3-4 Pedestrian stepping out between parked cars

3.4.2 Cyclist in own Lane

According to Deliverable 2.1 [7], cyclists formed 8,1% of all road fatalities in the EU in 2014. Therefore cyclists sharing road space with other traffic participants is a crucial scenario. Figure 3-5shows a cyclist driving in the same direction as the ego-vehicle on the right half of the ego-vehicle's lane. The cyclist is driving considerably slower than the ego-vehicle. Without action from either the ego-vehicle or the cyclist, a collision would occur at the CP.

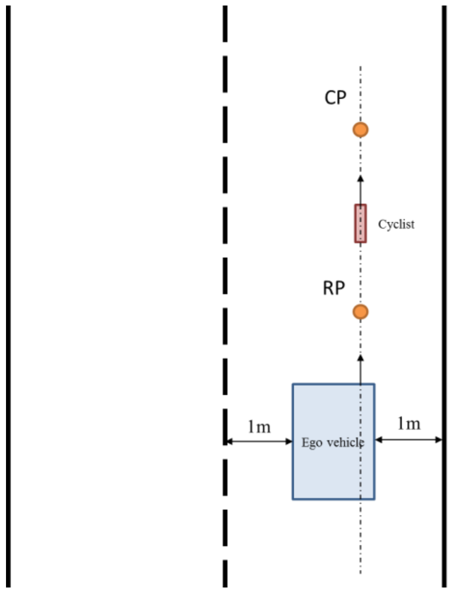

Figure 3-5 Scenario Lane change cyclist

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4 Driving Simulator

A simulator is used to test models or functions in a safe environment with the interaction between the model and the driver. These interactions can either be the handover phase to and from automated/autonomous driving functions, in case the system doesn't fully takeover in the phase the driver is assisted by an automated driving function or during the phase of fully automated/autonomous driving. This means that comfort and perceived safety has to be considered in all SAE levels of autonomous driving starting at level 1 up to level 5. The behaviour of the function under test is evaluated in terms of comfort and perceived safety which are the criteria's to assess the functionality in terms of „feel to be driven ." This doesn't aim at the safety criteria in the first place since the base functionality of a model/function in terms of safety can be assessed in pure simulation without a simulator (in this case a hexapod).

The simulator which will be used in this study is a hexapod with a mounted quarter passenger car cockpit mounted with steering, throttle, break and shifting feedback. The field of view is 180 degrees and the movement is in 3 directions and 3 axes limited by the degree of freedom of the hexapod. The simulator is controlled by a co-simulation framework which integrates the environment, the movement of the hexapod and the controllers, as well as the assessment software.

The controllers to be tested have to be provided as FMUs or FMIs with described interfaces. The assessment is done with a questionnaire which aims to categorize the perceived comfort and safety during the scenario. A correlation of the questionnaire with physical parameters of the chassis movement and/or measurable human parameters is preferred.

4.1 Technical Description of the Simulator

The enhanced AVL driver simulator is operated to fit ADAS evaluation and development in a safe environment. The environment and vehicle simulation models are interacting with each other AVL VSM™ is used as the vehicle dynamics simulation tool, and Vires Virtual Test Drive (VTD) as environment and sensor simulation tool. AVL Model.Connect™ is used as an interoperability and connection platform for data exchange and co-simulation.

This tool offers the possibility to connect different AVL or third-party tools and build up a co-simulation model. Coupling models with different solver time steps demand inter- or extrapolating from exchanged data. This can lead to coupling errors and time delays. AVL Model.CONNECT™ offers a self-developed coupling method, the so-called Nearly Energy Preserving Coupling Element (NEPCE), which minimizes this coupling errors and improves the overall stability of the system.

The vehicle body, including chassis, steering system, tires is simulated by AVL VSM.

The vehicle interacts and receives information from an environment simulation model, for this purpose Vires Virtual Test Drive (VTD) is used. It offers the possibility to set up an environment, consisting of traffic, road networks, traffic signs and lights and it can provide this data to other tools, for example for Vehicle-to-Vehicle or Vehicle-to-Infrastructure communication. Figure 4-1 shows in an abstract way how the components and software applications are linked together.

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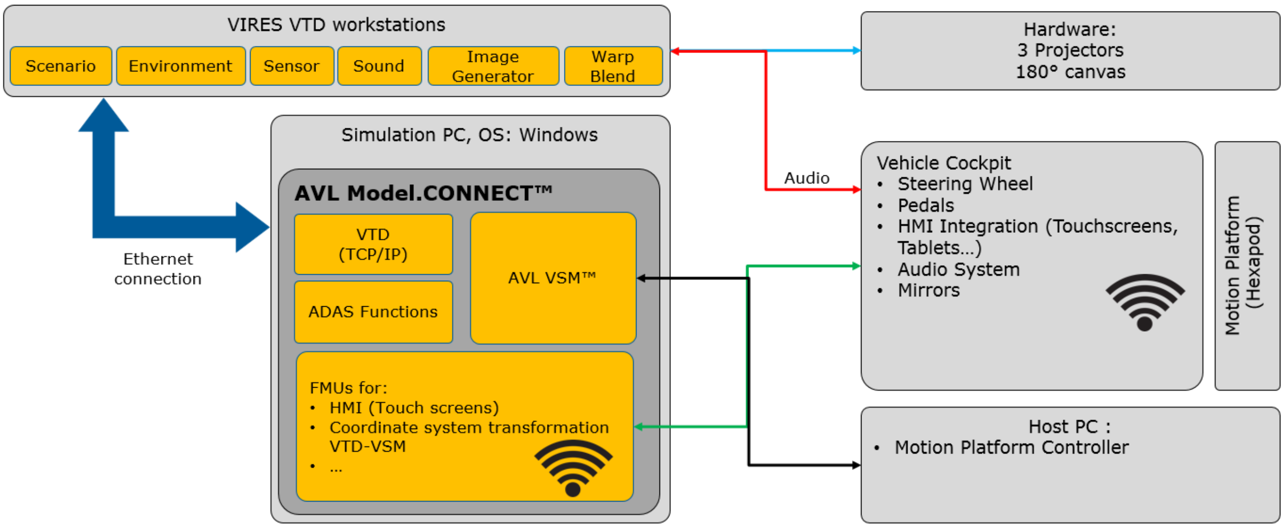

Figure 4-1 Block diagram of driver simulator

4.1.1 VDT – Vires Virtual Test Drive

VTD is a complete tool-chain for driving simulation applications. VTD is a toolkit for the creation, configuration, presentation and evaluation of virtual environments in the scope of road and rail based simulations. It is used for the development of ADAS and automated driving systems as well as the core for training simulators. It covers the full range from the generation of 3d content to the simulation of complex traffic scenarios and, finally, to the simulation of either simplified or physically driven sensors. It is used in SiL, DiL, ViL and HiL applications and may also be operated as co-simulations including 3rd party or custom packages. By its open and modular design it can easily be interfaced and integrated. [8]

4.1.2 Open Drive

OpenDRIVE® is an open file format for the logical description of road networks. It was developed and is being maintained by a team of simulation professionals with large support from the simulation industry. Its first public appearance was on January 31, 2006. The OpenDRIVE® data may be derived from road scans, navigation data, road network design software or other sources. It may be complemented by detailed surface information using the OpenCRG format. The resulting road information will be made available to e.g. vehicle dynamics, traffic simulation and sensor simulation via a layer of evaluation routines. Typical applications require that the road information be evaluated in real-time within strong time constraints. [9]

4.1.3 Open CRG

OpenCRG® fills the gap between the macroscopic description of road networks and the microscopic description of road surfaces. An implementation of OpenCRG® into the OpenDRIVE® file format specification has already been established in January 2008 with the release of OpenDRIVE® 1.2. By this, real road surfaces (e.g. from measurements) have become available to "classic" simulation applications. A curved regular grid (CRG) represents road elevation data close to an arbitrary road

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centre line. The reference line may be complemented by slope or super elevation and is defined by consecutive heading angles. The regular grid defines the elevation in proximity of the reference line. Columns are longitudinal cuts that are parallel to the reference line. Each row represents a lateral cut which is orthogonal to the reference line. [10]

The following graphic show how the environment is working together using the explained open formats.

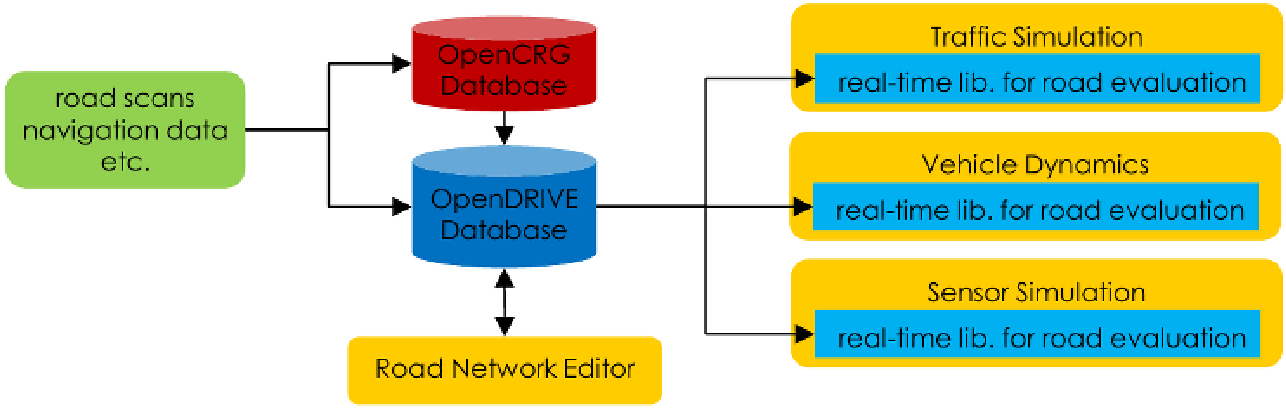

Figure 4-2 Environment for simulation with open formats [9]

4.1.4 AVL VSM

AVL Vehicle Simulation with AVL VSM 4™ supports an early solution of the conflicting goals of CO2 reduction & a high level of fun-to-drive. Calibration and validation become fast and easy and the number of vehicle prototypes is reduced significantly. Accurate, reliable and comparable results based on easy-to-use comprehensive vehicle models and consistent manoeuvres throughout the development process enable sound decisions with regard to technologies without last minute design changes.

Combined with AVL-DRIVE 4™ for objective vehicle assessment, AVL VSM 4™ enables frontloading of vehicle development tasks to reduce the number of prototypes, development loops and therefore costs.

4.2 Testing Description for Driver Simulator

Testing and validation of the exchanged data between these systems is essential to guarantee a failsafe and working ADAS functionalities.

In a first approach the input scenarios of the WP partners in an office environment have to be validated, if the exchanged data is in a running and stable co-simulation of all tools. This data has to be plausible and exchanged in the correct data format and order to guarantee a failsafe system which works correctly. In this office environment, a first estimation of the overall system can be done and the different simulation scenarios can be checked. With a stable and running office simulation model it is possible to connect with the advanced driver simulator and the hexapod to test driver's acceptance, comfort, and functionality. The vehicle's longitudinal, lateral and vertical accelerations are sent to a

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hexapod which translates this information into motion. By connecting the simulation model with AVL-DRIVE™ the subjective evaluation can also be compared with an objective evaluation.

To simulate specific scenarios, they have to be predefined and delivered in a special file format and have to follow a specific standard. VTD uses OpenScenario as a standard format to build scenarios and the OpenDrive standard format for the static environment generation. These files have to be provided as input as described above. If the static environment and the dynamic scenarios are delivered in these standard formats they can be simulated within VTD and on the Driver Simulator with the input and interaction of the drivers.
Furthermore, the vehicle models for AVL VSM™ have to be delivered by the vehicle owners to have equivalent simulator motion.

4.2.1 AVL Cockpit

The AVL generic vehicle cockpit is specially designed for the hexapod simulator. It is a dedicated driver seat with the quarter of a vehicle around it. This includes all controls needed by the driver and the fully mechanical steering actuator and a hydraulical break system.

The flexibility of the co-pit can be used to research various different use cases on the hexapod. Depending on the input of the users the cockpit can be adapted in many ways to fit HMI investigations as well as human perception and biological approaches. The measurement tools have to be provided and operated by the user using the hexapod.

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5 Conclusion

Driving tasks are series of complex interactions between the driver, vehicle, and his or her environment, especially in conditional automation (L3AD), because it also includes other road user(s) like pedestrian or human drivers. Understanding the interactions of humans with automated vehicles, both as a driver and as road user(s) is crucial and highly relevant to the development of successful automated vehicles. As a result, it is imperative to include perspectives and experiences of humans to further the effective development of automation in vehicles.

D2.2 summarizes the general-purpose questionnaire that will be submitted to the widest possible group of users with the aim to identify the preferred scenarios considering driver acceptance. While the first set of scenarios have already been identified from the core activities of the partners involved, these scenarios will be updated and also reflect the results of the questionnaire.

The AVL driving simulator has been selected for the field study to provide a safe and repetitive testing environment, unlike test track studies, which are by nature risky. Using a simulation environment enables TrustVehicle partners to have full access and flexibility in terms of additional measurement equipment and access to the driver. This is an improvement in terms of safe measurements and also allows for an ease of use with expensive equipment.

Scenario modelling on driving simulators is a complex process that requires technical assistance, which is why CISC and AVL researchers worked together in the specification of scenarios. By combining both knowledge on human behaviour (CISC) and specific technologies (AVL), the TrustVehicle project adhered to its objective to develop more appropriate and well-rounded scenarios.

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7 Annex

AUTOMATED VEHICLE SURVEY

We are involving in an European project on automated vehicle and we would like to know your opinion on this technology.

Autonomous vehicles are those in which at least some aspects of a safety-critical control (such as steering, throttle, or braking) operate without direct driver input. Vehicles that provide safety warnings to drivers (for example, a forward-crash warning) but do not take control of the vehicle are not considered autonomous.

A fully autonomous vehicle is capable of driving itself in various situations without a human driver to neither monitor, nor control the vehicle. In this project, we are rather considering vehicles able to conduct a few, not all, controls autonomously.

Autonomous vehicles may use on-board sensors, cameras, GPS, and telecommunications to obtain information in order to make decisions regarding safety-critical situations and act appropriately by taking control of the vehicle at some level. Examples of autonomous-vehicle technologies range from those that take care of basic functions such as cruise control, to completely self-driving vehicles with no human driver required.

Directions: Please answer the following questions as honestly as possible. There are no “right” or “wrong” answers. Your responses will be treated fully anonymous. This means that your responses will not be linked with your personal information

Q1) Had you ever heard of autonomous and/or self-driving vehicles before participating in this survey?

□ Yes

□ No

Q2) What is your general opinion regarding autonomous and self-driving vehicles?

Even if you had never heard of autonomous or self-driving vehicles before participating in this survey, please give us your opinion based on the description you just read.

□ Very positive

□ Somewhat positive

□ Neutral

□ Somewhat negative

□ Very negative

There are several different levels of autonomous-vehicle technology. Some of these technologies already exist now, while others are expected to become available in the future. Descriptions of each level of autonomous vehicle technology are shown below. Please take a moment to read each description carefully before continuing with the survey.

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Current technology: (according to 2014 SAE International)

Level 0. Driver continuously performs the longitudinal AND lateral dynamic driving tasks and monitors the environment.

Level 1. Driver continuously performs the longitudinal OR lateral dynamic driving tasks and monitors the environment. One driving task at a time (longitudinal OR lateral) is performed by the system.

Level 2. (Partial automation): System performs longitudinal AND lateral driving tasks in defined conditions/environments. Driver must monitor the driving task and the environment all the time.

Technology installed in Trust Vehicles:

Level 3. (Conditional automation): System performs longitudinal and lateral driving tasks in defined conditions/environments. The system recognizes its performance limits and requests driver to resume the dynamic driving task with sufficient time margin. Driver does NOT need to monitor the driving task nor the driving environment at all times, but he/she must always be in a position to resume the control of the vehicle when requested.

Future technology:

Level 4. (High automation): System performs the lateral and longitudinal dynamic driving tasks in all situations in a defined use case. Driver is not required during the defined use case. In case the vehicle is not able to perform the driving tasks, it is able to park itself into a safe location.

Level 5 (Full automation): The system performs the lateral and longitudinal dynamic driving tasks in all situations encountered during the entire journey. No human driver required.

Q3) Which of the following autonomous-vehicle technologies, if any, do you have on the vehicle(s) that you own or lease?

Please select one response only. If you have more than one vehicle with this technology, please select the most advanced level installed on your vehicles.

☐ I do not currently own or lease a vehicle

☐ Level 0: No automation. The driver is in complete and sole control of the primary vehicle controls (brake, steering, and throttle) at all times, and is solely responsible for monitoring the roadway and for safe operation of the vehicle. Vehicles that have certain driver support or convenience systems but do not have control over steering, braking, or throttle would still be considered Level 0 vehicles. Examples include systems that provide only warnings (forward collision warning, lane departure warning, blind spot monitoring), as well as systems providing automated secondary controls such as wipers, headlights, hazard lights, etc.

☐ Level 1: Automation at this level involves one or more primary vehicle controls (brake, steering, or throttle); if multiple controls are automated, they operate independently from each other. The driver has overall control, and is solely responsible for safe operation, but can choose to hand over limited control to the vehicle (such as cruise control); or the vehicle can automatically control a function (such as electronic stability control); or the vehicle can provide added control to aid the driver in certain situations (such as dynamic brake support in emergencies). The vehicle may assist the driver in operating one of the controls— steering, braking, or throttle—but each function is

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controlled independently from the others. Other examples of Level 1 systems include automatic braking and automatic lane keeping.

☐ Level 2: This level involves automation of at least two primary vehicle controls (brake, steering, and/or throttle) designed to work together to relieve the driver of control of those functions. Vehicles at this level of automation can share control with the driver in certain limited driving situations. The driver is still responsible for monitoring the roadway and safe operation, and is expected to be available for control at all times and on short notice. The system can relinquish control with no advance warning and the driver must be ready to control the vehicle safely. An example of a Level 2 system is adaptive cruise control in combination with automatic lane keeping. Automatic parking systems are also considered Level 2.

☐ I do not know if my vehicle has any of these technologies.

Q4) Level 3 vehicles are expected to provide limited self-driving automation. Vehicles at this level enable the driver to hand over control of all safety-critical functions under certain traffic conditions, and to rely on the vehicle to monitor for changes that require switching back to driver control. The driver will be expected to be available for occasional control, but with sufficiently comfortable transition time. An example would be a self-driving car that can determine when the system is no longer able to support automation, such as in a construction area, and then signals the driver to take control of the vehicle with an appropriate amount of time to safely react. The major difference between Level 2 and Level 3 is that at Level 3, the vehicle is designed so that the driver is not expected to constantly monitor the roadway while driving.

How concerned would you be about driving or riding in a vehicle with this level of self-driving technology?

□ Very concerned
□ Moderately concerned
□ Slightly concerned
□ Not at all concerned

Q4a) If you are concerned, could you explain why?

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Q5) Level 4 vehicles are expected to provide complete self-driving automation in defined use cases. The vehicle will be designed to perform all safety-critical driving functions and monitor roadway conditions for a certain use case (e.g. when driving on a highway). The “driver” will provide destination or navigation input, but will not be expected to be available for control at any time during “automated part” of the trip. In case the car cannot handle the driving situation anymore, they are able to park themselves safely.

How concerned would you be about riding in a vehicle with this level of self-driving technology?

□ Very concerned
□ Moderately concerned
□ Slightly concerned
□ Not at all concerned

Q5a) If you are concerned, could you explain why?

Q6) Level 5 vehicles are expected to provide complete self-driving automation. The vehicle will be designed to perform all safety-critical driving functions and monitor roadway conditions for an entire trip. The “driver” will provide destination or navigation input, but will not be expected to be available for control at any time during the trip. This includes both occupied and unoccupied vehicles. By design, safe operation rests solely with the automated vehicle system.

How concerned would you be about riding in a vehicle with this level of self-driving technology?

□ Very concerned
□ Moderately concerned
□ Slightly concerned
□ Not at all concerned

Q6a) If you are concerned, could you explain why?

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Q7) How likely do you think it is that the following benefits will occur when using **completely self-driving vehicles (Level 5)**?

Please select one response per row.

		Very likely	Somewhat likely	Somewhat unlikely	Very unlikely
a.	Fewer crashes with other vehicles	□	□	□	□
b.	Fewer crashes with pedestrians and bicycles	□	□	□	□
c.	Reduced severity of crashes	□	□	□	□
d.	Improved emergency response to crashes	□	□	□	□
e.	Less traffic congestion	□	□	□	□
f.	Shorter travel time	□	□	□	□
g.	Lower vehicle emissions	□	□	□	□
h.	Better fuel economy	□	□	□	□
i.	Chance for elder and disabled people	□	□	□	□

Q8) How concerned are you about the following issues related to **completely self-driving vehicles (Level 5)**?

Please select one response per row

		Very concerned	Moderately concerned	Slightly concerned	Not at all concerned
a.	Safety consequences of equipment failure or system failure	□	□	□	□
b.	Legal liability for “drivers”/owners	□	□	□	□
c.	System security (from hackers	□	□	□	□
d.	Data privacy (location and destination tracking)	□	□	□	□
e.	Interacting with non self – driving vehicles	□	□	□	□

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		Very concerned	Moderately concerned	Slightly concerned	Not at all concerned
f.	Interacting with pedestrians and bicyclists	□	□	□	□
g.	Learning to use self-driving vehicles	□	□	□	□
h.	Degrading manual driving skills	□	□	□	□
i.	System performance in poor weather	□	□	□	□
j.	Self- driving vehicles getting confused by unexpected situations	□	□	□	□
k.	Self-driving vehicles not driving as well as human drivers in general	□	□	□	□

Q9) How concerned are you about the following possible scenarios with **completely self-driving vehicles (Level 5)**?

Please select one response per row.

		Very concerned	Moderately concerned	Slightly concerned	Not at all concerned
a.	Riding in a vehicle with no driver controls available (no steering wheel, no brake pedal, and no gas pedal/accelerator)	□	□	□	□
b.	Self-driving vehicles moving by themselves from one location to another while unoccupied	□	□	□	□
c.	Fully self-driving vehicles on motorways	□	□	□	□
d.	Fully self-driving vehicles on rural roads	□	□	□	□
e.	Fully self-driving vehicle in the cities	□	□	□	□
f.	Fully self-driving vehicle driving in the residential streets	□	□	□	□
f.	Commercial vehicles such as heavy trucks or semi-trailer trucks that are completely self-driving	□	□	□	□

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		Very concerned	Moderately concerned	Slightly concerned	Not at all concerned
g.	Public transportation such as buses that are completely self-driving	□	□	□	□
h.	Taxis that are completely self-driving	□	□	□	□

Q10) How interested would you be in having a **completely self-driving vehicle (Level 5)** as the vehicle you own or lease?

□ Very interested
□ Moderately interested
□ Slightly interested
□ Not at all interested

Q11) How many years after the technology is introduced to the market would you feel comfortable purchasing a car with an autonomous driving system?

□ Immediately □ Within a year □ 1 – 2 years □ 3 – 4 years □ More than 4 years

Q12) If you were to ride in a **completely self-driving vehicle (Level 5)**, what do you think you would use the extra time doing instead of driving?

Please select one response only.

□ Read
□ Sleep
□ Watch movies/TV
□ Play games
□ Enjoy the music
□ Work
□ Use mobile phone
□ Watch the road even though I would not be driving
□ Look at the landscape
□ I would not ride in a completely self-driving vehicle
□ Never thought about that
□ Other (please specify):

Q13) Of the following, rank how much important for you are these topics:

□ Well-developed laws for the development, sale, and use of autonomous cars

1 2 3 4 5

Low importance High importance

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□ Affordable cost for an autonomous car

1 2 3 4 5

Low importance High importance

□ Personal safety and the safety of those around you while operating an autonomous car

1 2 3 4 5

Low importance High importance

Now we would like to know some basic background information about you.

Q14) Which is your gender?

□ Female

□ Male

□ Other

Q15) Which is your native country?

Q16) What is your age?

□ 18 to 29

□ 30 to 39

□ 40 to 49

□ 50 to 59

□ 60 to 69

□ 70 or older

Q17) According to the international classification of education (ISCED), what is the highest level of education you have completed?

□ Level 0 – Less than primary education
□ Level 1 – Primary education
□ Level 2 – Lower secondary education (e.g. secondary school, junior secondary school, middle school, junior high school)
□ Level 3 – Upper secondary education (e.g. secondary school stage two/upper grade, senior secondary school, high school)
□ Level 4 – Post-secondary non-tertiary education (e.g. technician diploma, primary professional education)

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□ Level 5 – Short-cycle tertiary education (e.g. master craftsman programme, higher technical education, community college education, technician or advanced/higher vocational training, associate degree)
□ Level 6 – Bachelor's or equivalent level (e.g. bachelor programme, licence of first university cycle)
□ Level 7 – Master's or equivalent level (e.g. master programme or magister)
□ Level 8 – Doctoral or equivalent level (e.g. PhD, DPhil, D.Lit, D.Sc, LL.D, Doctorate)

Q18) What is your current level of employment?

Please select only ONE option that best describes you.

□ Employed full-time

□ Employed part-time

□ Self employed

□ Not currently employed

□ Homemaker

□ Retired

□ Full-time student

□ Part-time student

Q18a) If you are employed or student, could you specify your field?

…….

Q19) What kind of vehicle do you use most often?

Please select one response only.

□ Passenger car (any type or size)

□ Minivan / van / MPV (multipurpose vehicle)

□ Pickup truck

□ Motorcycle / scooter

□ Bicycles

□ Public transport

□ Other (please specify):____

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Q20) without counting scratch in a parking lot, how many car accidents have you been involved in within the last five years?

□ Zero □ One □Two □ Three □ More than three

Before ending, if you would like to add any comments, please use the space below

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Thank you for completing this survey **about automated vehicles!**

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