Designing cooperative interaction of automated vehicles with other road users in mixed traffic environments

interACT D1.3 – Identification of relevant effects of interACT system on safety, security, ethical, liability and legal aspects

Work package	WP1: Scenarios, Requirements and interACT System Architecture
Task	Task 1.4
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Glossary of terms

Term	Description
Automated vehicle (AV)	Vehicle that provides automation of longitudinal and lateral vehicle control and can free the driver from the driving task
external HMI (eHMI)	External Human-Machine-Interface of the AV that is designed to communicate with surrounding traffic participants
Interaction	Within interACT interaction is understood as the complex process where multiple traffic participants perceive one another and react towards the continuously changing conditions of the situation resulting from actions of the other TP, to achieve a cooperative solution. These actions and reactions involve various means of communication
On-board user	Human on-board of the AV who acts as a driver in all cases the AV cannot handle (SAE level 3) or is a passenger for all SAE 4 and 5 applications
Other road user	All possible road users from the perspective of the ego vehicle (the AV) i.e. pedestrians, bicyclists, motorcyclists, vehicles, automated vehicles
Use Case	Functional description of the behaviour of the AV in a traffic situation

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List of abbreviations and acronyms

Abbreviation	Meaning
AV	Automated vehicle
D	Deliverable
eHMI	External Human-Machine-Interface
GNSS	Global Navigation Satellite System
GRE	Working party on lighting and light-signalling under UNECE
GTB	Groupe de Travail Bruxelles 1952
HMI	Human Machine Interface
HRU	Human Road User (e.g. pedestrians, cyclist, vehicle driver)
ISO	International Organization for Standardization
LED	Light Emitting Diode
NHTSA	National Highway Traffic Safety Administration (USA)
SAE	Society of Automotive Engineers
TP	Traffic participant
(UN)ECE	(United Nations) Economic Commission for Europe
VAS	Vehicle Automation Status
WP	Work Package
R&D	Research and Development
OEM	Original Equipment Manufacturer
MAC	Message Authentication Codes

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Executive Summary

The **interACT project** aims to study and model interactions among human traffic participants as well as to develop software and hardware, which will enable an automated vehicle to interact with other traffic participants and on-board users. In its **Work Package 1**, the interACT scenarios to be addressed within the project are selected, detailed and documented. This WP also collected specific requirements for the development of the interACT solutions. Human Factors as well as technical requirements are documented taking legal, security, ethical and safety issues into account.

Deliverable 1.3 mainly consists of expert workshop results and expert opinion regarding the needed changes in standardisation, legal frameworks, privacy and security, required for introducing AVs in real-traffic (such as the interACT system). D1.3 addresses exactly these topics: safety, security, ethical, liability and legal issues related to the safe integration of AVs into mixed traffic environments. Safety, security, ethical, liability and legal issues will be identified and specified for safe, intuitive and cooperative interaction of the AV with other road users and the AV with its on-board user.

A workshop, dealing with the interACT research questions regarding safety, security, ethical, liability and legal issues, took place during the ISO Meetings of ISO/TC22/SC 39 and was organized in cooperation with members from the ISO. Results from interACT along with two additional topics from the field were presented followed up by intense expert discussions. The interACT results supported current draft versions and provided further references, data and details for the ISO group. Furthermore, two potential topics for new working items were identified: the utilization of Wizard of Oz methodology for testing eHMI and the model-based evaluation of eHMIs.

Moreover, additional expert opinions regarding the topic safety, security, ethical, liability and legal issues were collected by conducting interviews with experts in the respective fields. Therefore, interACT project partners interviewed external (from outside the project) experts regarding interACT specific questions with regard to safety, security, ethics, liability and legislation. Key facts are summarised in the last chapter of D1.3.

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1. Introduction

1.1 Purpose and scope

Automation of the driving task is expected to increase road safety and improve traffic flow, among other possible benefits. Therefore, a lot of efforts focus on the development and market deployment of vehicles that can automatically perform parts of the driving task. Several automated vehicles (AVs) have been demonstrated in real traffic. An issue that has not been studied in depth yet, refers to the interaction of AVs with other traffic participants. Interactions between human traffic participants, which include the communication of own intent and anticipation of others' intent in order to mutually agree on a common future motion plan, are a significant part of the driving task. An AV needs to interact with other traffic participants, in order to efficiently and safely share the road infrastructure with them.

The interACT project aims to study and model interactions among human traffic participants and develop software and hardware, which will enable an AV to interact with other traffic participants. During interACT's Virtual Final Event (18th & 19th June 2020) keynote speaker Mr. Tom Alkim, Policy Officer Connected & Automated driving at the European Commission, explained that next to technical and infrastructural aspects non-technical issues like trust, acceptance, user centred design, ethical issues, cyber security and data protection are getting more and more attention. Only if all technical and non-technical questions are answered, Automated Driving in mixed traffic may be introduced in a large scale.

In its Work Package 1 (WP 1), interACT has selected use cases which are the most relevant according to the consortium's view on mixed traffic scenarios. The selected use cases cover urban roads, intersections and parking spaces, because in such environments interactions among traffic participants were expected to be needed. Based on these use cases, this document delivers workshop results and expert opinion on what needs for changes in standardisation, legal frameworks, privacy and security are required for introducing AVs such as the interACT system in mixed traffic environments.

1.2 Intended readership

This deliverable provides a view beyond the boundaries of the project. Internal and external partners deal with the issues on safety, security, ethical, liability and legal aspects in form of workshops and expert interviews. It serves as a representative extract of exchange and twinning activities on mainly non-technical aspects. This deliverable is provided to all project partners, our Project Officer, the reviewers and the European Commission. Furthermore, it is publicly available and intended to provide valuable insights and outlooks for our stakeholders, other researchers, industrial partners and the general public about interACT and related topics and activities.

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1.3 Relationship with other interACT deliverables

This deliverable completes the work in WP 1 “Scenarios, Requirements and interACT System Architecture”. It is related to and it is also a meaningful addition to D1.2 “Requirements and system architecture and interfaces for software modules”, where already a first list of requirements regarding safety, security, ethical, legal and liability issues was collected by all interACT partners.

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2. Expert interviews on safety, security, ethical, liability and legal aspects

Based on general requirements collected in WP 1 and documented in D1.2, the interACT partners got an overview about safety, security, ethical, liability and legal aspects in an early phase of the project. At the end of the project period, the partners deepen important requirements by involving external experts in the project through interviews.

The form of the expert interview was chosen in order to illustrate to the reader, which core questions are currently at stake and in what form these need to be answered now and in future. Legal, safety, liability, ethical and security aspects play an essential role in the introduction and distribution of automated vehicles in a historically grown infrastructure.

2.1 Legislation

As already described, interACT dealt with the "Design of cooperative interaction of AVs with other human road users (HRUs) in mixed traffic environments". In the course of the project the partners (especially in WP4) developed two different potential interaction strategies of an AV as well as human machine interface (HMI) designs, which serve as a benchmark for the development of future AVs. During the development of the external HMI (eHMI) components, the consortium partners made various decisions that seemed to be reasonable and correct for the implementation of the strategies and designs, but which are partly not in accordance with existing ECE regulations on signal functions of manually driven vehicles. Thus, a light colour was chosen, and installation spaces were developed that are currently not intended for exterior vehicle lighting functions. Figure 1 gives an impression how a vehicle can look like by using the interACT eHMI solutions.

Figure 1: Novel eHMI for interACT AVs – 360° Light Band (left) and Directed Signal Lamp (right).

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Important questions regarding legal aspects of 'Novel eHMI for AV on public roads' were discussed between interACT project partner *Marc Kaup (HELLA)* and the external expert *Helmut Tiesler-Wittig (Lumileds)*. Mr. Tiesler-Wittig is an employee of the TIER2 supplier *Lumileds* and has been deeply rooted in the automotive lighting industry for more than 30 years. He is also an active part of various forums (GTB, SAE, CLEPA, LightSightSafety, …) dealing with technical and legal aspects of new lighting functions. Having a degree in Optics, he works on the technical side of automotive lighting in different roles from engineering to application. Since 1992 he is involved in expert panels to contribute to technical regulations and standards.

Marc Kaup (HELLA): Helmut, why do we even deal with the topic 'Novel eHMI for Automated Vehicles in mixed traffic'? What are possible benefits?

Helmut Tiesler-Wittig (Lumileds): It can be assumed that with the introduction of automated vehicles on public roads this "mixed traffic" can last for a very long time. Calculations consider this to be dominant for more than 20 years, and then with a smaller portion still there will be non-communicating vehicles on road. In principle, the introduction of automated vehicles is intended to increase traffic safety. However, increasing trust and acceptance in a foreign technology as well as increasing traffic flow also play a decisive role. Here, a human-machine-interaction instead of a human-human-interaction or as a meaningful supplement can make a decisive contribution. It is only logical that light acts as a medium for the transfer of such messages. Light signals in and on the vehicle are known, internationally established and understandable. And even if they should not be intuitive, they are always simple, clear and learnable.

Marc: Who is currently dealing with the legal aspects of light-based HMI for AVs? Which results are included in which form in the discussion within which committees?

Helmut: Basically, this is an interdisciplinary topic, which automotive manufacturers, suppliers and academic partners deal with equally – e.g. in joint funding projects. This is extremely important. There are also international circles. It is not only in the USA (SAE, NHTSA) that people are talking to politicians and regulators; international discussions are also underway in Geneva. The experts who work in an advisory capacity to the UNECE have compiled a collection of data and an overview of existing studies - freely accessible - within the framework of the GRE Task Force.

Link: *https://wiki.unece.org/pages/viewpage.action?pageId=73925596*

In the event that the regulators take a decision to discuss legal framework conditions, the lighting engineers are prepared to make a contribution to the safe and smooth introduction of automated vehicles in mixed traffic.

Marc: If 'Novel eHMI for AV' in the context of R&D activities is generally considered beneficial, what will be changed in terms of eligibility, regulations and legislation?

Helmut: First of all, it is not yet clear to all parties involved that an additional eHMI is better than no eHMI at all - any concrete results from studies therefore continue to help. Furthermore, the exchange

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between individual committees must be maintained and improved. Regardless of this, the GTB Working Group on Signal Lighting (WGSL) has made recommendations to the UNECE on how an additional eHMI device could look like. Not only Europe, but also ECE affiliated countries like Japan are in the same boat. In addition, there is a constant, comprehensive exchange with the American SAE. The recommendations already include minimum and maximum light intensities to ensure visibility both day and night. The light colour is practically fixed. The range between blue and green has proven to be appropriate on the basis of studies and restrictions already in force. It is good to see that interACT supports this thrust. In addition, with regard to mounting positions, there is only the recommendation that the device should be positioned centrally on the vehicle and that the front and rear should be fitted primarily. Furthermore, the light-emitting surface has not yet been regulated. Here, the vehicle manufacturer should initially be granted a certain degree of leeway, particularly depending on the vehicle type.

Marc: These recommendations or guidelines currently refer primarily to a Vehicle Automation Status (VAS) Lamp, i.e. an eHMI that merely and permanently sends the message 'AV is in automated mode'. So GTB and SAE are primarily concerned only with this?

Helmut: Both SAE and GTB are technical expert bodies. Since the use of a light signal fundamentally creates continuity, as mentioned above, vehicles have been transmitting information via light for 100 years, these experts have told themselves that it makes sense to be prepared. For this reason, the technical framework conditions have first been discussed in these committees in the event that the legislators decide ad hoc that an additional signal must be sent by an AV. However, the VAS display is only the starting point. We must not sit back. We must take the next steps together to continuously improve human-machine interaction. There is always a need for communication of drivers today and AVs tomorrow.

Marc: However, to stay briefly with the VAS display or Marker Lamp (SAE term): Can such an indicator really help to increase the trust & acceptance mentioned at the beginning or is the opposite to be feared, because the message 'Be aware of me, I am an automated vehicle' is implicitly sent?

Helmut: I refer to the VAS display as "relaxation lamp". I can be relatively sure that when I see a vehicle marked in this way, it will behave in accordance with the rules. But again, we have to continue working on the topic of what can be communicated beyond that or instead of that in a meaningful way on the part of the AV via eHMI. interACT makes an important contribution here, but it goes on.

We thank Helmut Tiesler-Wittig for this interesting interview and his opinions on novel eHMI elements for AV on public roads.

2.2 Safety & Liability

Safety is an important goal within the interACT project. The developed autonomous driving functions in WP 3 are supported by a safety layer. This layer takes care of ensuring that the execution of planned

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motions does not results in collisions with other traffic participants (more details can be found in deliverable D3.2). More specifically, the proposed safety approach in interACT guarantees that autonomous vehicles do not cause collisions with respect to all feasible and legal future motions of other traffic participants. Thus, the proposed approach also addresses liability issues, since collisions are only possible if other traffic participants violate traffic rules. To discuss current safe motion planning and the impact of the proposed safety concept, the interACT partner *Christian Pek (Technical University of Munich, Informatics)* interviewed the postdoctoral researcher and group leader *Dr. Johannes Betz* from the *Chair of Automotive Technology at the Technical University of Munich*. Dr. Betz does research in motion planning and control for autonomous vehicles, which also covers various safety aspects.

Christian Pek (TUM, Informatics): What are the safety challenges for autonomous vehicles?

Dr. Johannes Betz (TUM, Automotive technology): Overall, safety means ensuring that the AV is doing everything that I as a driver am supposed to do correctly based on its algorithms (differences between level 3, level 4, level 5). Firstly, there are currently no holistic tests that can ensure, that the autonomous driving algorithms are doing correct calculations. Secondly, there are different approaches to ensure internally within the algorithms, that they are using a correct input and create a correct output. To date it is unclear what the correct approach is. Thirdly, by using Deep Learning algorithms there are currently no processes and approaches to ensure that the outcome of those algorithms is correct. On a high level, the safety challenges for autonomous driving are still the correct perception of the environment and the motion planning of the vehicle.

Christian: Why is safe motion planning such a difficult problem?

Dr. Betz: First of all, planning of the path and behaviour (= motion) is a complex task where a lot of things have to be taken into account. You have to perceive information of the environment on an accurate level first, then you need to have a good idea how other traffic participants might behave in the next seconds (prediction). When you think you might have done a good job there, then you have to search in a short time and in an efficient way the path where your car should drive. In addition, you have to ensure that the motion you have planned is secure and safe. Therefore, planning the motion of an autonomous vehicle is very complex.

Christian: How should safety be addressed in the development of autonomous vehicles?

Dr. Betz: Safety has to be addressed on different levels. First of all, on a low algorithm level (e.g., interval test of input and output data, plausibility checks through models or comparison of different data sources). Secondly, on a high-level algorithm (e.g. external monitoring devices like a watchdog, independent redundancies with different software structures). Thirdly, on process level by testing a specific number of selected scenarios, either in the simulation or at real testing.

Christian: Are large research projects necessary to solve the safety challenges?

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Dr. Betz: Yes, I think so. When it comes to safety in autonomous driving we need interdisciplinary projects with different knowledge from different areas e.g. computer science and mechanical engineering. Large projects can help to overcome these challenges by bundling the knowledge.

Christian: Do you think that safety can only be solved in an interdisciplinary fashion?

Dr. Betz: Yes.

Christian: Do the proposed safety concepts in interACT solve any of these challenges?

Dr. Betz: Yes, the concepts from interACT can solve these addressed challenges. These algorithms made it possible to secure planned manoeuvres at runtime. In this case, the safety is formally verified by means of reachability analysis instead of estimating the probability of accidents as in previous work. The above-mentioned prediction can be done in a set-based prediction. This quickly limits the drivable range of your own vehicle; short planning horizons must be selected to ensure that you always achieve a safe condition. Therefore, the approach of fail-safe manoeuvres helps to secure a final safe path of the vehicles.

Christian: How much impact will interACT generate on ensuring the safety of autonomous vehicles?

Dr. Betz: From my point of view the research from interACT can impact the development of safety for autonomous driving a lot. This research is more or less the baseline for further enhancements, e.g., the integration of traffic rules and algorithm improvements.

Christian: What is missing to realize a common safety standard in the industry?

Dr. Betz: I am not sure if everyone is interested in reaching a common safety standard. The current safeguarding processes at the OEMs are developed by them only and ensure that the vehicle behaves like they developed it. The processes for securing these standards has spread and where adopted by others. I am not 100% sure, if there needs to be a common standard, because there are different opinions on WHEN a safe standard is reached.

We thank Dr. Johannes Betz for this interesting interview and his opinions on current safety challenges for autonomous vehicles.

2.3 Ethics & Liability

The automated driving functions developed within interACT will require the perception of the AV's surrounding, identify corresponding situations and make decisions based on the information it acquired. Additionally, the communication interface in the form of eHMIs will enable interaction with other road users. Therefore, the interACT technologies aim to ultimately affect other road users. To ensure the ethical acceptability of the developed technologies, the interACT partner *André Dietrich (Technical University of Munich, Chair of Ergonomics)* interviewed the research associate *Antonio Bikić* from the *Munich Center for Ethics* at the *Ludwig Maximilian University of Munich* using the web

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conference tool Zoom. Antonio Bikić studied philosophy and computational linguistics/computer science. His research is focussed on ethics of artificial intelligence, especially in the context of autonomous vehicles.

André Dietrich (TUM, Ergonomics): Antonio Bikić, you are active in the field of ethics and automated systems. What is your research topic and why do you think that ethics will play a key role in automation?

Antonio Bikić (LMU, Munich Center for Ethics): My research focus is ethics in automated systems. More specifically, I am researching which influences semantics has on decision-making and problem solving processes. Generally, a behaviouristic thought model is utilized, therefore no semantics. One of my main questions is how to generate behaviour that is interpretable as ethical and intelligent by humans. Is it necessary that a machine understands an underlying problem (semantics) or is a syntax sufficient? A well-known example to this problem is the Chinese Room Argument, which – put simply – I am applying to automated vehicles.

André: Why is Ethics important?

Antonio: Humans expect natural persons in all ethically informed decisions. Machines increasingly replace this. Can we give these systems responsibility, and if yes – to whom and how? Which ethical model should a machine follow?

André: What are – in your opinion – the biggest ethical challenges for automated driving in urban environments currently?

Antonio: The biggest challenges in my point of view are liability, intercultural differences and the incentivisation of other road users. Liability deals with the question of accountability when problems occur. Possibilities are the on-board user, the OEM branding the vehicle, the supplier providing the automation or the individual contractor writing the code – each of which comes with its own advantages and disadvantages. Intercultural differences pose a challenge, but also local differences in traffic within a country, especially when comparing urban traffic between cities. The third challenge is the incentivisation (or nudging) of other road users. How do we deal with AVs incentivising other road users to a specific behaviour? It could be that by trying to act correctly, AVs might be harmful for traffic as a whole.

André: Where does automated driving stand currently in regards to ethics? Who is currently dealing with ethical aspects of automated driving?

Antonio: Especially dilemmas are researched by philosophers, jurists and ethic commissions, however there is no jurisdiction on these situations. In general there are many projects around the world dealing with ethics in automated driving, however most of them are dealing with dilemmas. There are many more moral conflict situations, which are no dilemmas. Imagine a motorcycle cutting into the lane of the AV on a highway. The AV needs to brake but could potentially endanger the driver or vehicle behind. These situations can become critical but are no dilemmas, as you can construct a "good" outcome.

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We are currently at the beginning of ethical research within the automotive industry and are establishing the understanding to differentiate between ethics and law.

André: Are there efforts for standardization to ensure an ethical approach of introducing AVs? Are there guidelines or code of conducts for developers and/or OEMs?

Antonio: There are some standardization efforts, as natural persons are affected by AVs. These range from the European Union to standardization bodies such as DIN and ISO. As acceptance of automated driving is key for this technology to be successful, developers and OEMs show an increasing willingness to deal with ethical questions in regards to automated driving.

André: interACT aims to introduce novel HMI elements to communicate with unequipped road users. Do you think this will ensure that vulnerable road users are able to correctly understand the vehicle's intention?

Antonio: In principle, yes. The communication capability of AVs is very sensible, as not all situations will be resolved by anticipatory driving. The problem however is the conveyed message and its coding – especially considering intercultural differences. The AV needs to sense, whether the addressee perceived and understands the transmitted message to react appropriately. In general, eHMIs as a tool for AVs to interact with other road users is definitely a step into the right direction.

André: The majority of our studies find positive effects of eHMIs in regards to time savings and subjective perception. However, some of our studies indicate that eHMIs could be misunderstood or overly relied upon, leading to potentially unsafe situations. How would you approach these benefit vs disadvantage problems?

Antonio: This is a very ethical question. There are various ethical systems of which I will present two common ones. In Utilitarianism or Consequentialism, the overall effect is considered: if an action for example has positive consequences for 90% of the population but not for the other 10% yielding a total increase of the common weal, then it could be okay to limit the rights of those 10%, even without asking them. In Deontological Ethics, fundamental rights of every individual need to be respected. This means that even if 90% would profit from an action, one cannot limit the rights of the other 10%. Therefore, the big question at hand is, which of the (many more) ethical systems are deemed to be correct for approving AVs and the eHMIs.

In general, the acceptable residual risk introduced by AVs needs to be thoroughly studied and minimized. Leaving our houses, we agree to face hazards from the world outside. If this risk decreases with the introduction of AVs, we could argue that the residual risk is reduced and therefore the introduction of AVs into traffic is ethically feasible. If the risk increases, we should question the use of this technology altogether.

André: One work package of interACT dealt with the development of automation algorithms of the vehicles. One part of that was the Safety Layer, which was proven to minimize collision risks. However, some of the studies dealing with eHMIs showed that while there were increases in efficiency in

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interactions, new risks in the form of miscommunication were introduced. Should both systems be evaluated individually or would you suggest to look at the complete vehicle?

Antonio: Generally, the entire system should be evaluated. If however, a subsystem worsens the overall system, the best approach would be to identify the situations in which problematic decisions can be made by the automation and avoid these situations or hand back control to the on board user. In this specific case, you would want to identify the situations, in which communication can be misunderstood and not communicate in these situations.

André: Our traffic observations have shown that human drivers often bend the rules to get forward (e.g. inching into a busy and congested intersection) or to adapt to uncommon situations (e.g. overtaking a delivery van, parked illegally). Should an automated vehicle be allowed to mimic this behaviour and thus be allowed to break rules in situations humans would normally too?

Antonio: From the perspective of the precautionary principle the correct answer would be: No. Even if mimicking human behaviour seems feasible, for automated vehicles to function properly in traffic, existing rules need to be adjusted. If "illegal" behaviour by AVs is allowed, other road users cannot predict, how this vehicle will behave in specific situations. In favour of whom would the vehicle base its decision on – the on board user or other traffic participants? AVs breaking rules to advance in traffic contradicts the precautionary principle, which is statutory in the European Union. Minimizing risks by AVs is not possible if we allow rules to be broken. Therefore, if existing rules lead to complications, which human road users resolve by breaking them, these rules need to be adjusted or extended to cover these situations. Exemptions need to be formalized in detail so that automated vehicles can deal correctly with as many situations as possible.

André: This would mean a human driver or (e.g.) tele-operator would need to intervene in this situation, right? However, this could potentially cost time (esp. in Level 5 autonomous driving) – wouldn't a stopping vehicle be an additional obstruction and possibly safety issue for traffic?

Antonio: The underlying question is, whether a stopping AV would create more problems. However, without a legal basis the automation would need to break rules to sensibly resolve the situation. The issue is that we cannot gauge how many rules need to be broken until the vehicle returns to a rule compliant state. In the worst case, the vehicle would manoeuvre from one "bad" condition to the next one. For the on-board user it would be very hard to take responsibility in these situations, as he/she would not know, how the vehicle would react in these situations. If situations that require a bending of the rules occur often, than the rules need to be adjusted with thoroughly detailed exemptions.

André: Many automated systems that need to interact with humans rely on complex sensing and recognition technologies. Some of them process personal data, e.g. in computer vision algorithms. Until which extent would you argue that this is unavoidable for progress? Should an AV base its decision-making e.g. on the perceived ethnical background of the interaction partner?

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Antonio: Let us assume that 50% of all road users lived their whole life in one environment and 50% did not – regardless of their characteristic attributes. How can we know, who lives here and who is a visiting tourist? Is this technology still beneficial, considering the potential drawbacks? The real question that needs to be asked is which information is necessary for the AV for its decision-making – should the automation make use of characteristic attributes such as skin and hair colour? The German constitution states that humans cannot be discriminated based on their appearance – this should also apply to algorithms. The bigger question at hand is how the information is used. For example, using the skin colour to determine, whether a road user might understand the AVs communicated message, might lead to discrimination, as the interacting person might falsely be identified as someone who does not.

André: What about age? One could argue that decelerate for an elderly person with a walking aid in comparison to a young jogger might be beneficial, as the jogger might be able to utilize smaller gaps in traffic. We as drivers utilize visual information of the other road users' appearance; shouldn't the AV do that too?

Antonio: Nobody should be discriminated in regards to age, sex or ethnicity. The question is, if yielding to an elderly person is discriminating. This is an example for positive discrimination, which was a big discussion point in the dilemma scenarios. In your described situation, there is certainly a benefit to yield. However, the automation might develop a bias towards elderly people by e.g. drive slowly whenever encountering an older road user, which in turn could discriminate healthy and active elder people.

André: Regarding the data an AV acquires – sharing information with other automated vehicles or even central systems can be very beneficial to enhance mobility. Are there ethical concerns regarding the sharing of information?

Antonio: The cleanest approach would be, if the AV uses the acquired data to base its decision on and deletes it afterwards. Transferring information to other AVs can be beneficial, but different types of information have different time horizons. Ethically there is no problem, if generic information, e.g. of a broken down vehicle, its colour and brand, is shared with other AVs. However, this information should be kept up to date, as AVs could make bad decisions when using obsolete information. However, sharing and storing data centrally is problematic, as many different persons might have access to that information and could potentially use it in not-intended ways, leading to privacy issues.

André: Therefore, transferring and storing information, such as images of faces or vehicles, centrally to train recognition algorithms is an issue?

Antonio: This is a complicated matter. If data is needed for training, informing other road users that there is a vehicle recording should be a priority. However, apart from ethics: If the public is told that they are recorded in order to enable automated driving, then this would certainly lower the general acceptance towards AVs. Which risks and biases could come from that? This is a question, which needs to be examined.

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André: Is interACT on the right track trying to generate a holistic understanding of AVs in all possible regards or do you think it is too early for this? Is Ethics this a topic that should be addressed today even before the technology exists?

Antonio: Yes, definitely. Research ethics is an important step for research projects. Projects should define boundaries based on research ethics and begin to develop technology afterwards. Of course, your project is close to the end, but the development of urban automated driving is still ongoing therefore now is a good time for the holistic approach combining liability, safety and ethical aspects with the technological development.

We thank Antonio Bikić for the informative interview and his insights to ethical challenges in automated driving.

2.4 Security

At the end of the expert interview series, interACT project partner Johannes Rünz (BOSCH) discussed several things with regard to security issues with Jürgen Klarmann, who is working at *Robert Bosch GmbH* since 2002. He is leading the Center of Competence Security of the business unit Chassis Systems Control.

Johannes Rünz (BOSCH): Let’s start with the first question, what is security and is there a special need in the context of automated driving?

Jürgen Klarmann (Robert Bosch GmbH): It might be best to narrow down security to an operation in the detection and mitigation of attacks. Security is the protection of systems from threats to hardware, software, as well as to the services they provide. Security impacts concern in general safety, financial, operational and privacy as well as legal aspects. Safety impacts as damage, disruption or misdirection are of particular interest in the context of automated driving. In comparison to non-automated vehicles, the challenges are the connectivity inside automated vehicles and especially new safety requirements on availability. Furthermore, security issues in automated mostly lead to safety implications and therefore have to be prevented.

Johannes: This is a bit abstract, what are conceivable attacks in security context and what are the common strategies to prohibit these attacks?

Jürgen: Usually, attackers aim at manipulating the input or the components to disrupt the system or compromise it in some other way. Securing systems against cyberattacks typically involves three security objectives, the so-called CIA Triad. The “C” stands for Confidentiality and refers to cryptographic methods ensuring that the information is only available to those who are authorized for it. These methods can also be used to protect personal data. The “I” stands for Integrity and refers to cryptographic techniques that allow to detect data manipulation by unauthorized parties. In this context, this also includes authentication which can be subdivided into entity authentication and data

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origin authentication. Entity authentication refers to methods for establishing the identity of the communicating parties in a cryptographically secure manner. In contrast, data origin authentication refers to methods for verifying whether a received message was sent by the legitimate party. The last letter “A” stands for Availability. Availability means that data of an information supplier is accessible timely reliable for other components. The data availability is a particular challenge in the context of automated driving, due to new requirements on availability, which are very challenging.

Johannes: You have said that especially the safety of traffic participants is an interest, is there an overlap between safety and security issues?

Jürgen: Yes, there is a link between safety and security. Both safety and security issues can lead to similar system failures. The underlying reasons, however, are very different. Failures caused by safety issues result from either systematic or random errors like permanent or temporal malfunction of some parts of the electronic equipment. In contrast, failures caused by security issues results from deliberate manipulations performed by an active attacker. Therefore, in security we always faced with an intelligent opponent who tries to sidestep the protections. The problem is that security issues in automated vehicles can lead to safety implications. As a result, a connected vehicle with distributed subcomponents must be secure against cyberattacks in order to fulfil the safety requirements.

Johannes: What does that mean regarding the prevention of the error patterns?

Jürgen: Safety issues are prevented by reducing the risk, this means that the probability of occurrence of harm and the severity of that harm are evaluated and minimized by special strategy. For example, messages on a bus are protected with a checksum, so that it is protected against failures on the physical transmission channel with a very high probability. In contrast, security issues are caused by an intelligent attacker who wants to manipulate the system. Security therefore cannot rely on stochastic methods in the same manner as safety does. Security uses cryptographic methods with secrets which have to be hidden from attackers. Furthermore, the information should be accessible with low computational effort if the secret is known.

Johannes: You said that in safety manner, the protection is for example a checksum. What could be a solution in security manner?

Jürgen: In this specific example, to ensure security we have to provide integrity and authentication, which means entity authentication as well as data origin authentication. In the security context in this example, we are not working with security simple CRC codes but with Message Authentication Codes (MACs) which provide integrity, authentication and are able to detect bit errors during the transmission. MACs are based on secrets and are computationally infeasible to fake without the knowledge of the corresponding secrets. One special issue in this context are so-called replay attacks where the adversary first eavesdrops on the legitimate communication to collect the messages exchanged by the legitimate parties, and later on replays the messages – possibly in a different order – to manipulate the system. To prevent such attacks, MACs may be used that incorporate counters or timestamps.

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Johannes: What is the motivation of system attackers in the context of automated driving?

Jürgen: Several motivations are perceivable. Up to now, one main motivation is the control over the automated driving vehicle. These attacks are typically carried out by security researcher, whose main motivation is to publish their work, thereby gaining popularity and status within their respective research community. The second large group of attacks on automotive systems is motivated by monetary gains, e.g., like with chip tuning. Finally, the most severe attack class to deal with are attacks aiming to inflict damage to the passengers of the car or other traffic participants.

Johannes: In the interACT project we developed new exterior HMI elements to interact with other traffic participants, like pedestrians and or other manually driven vehicles. Is this also interesting in the context of security?

Jürgen: Yes of course, developers who want to get publicity and because of that, lightning systems can be an interesting target for attackers. Furthermore, exterior HMI is also safety relevant as it influences the behavior of other traffic participants. Thus, under no circumstances should such a system be attacked, so every interface in the chain to the exterior HMI should ensure data integrity, entity authentication and data origin authentication.

Johannes: One minor topic in the interACT project is the usage of pedestrians' mobile phone localization through GNSS as an additional sensor to improve the situation assessment of the automated vehicle. Is that from the security perspective a challenge?

Jürgen: We have to split this into three sub problems: First, there are the sensors, which can be target of jamming and spoofing attacks. Jamming means that the sensor is blind, which leads to that in the case of GNSS the received signal is overloaded with a signal transmitted by the attackers. Spoofing attacks are more complex and the attackers provide a signal, which leads to a fake position measurement in the mobile phone. These attacks have to be detected to provide data integrity by the system.

The second security issue is the data processing in the smartphone. It must be nearly impossible to manipulate the signal processing chain including the interface to the wireless transmission channel. The data integrity must be maintained in the smartphone.

The third problem is the communication channel. Here we have to ensure the whole CIA Triade. In addition, it is important to ensure non-repudiation. This means that the smartphone is not able to deny previous messages if the information is also safety relevant.

For a direct communication between traffic participants, the standard IEEE 802.11p was developed which ensures the requirements on the wireless communication channel.

We thank Jürgen Klarmann for this interesting interview and his opinions on security issues.

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3. ISO Workshop

3.1 Introduction

An interACT specific workshop within the half-yearly ISO Meetings of ISO/TC22/SC 39 was organized in cooperation with members from the ISO. The aim of the workshop was to present the results of interACT and contribute to discussions on further standards of the ISO group. While the planned physical meeting had to be cancelled due to the COVID-19 crisis, the workshop was moved online using a web-conference tool. As conducting physical workshops with audience-participation (comparable to the one hosted in Vienna (see D6.1)) is cumbersome online and can deter listeners, a conference like format was chosen. Results from interACT along with two additional topics from the field (see below) were presented in 15 minutes presentations followed up by 10 minutes discussions. Prof. Klaus Bengler (TUM, Chair of Ergonomics) moderated the online event and concluded the workshop with a joint discussion on the presented findings. The online event took place on the 20th of April 2020 from 12:00 to 5:00 p.m.

Table: List of presentations and their abstracts from the interACT – ISO Workshop.

Presenter	Title and Abstract
Anna Schieben (DLR)	**interACT project overview**
André Dietrich (TUM)	**The role of AV Motion and Communication** Understanding current traffic interactions might help to identify what road users need to interact with AVs in the future. Results from field observations, simulator experiments and test track studies conducted within interACT are presented. Sequence diagrams are introduced as a tool to describe observed interactions across different scenarios.

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Florian Weber (BMW)	**Interaction strategies and eHMI designs of the interACT project** interACT's HMI-concepts were developed in a user centered design process taking into account human interaction strategies derived from observational studies and developing and improving eHMI design in an iterative way incorporating user feedback. Further development focused on technical components for visual transfer of messages, i.e. the technical implementation of new light-based exterior components for the AV (eHMI). Final outputs are prototypes, which provide a visual communication system around the whole vehicle for communication with other traffic participants. In detail: Two eHMI technologies were selected, developed, implemented and integrated – a 360° LED Light Band and a so-called Directed Signal Lamp. These devices put the project into a position to implement an intention based or perception based interaction strategy or a combination of both.
Andreas Keinath (BMW)	**A methodological approach to determine the benefits of external HMI during interactions between cyclists and automated vehicles: A bicycle simulator study** To ensure safe interactions between automated vehicles and non-automated road users in mixed traffic environments, recent studies have focused on external human-machine interfaces (eHMI) as a communication interface of automated vehicles. Most studies focused on the research question which kind of eHMI can support this interaction. However, the fundamental question if an eHMI is useful to support interactions with automated vehicles has been largely neglected. The present study provides a methodological approach to examine potential benefits of eHMIs in supporting other road users during interactions with automated vehicles. In a bicycle simulator study, 20 participants encountered different interaction scenarios with an automated vehicle that either had the manoeuver intention to brake or to continue driving. During dynamically evolving situations, we measured their behaviour during interactions with and without eHMI. Additionally, the comprehensibility of the eHMI was measured with a special occlusion method. The results revealed that the eHMI led to more effective and efficient behaviour of the cyclists when the automated vehicle braked. However, the eHMI provoked safety-critical behaviour during three interactions when the vehicle continued driving. The set-up, experimental design, and behavioural and comprehension measurements can be evaluated as useful method to evaluate the benefits of any given eHMI.
Emanuel Souse (CCG)	**The role of visual and auditory cues in pedestrians' crossing decision** When crossing a street, pedestrians must evaluate the motion of approaching vehicles and make a potentially critical decision of whether to cross or not. Understanding the decision-making process is crucial to increase pedestrians' safety. Here we report on a study with real subjects, using a CAVE-like virtual environment, in which we simulated middle-street crossing situations. We manipulated the speed pattern of the approaching vehicle (visual cue) as well as the resulting sound (auditory cue) and observed the effect on subjects' decision-making. Results point to a predominance of visual cues in the decision process, and a continuum in risk-taking behaviour.

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Presenter	Title and Abstract
Marc Wilbrink (DLR)	**Selection of test scenarios** This presentation illustrates the selection process for use cases and scenarios in interACT. A framework for use case and scenario description will be shown. The interACT use cases and scenarios have been selected using a stepwise process of intensive discussions within the consortium. Starting with some open brain-storming discussions the use cases were aggregated and rated by the partners against several criteria (such as relevance for safety, need for interaction behaviour etc.). Four "must-have" use cases of highest relevance were defined. These use cases are covered in all technical WPs and also evaluated and demonstrated in the interACT project.
Yee Mun Lee (ITS Leeds)	**Selection of evaluation criteria and methodologies** This talk provides an overview of the methodologies used in interACT to evaluate the communication solutions developed in the project, along with outlining some of the key findings obtained. A set of evaluation criteria were identified to assess the impact of external and internal HMIs and demonstrator vehicle movement patterns on AV interactions with other road users, with an emphasis on exploring both the individual and societal impacts of these solutions. Studies were conducted using HMDs, pedestrian and driving simulators, test-tracks and real world environments, with results providing insights into how the interACT communication solutions might facilitate interactions with human road users.
Gustav Markkula (ITS Leeds)	**Conceptual frameworks and quantitative models of human-AV interactions** The first part of this presentation introduces a conceptual framework for understanding and describing road traffic interactions, providing stringent definitions for a number of pre-existing and new terms which may be useful in this standardisation context, such as: "space-sharing conflict", "interactive behaviour", "interaction", and a taxonomy of different types of behaviour that road users exhibit in interactions. The second part explains how quantitative models of road-crossing behaviour can be used to estimate the impact of different AV interaction designs in such situations. These methods, and the impact metrics that can be obtained from them, may also be of interest to ISO.

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3.2 Results

While the online nature prohibited in depth exchanges between the workshop participants, it enabled a higher number of participants: up to 67 participants were attending the online event globally.

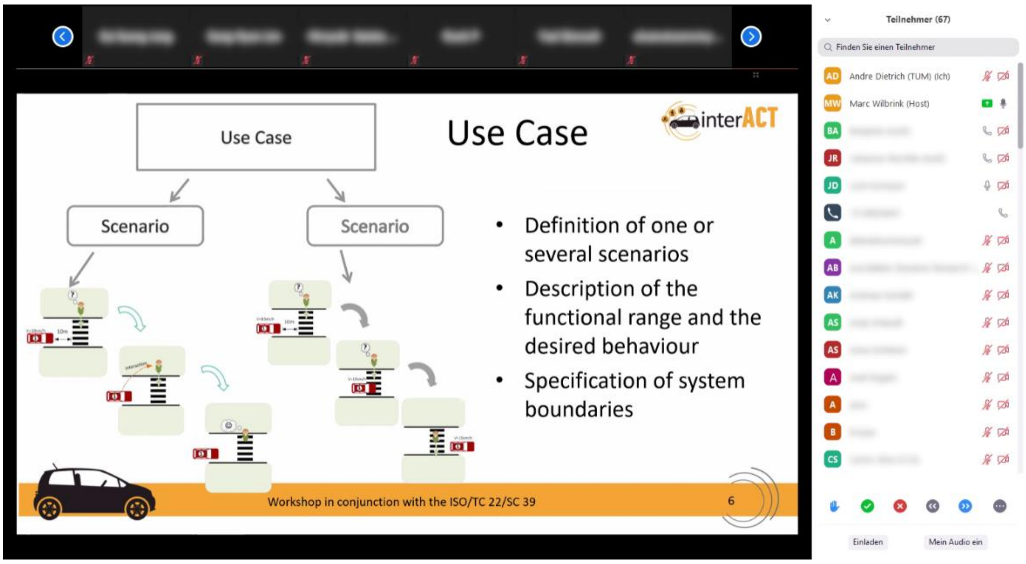

Figure 2: Screenshot of Marc Wilbrink's presentation on the selection of test scenarios

At the end of the workshop, all findings and discussion topics were summarized by Prof. Klaus Bengler and categorized for their use in current and future ISO activities. The following categories were chosen:

- Notes / Discussion: Interesting or novel contents from the presentation or discussion not fitting into the other categories.
- Informative / Reference: Topics supporting existing ISO work items, including drafts.
- Revision of Documents: Contents that are valuable for the revision of an existing document.
- New Activities: Any content or topic that should be considered as an input for future standardization activities

Mainly, the interACT results supported current draft versions and provided further references, data and details. Bilateral exchanges between presenters and experts from the ISO were confirmed. Two potential topics for new working items were identified: the utilization of Wizard of Oz methodology for testing eHMI and the model-based evaluation of eHMIs.

Meeting minutes of the event were stored as an ISO N-document (ISO report N-357, Issue Date 2020-05-11, ISO/TC 22/SC 39/WG 8).

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4. Summary

To complete Work Package 1 in general, and Task 1.4 in particular, this deliverable presents the results of four expert interviews and one workshop within the ISO meeting regarding the integration of AVs into mixed traffic conditions, focusing on safety, security, ethical, liability and legal aspects, issues and challenges. The key facts are summarised below.

Safety

- Motion planning is a challenge, as many variables need to be considered in real time to ensure a safe manoeuvre at all times.
- No holistic tests currently exist that prove that AVs do the correct calculations.
- interACT formally verifies its manoeuvres by the means of reachability analysis. The research that interACT has conducted on the safety layer will serve as a baseline for further projects.

Security

- Security is the protection of systems from threat to the hardware, software and services they provide. The special challenges are the connectivity inside automated vehicles and especially new safety requirements on availability.
- Securing systems against cyberattacks typically involves three cryptographic goals, the so-called CIA Triad – Confidentiality, Integrity, Availability.
- Several components of the AV need to be protected, e.g. an eHMI. External Human-Machine Interaction is safety relevant as it influences the behaviour of other traffic participants. Thus, under no circumstances such a system should be attacked. Every interface in the chain has to ensure data integrity, entity authentication and data origin authentication.

Ethics

- Dilemmas are only one part of ethics (maybe neither the most relevant) in highly automated driving; many moral conflict situations in traffic are more common and need thorough examination in the future to ensure that AVs follow ethical guidelines.
- eHMI solutions are a good way to enable communication with other road users, especially if a situation cannot be resolved by anticipatory driving.
- The residual risk for the whole public should be reduced with the inception of automated vehicles on urban roads. However, utilizing characteristic attributes of other road users to base an AV's decision upon needs to be treated very carefully to inhibit discrimination. Furthermore, the privacy concerns of other road users need to be respected to ensure trust.

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Liability

- There are many possible entities that may assume accountability in case of problems with the AV. New legislation is necessary to ensure that these problems are covered, as the machine itself cannot be accountable.
- Road regulations need to be adjusted and specified so that AVs – which should be rule-compliant – can resolve situations, which humans currently resolve by breaking the rules.

Legislation (with focus on novel eHMI components)

- Increasing trust and acceptance in a foreign technology by novel eHMI components will play a decisive role.
- Light signals in and on the vehicle are known, internationally established and understandable. And even if they should not be intuitive, they are always simple, clear and learnable.
- ECE and SAE recommendations or guidelines currently refer primarily to a VAS Lamp. However, the VAS display is only the starting point, with the need to improve human-machine interaction continuously.

The ISO Workshop showed that the interACT topics are in line with current standardization efforts and serve as input for existing and future documents.

This deliverable is the successful conclusion of WP 1. It shows how interACT contributes to the discussion regarding automated vehicles, in particular about the aspects of safety, security, ethics, liability and law.

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Designing cooperative interaction of automated vehicles with other road users in mixed traffic environments