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CARTRE
Coordination of Automated Road Transport Deployment for Europe

Brussels, Tuesday, 30 October 2018

Position Paper on In-Vehicle Enablers

Summary

This document focuses on in-vehicle enablers. Automated driving will change the vehicle and expand the vehicle system towards network and backend layer. In-vehicle technology enablers have to be considered highly relevant to achieve the transformation of digitalization and connectivity within increasing safety margins and within a cost frame - able to pave market introduction.

Main technological challenges:

- Transfer of responsibility and decision-making from the driver to the vehicle (fail operational ability today typically implemented by redundancies)
- Significant performance and reliability increase for perception (sensors) and cognition (computing power) including the use of powerful CE-HW (e.g. for computing) and the necessary automotive-adaption for safety as well as the synchronization of automotive lifecycles with the much shorter EC-lifecycles.
- Expansion of the vehicle system towards network and backend layer enabled by data driven cloud services and cellular 5G/LTE-V connectivity improvements. Many underlying systems as e.g. enhanced integrated safety system will also belong to the network and backend layer with all constrains and implications a safety system requires.

Main influencing challenges:

- The safety-margin and the verification/validation process (V/V) is still not defined. Regulations for V/V and methods have to be developed and harmonized within Europe and worldwide.
- Harmonization of interfaces of the "digital / connectivity" industry with the automotive industry have to be overcome and regulations need to be established.
- Cost since the technology has to be affordable without compromising on safety or efficiency

This report provides background and dependencies according to the given main challenges. The core of connected and automated driving, the automation technology itself, is explained and can be addressed in the respective Deliverables of WP5 (future research needs) and WP3 (know how network).

The original scope of this deliverable as in the description of action was very broad, covering the whole spectrum of technologies for automation ("Automation Enablers") in depth and at the same time the wide field of thematic areas around these technologies. Since WP 2.1 coordinates the position papers covering the thematic areas, they are not mentioned in this deliverable. Therefore, this report outlines main challenges and background for in-vehicle technology enablers of connected and automated driving. It touches other CARTRE themes, which have relation to in-vehicle technology enablers as e.g. the need for policy and regulation but always within the focus of the in-vehicle technology enablers, based upon analysis and expert estimations of different automotive stakeholders and scientific bodies. It gives direction to the work on future research needs, which is included in WP 5.1. Also, related outputs from already active R&I projects in this field are an important framework. They are summarized in Deliverable 3.1 and are not covered again in this Deliverable.

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Introduction

In-vehicle technology is the key enabler for connected and automated driving (CAD). The domain has been under rapid development during the last decades and vehicle properties and functionalities are increasingly realized in software, through complex in-vehicle electronic network connected to sensors and actuators. Advanced Driving Assistance Systems (ADAS) with the aim to warn and assist the driver are available in vehicles today, together with methods and tools for development, test and certification. Introduction of automation will build on these technologies, methods and tools.
Mobility automation towards SAE level 3 (refers to the SAE based standardization of automation levels for vehicles, beyond level 3 the driver is not directly responsible for the driving task) and higher is associated with three strong changes (also referred to as disruptive elements in this paper):

- **The physical change** – "driver acts no more"
- **The responsibility change** - "driver decides no more"
- **The vehicle change -** vehicle becomes part of the communication network; "vehicle talks to other vehicles, cloud, and infrastructure"

These changes impose three main challenges with strong consequences for in vehicle technology enablers:

- **Society expectations** like higher safety margins, ethic and mobility issues (e.g. traffic jam and pollution reduction) are imposed by the application of new technologies for which a consensus has to be established.
- **Costs / Complexity:**
  - Significant safety relevant system changes and extensions are required which can lead to a strongly divergent solution space of functional and technological combinations.
  - The fusion process of the digital/telecommunication world and the automotive world.
- **Time to market:** It has to be avoided that existing, lacking and different European regulations slow down development and deployment of automated driving in Europe.

The scope of this report is to reflect the influence of the changes and challenges to the in-vehicle technology enabler and assign recommendation.

1. *Overview of changes mapped on layer-structure*

This chapter gives a compact overview of the changes of the entire vehicle system, which is affected by high-level automation. At first, these changes are focused on three disruptive elements (a) physical change, (b) responsibility change, and (c) vehicle change. Each of these elements is analysed with respect to the impacts caused. Finally, six main systemic-changes are derived by these requirements. The idea of this break-down is to propose a path to structure future developments in the area of highly automated driving (HAD). The figure below shows an overview of the motivation chain of in-vehicle technology enablers concerning automated driving.

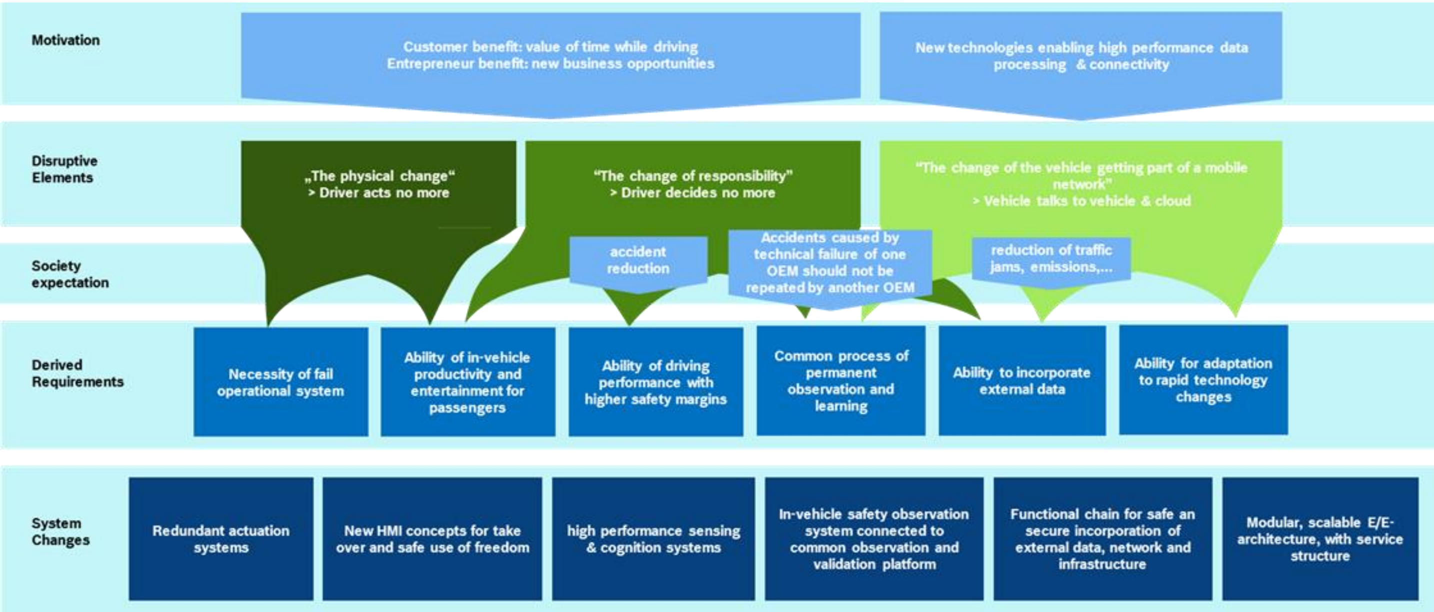

Figure 1 Overview of the motivation chain of in-vehicle technology enablers concerning automated driving

Motivation of automated driving

For the following observations, it is important not only to consider the influence of in-vehicle technology enablers on expectations and their underlying motivations but also to consider the influence of technology development and legal framework on in-vehicle technologies enablers.

Disruptive elements of automated driving

- The physical change:

The role of the driver as observer, sensor, decider and actuator switches to the vehicle, i.e. the driver is no more a backup for "fail-safe" functionalities.

Consequences: The driver cannot be considered a mechanical backup. The system design has to cover "fail operational" abilities. ("fail safe": driver has to back up the driving task, "fail operational": vehicle has to backup instantaneous the driving task; both modes can provide degraded functionality) The typical "fail operational" design of braking, steering and subsystems as e.g. the power-net needs additional measures compared to "fail safe" requirements. Interferences of different systems, e.g. with the power-net, leads to a considerable complexity and thus to an enormous solutions space.

- The responsibility change:

Transfer of decision-making from driver to vehicle. Changes, uncertainties and given risks of open world traffic originally handled by the driver are now to be handled by the vehicle itself, i.e. the "driver is no longer making decisions or taking actions (can also be referred to as driver responsibility)".

Consequences: product liability risks transfer to OEM (and its tier-1 suppliers) and together with higher safety expectations - driven by society expectations - result in a common and permanent observation and learning platform.

- The vehicle change:

The vehicle becomes part of multiple communication networks and cooperative systems, i.e. "vehicle talks to other vehicles (V2V), cloud, and infrastructure (V2x)".

Consequences: External mobility data will be part of driving functions including safety impacts. Vehicle subsystems impose needs for in- and external data exchange. The vehicle must be able to handle failing communication links reliably.

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Society expectations

- Increased safety and accidents reduction
- Reduction of emissions and energy consumption
- Improved traffic flow
- Increased convenience and the possibility to use driving time for something else
- Reduction of personal mobility costs and goods transport costs
- Offering individual mobility to handicapped/impaired persons
- Reduction of “business” costs (automated/driverless trucks, busses, utility vehicles, etc.)

Derived requirements

- Necessity of a fail-safe and secure operational system
- In-vehicle productivity, convenience and entertainment
- Improved driving performance with higher safety margins
- Common process of permanent observation and learning
- Reliable data exchange with other road users and road infrastructure
- Ability to incorporate external data
- Ability for adaptation to rapid technology changes

Related system changes

- Robust actuation systems e.g. braking, steering, power-net for “fail-safe and secure operational” ability.
- New HMI concepts for take over and safe use of freedom e.g. driver observation to bring the driver back into the loop is necessary and passive safety concepts to keep the driver, passengers and other road users safe in case of an accident.
    - Must also be designed in a way that keeps the various end-users in mind (i.e. must be flexible in their application)
- High-performance perception and high-performance cognition systems including redundancy, which require high performance in-board computation. In-vehicle safety observer system (system observation of health-state) connected to a common observation and validation platform including the “black-box”.
- Functional chain for safe and secure incorporation of external data, network and infrastructure e.g. network unit; redundancy when a communication link fails.
- Modular and scalable E/E-architecture, with service structure e.g. to cope with changing data demand of subsystems.
    - For example, increaing levels of automation in urban environment requires more sensors than for highway AD driving. This eventually creates the demand for an increased computational power which requies adaptability or scalability of vehicle architecture.

The impact of these system changes is that the in-vehicle system boundaries change. The network and backend layer will expand the vehicle system and its subsystems. Thus, regulations, methods and architecture have to be incorporated for these layers. The figure below illustrates this change.

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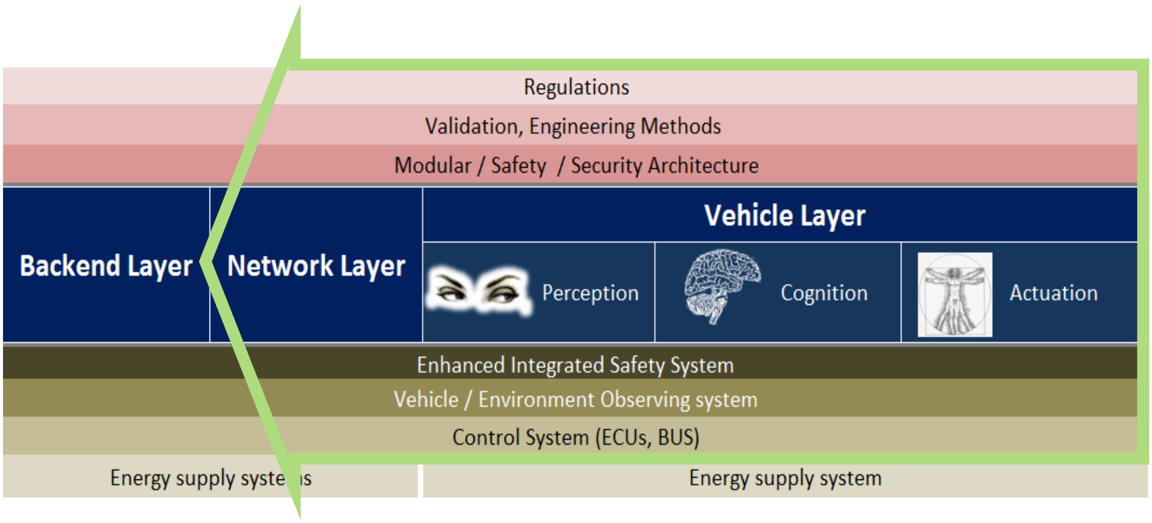
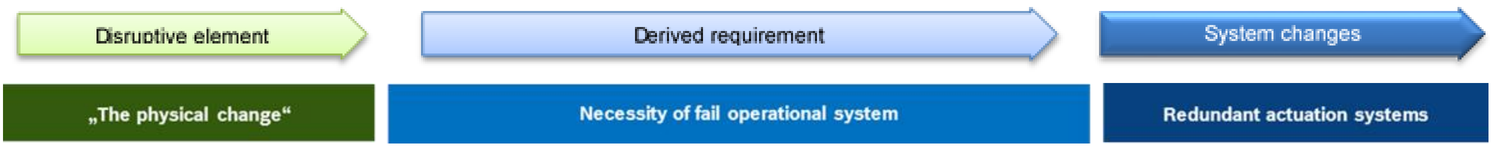


Figure 2 in-vehicle system network and backend layer

2. Systematic break-down of in-vehicle system changes, impact and consequences

The next section considers the impact and consequences of each main change of in-vehicle system by its root causes (the disruptive elements) and its derived requirements on system level.

Redundant actuation systems - from fail-safe to a fail-operational system



- State of the art

Currently all scenarios for possible failures caused by the vehicle are using the driver as an observer and physical backup. In case the driver does not conduct the driving task this assumption is not valid anymore. In case of a critical failure e.g. of the steering system, the driver is not able or prepared to take over the physical driving task, depending on the level of automation.

- Motivation for fail safe and secure operational ability

"Fail safe operational" requirement: for possible malfunctions as e.g. a single point failure of a system, the vehicle has to cover a remaining driving task to ensure a minimum risk scenario. Example: the steering system itself has to cope for own single point failures e.g. by internal redundancy of the steering system.

- Technology approaches for redundant actuation systems

Technology approaches for redundant actuation systems could be assigned to the related subsystems for:

  - Braking
  - Steering
  - Subsystems as power-net, data-transfer

All solutions applying redundancy to the systems and subsystems are highly dependent on the level of automation. All solutions will be carefully selected between concepts for functional redundancy and internal redundancy. The redundancy-distribution of the power-net and the data-system strongly depends on the concepts for braking and steering systems. The given interdependence leads to a considerable complexity – especially because every kind of redundancy or even only changes cause additional costs.

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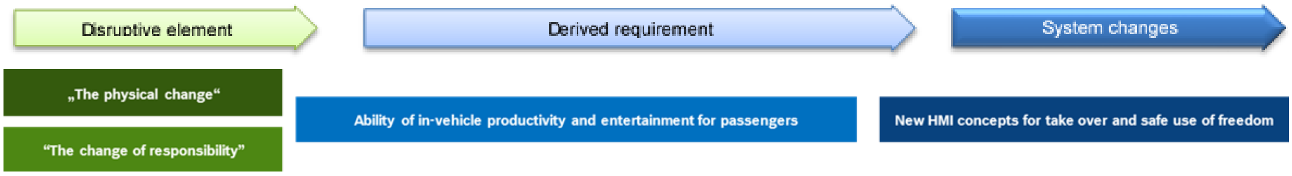
3. New HMI concepts for take over and safe use of freedom



- State of the art

In-vehicle safety margin: The technology to mitigate the severity of injuries today consists mainly on crash structures (chassis), belt- and airbags systems. Belt- and airbags systems only work efficiently if the passengers keep their bodies and extremities within a certain area of their seat. Any displacement of the belt or significant movement of the passenger out of a certain area (out of position case) decreases the nominal safety margin significantly.

- Motivation for ability of in-vehicle productivity and entertainment for passengers

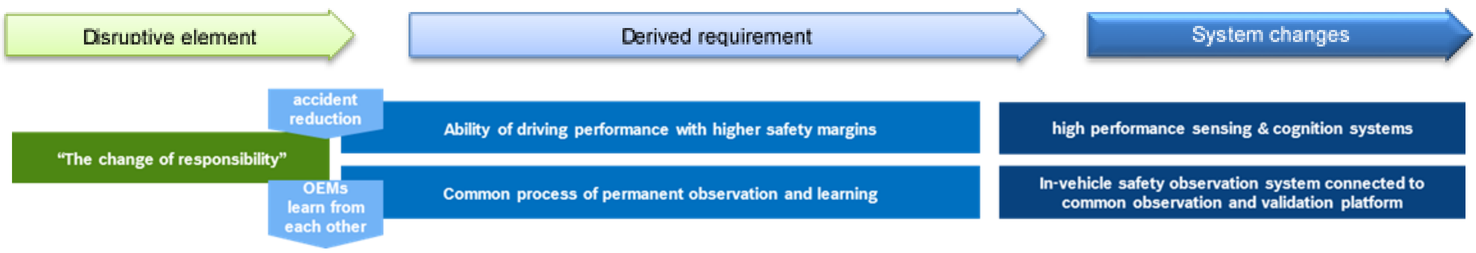
Expectation of passengers: Entertainment, productivity, relaxation, health and other purposes. When no longer being occupied by driving tasks, driver and passengers expect offers on a wide range of opportunities, which give driving/traveling by vehicle a completely new meaning, but require many new solutions for vehicle interiors.

- Technology approaches for new HMI concepts for take over and safe use of freedom

In order to cope with the expectations of the passengers to use the freedom and also keep or even increase the safety margin for individually unavoidable accidents it is necessary to develop new HMI (Human Machine Interface) concepts and thus components. Foreseeable are:

- New “take over” approaches for the steering task.
- Combined safety systems using driver and perhaps passenger monitoring, and new restraint systems providing the expected benefit (e.g. new belt /seat combinations).
- Innovative communication systems like windshield-screens, new haptic HMI concepts or combined communication-control technologies incorporating e.g. voice and gesture.
- New control concepts for steering and braking providing a safe responsibility transfer and enabling more free space within the vehicle.

4. High performance sensing & cognition systems and in-vehicle safety observation system connected to common observation and validation platform



- State of the art

Current public safety expectations relate to a mean value of observed accidents. The current risk taken by drivers is an individual risk, based on a decision between personal comfort and personal accident risk. The current risk is also temporary and depends on many driver-related factors such as emotions, health-state and on external factors (ODD) including weather conditions. In addition, that are other factors often not even realized by the driver.

- Motivation for ability of driving performance with higher safety margins and common process of permanent observation and learning

Society expectation 1: accident reduction - The public expectation towards an Artificial Intelligence (AI) algorithm and related technology (e.g. perception) is to avoid accident risks and lower the number of accidents. However, does the public accept that we have on the one hand considerable lower accident numbers and on the other hand, the automated vehicle sometimes could fail and cause new accidents? The simple reason behind this is that people believe that algorithms can permanently minimize risk. So public expectation is that algorithms are able to do so and if not yet, that technology (e.g. perception technology) has to be developed further before we let it enter the market.
Society expectation 2: Looking at the extremely complex environment of traffic situations, the expectation is that after the homologation process of a highly automated vehicle, new unpredictable, but risky situations may occur because of a certain environmental change. Uncertainties and risks in field have to improve the performance of all vehicles. This implies not one vehicle learns for itself, but aggregates data. The data of many vehicles will be analysed (e.g. in case of near misses), based upon this - new knowledge will be created and redistributed to adaptable vehicles – this process could be called as "**Coordinated and Shared Community learning"**.

- Change of risk responsibility

Clarifying the responsibility for accident occurrence is much more complex with automated driving. Today, the expectation is that responsibility for system failures lies with the OEMs, suppliers and that the driver/owner/user will ensure maintenance, usage and tampering. However, it is important to note that these responsibility notions are not yet clearly defined and just assumptions. Further work is required at national and EU-level to designate responsibility. At this point though, no matter whom the responsibility lies with, documentation of the internal system state is required to provide accurate readings and information in case of accidents (data logging).
Consequence: Public safety expectations increase, compared to current state of the art. Thus, safety of functions has to perform significantly better than current drivers perform - especially in order to keep current comfort e.g. speed. The disappearance of the responsibility of the driver also forces systemic answers.

- Technology approaches

High performance sensing systems: surround sensing systems including localization and networking systems with a significant high performance level (redundancy included). In addition, **high performance cognition systems:** high computing power and (with included redundancy) - the argumentation for redundancy follows the same concept as for actuation redundancy. In order to reach the required performance levels of cognition and perception systems, a change of E/E-architecture towards high performance with the necessary computational power is also necessary.
In-vehicle safety observation system connected to common observation and validation platform, Self-observing / data recording systems – for increased safety and evidence provision have to be established.

- Background of in-vehicle safety observer system connected to common observation and validation platform

Related to "Community learning" is the establishment of a **"Permanent safety procedure"** compared to today's one-time homologation process. The reason behind lies in the fact that it has to be ensured, that safety-relevant changes are proceeded by a safety–proven process.
Also related to "Community learning" is the establishment of a "**Permanent observer system"** at the vehicle, which provides the safety relevant vehicle-data for "Community learning" and enables to cope with the safety requirement for an independent instance and last but not least increase the safety performance of the vehicle (e.g. by health monitoring).
The installation of an in-car observation system is highly favourable supporting community learning and ensures safe application of updates (permanent safety updates). Data recording will also be necessary to document any incident. To make sure that content and process of software and hardware upgrades keep or increase the safety of the whole vehicle, it is paramount across OEMs and Tiers to establish a **common standardized safety process**.
Main consequences on system changes according to "Common process of permanent observation and learning":

- Standardized interfaces

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- A common observation and validation platform and a procedure for permanent field-observation.

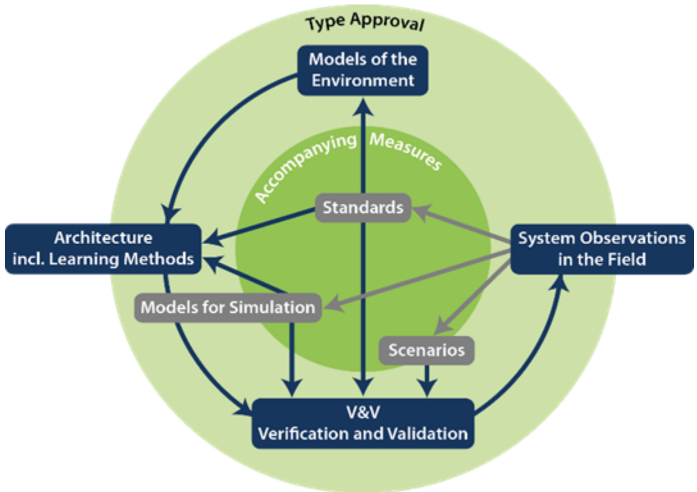
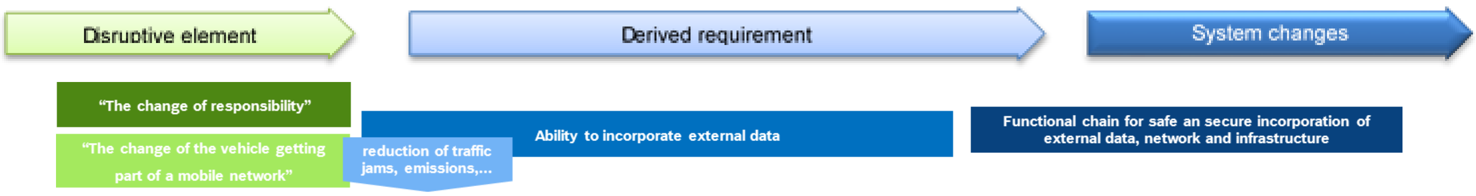


Figure 3 Common observation and validation platform, Source SAFETRANS organisation

5. Functional chain for safe and secure incorporation of external data, network and infrastructure



- State of the art

Current vehicle systems already use external data typically with limited safety relevance but not timing relevant, e.g. updating over the air for non-safety relevant purposes with timing relevance like entertainment.

- Motivation for ability to incorporate external data

Common process of permanent observation and learning leads to incorporation of external data and transmission of internal data externally. The reason for this exchange is based on the need for dissemination of common event triggers to store the right data and the need to continuously back-store event- and status data for liability reasons. The technology providing connectivity and backend services has so far demonstrated faster innovation cycles than the automotive industry. Furthermore also the subsystem as e.g. braking, steering and power–net will impose an independent need for data exchange e.g. for maintenance reasons or in order to reduce complexity of the complete vehicle system. In addition, the different subsystems will develop on own independent cycles. Their need for information exchange towards external data and also internal data will develop in a different way.

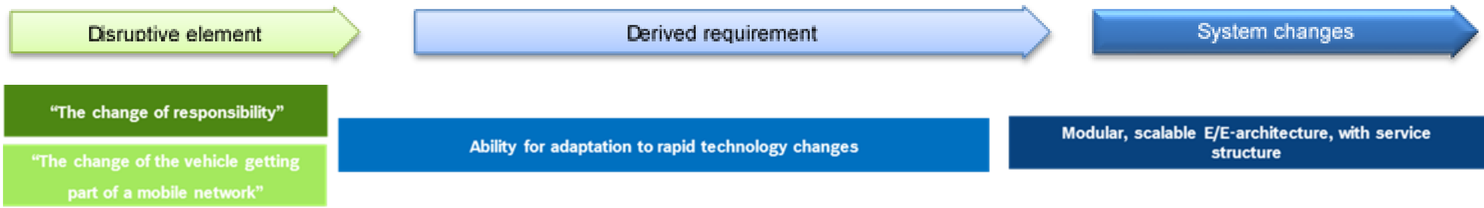
External data will be used for safety relevant vehicle functions. The current accident risk taken by the median of drivers is higher than the expected risk of the society to be taken by the vehicle (OEM) (see also higher safety expectations). This circumstance becomes important for e.g. urban areas where the possible driving speed could be strongly reduced in order to cope with the increased public safety expectation (imagine driving in a crowded area with side-parking cars). One of the possible measures to increase safety and/or keep a comfortable speed is the use of external data (e.g. for localization of pedestrian), collected via IoT concepts. For certain vehicle functions, external data is the only solution to improve performance. The reason is typically obscuration of objects. Some traffic situations as overtaking with oncoming traffic or e.g. complex urban traffic situations like crossings can be approached in a safe, agile and comfortable way with external data (V2X). After a certain point of perception-performance, it is cheaper to use external data than additional or improved surround sensing components. The extent of this point highly depends on the function and its conditions. Therefore, the driving issue for use of external data is the cost - performance ratio (e.g. a safe information about a construction zone on a highway could increase the medium speed for this highway function), balanced with external data availability considerations.

Societal expectation: solving mobility issues (e.g. no traffic jams, optimal usage of infrastructure, reduction of emissions) leads to data exchange concerning traffic flow from e.g. public infrastructure or from other vehicles. Cyber-security.

- Technology approaches for functional chain for safe and secure incorporation of external data, network and infrastructure

Vehicles will provide a connectivity unit, probably containing multimodal ability (see also “common observer platform”). Secured connections are key. Failing security mechanisms are a showstopper for wide-scale usage of external data. Cyber-security measures like encryption, firewalls etc.

6. Modular, scalable E/E-architecture with service structure



- State of the art

Current vehicles systems typically have very limited ability for modularity. Often, designed systems are “not changeable”.

- Motivation for Ability for adaptation to rapid technology changes

Increase of knowledge is growing exponentially and therefore, it is to be expected that future mobile systems will be adaptable for changes in order to incorporate new knowledge and changes as e.g. safety updates. The **rapid technology change** of the digital and telecommunication world requests an **adaptable and modular system** (e.g. safe flash over the air, scalable HW e.g. network unit).

- Technology approaches:

Modular, scalable E/E-architecture, with secure service structure, separated hardware and software systems.

Challenges

This chapter provides a different perspective to the challenges derived in chapter 4. Thus, the given and additional challenges are grouped under the following clusters: *societal expectations, cost/complexity,* and *time to market*. One leading challenge is to come to a viable cost-benefit ratio and master complexity for the strongly divergent solution space of functional and technological combinations within an uncertain regulative environment and significant market pressure

Costs / Complexity

- Safety
    - How to safely handle the complexity and dynamics of urban traffic by automated vehicles?
    - How to ensure smooth transition between automated and non-automated and automated vehicles, or manage their coexistence in mixed traffic?
    - How to assess the risk of automated vehicles?

  - How to define/specify "acceptable" safety level?
  - How to find synergies concerning the aggregation of field data for development and test in Europe?
  - How to deal with performance differences of vehicles?
  - How to deal with security issues and antagonistic threats, including cyber-security?
  - How to define (legal) responsibility during accidents or any other type of non-normal driving event?
    - What role do the technical stakeholders (OEMs, suppliers, IoT companies, etc.) play and what role does the “driver” play? Also has to take into consideration that varying infrastructure and traffic environments will most likely impact these negative events, raising the complexity of the “who’s to blame” question.

- Function /market
  - The complete functional chain from perception via decision making to actuation must fulfil significantly enhanced robustness and fail operational requirements. Facing a variety of vehicle concepts and use cases, this will only work with vehicle system architectures built upon modularity, scalability, standardization and maintenance. This includes in particular also software architectures.
  - For environmental perception, robust, complementary and highly reliable sensor systems must be provided. These must satisfy reliability requirements by using redundant technologies for each area. Depending on the specific AD use case, the affordable sensor configuration has to be evaluated.
  - Vehicle localization is one essential enabler for higher levels of automation. This leads to the need for an on-board available HD map, which must be precise and up-to-date. From the vehicle perspective, efficient, resilient and reliable communication networks have to support these next-stage requirements.
  - Not to mention that there is a strong interference of in-vehicle technology enablers with safety validation and roadworthiness testing in relation to the ODD.
    - Opportunity for market to use ODD as CAD enabler if developed with the proper infrastructure and driving use case information (takes into consideration road types, varying traffic scenarios, and weather); ODD involvement will enable reducing risks and complexities
  - How do we ensure robust environmental sensing?
  - How to upgrade older automated vehicles to current state of the art?
  - How to align functional and technical capabilities with market expectations in terms of cost and end user benefit (e.g. limitation of road usage or speed limitations)?
  - How to balance “eye” and “brain” of in-vehicle and external infrastructures in order to optimize safety, availability and comfort?

- Society expectations
  - How to balance between safety and traffic as well as energy efficiency for automated vehicles?
  - How to involve and meet society expectations concerning technology, including privacy issues?
  - How to gain acceptance e.g. of "slow vehicles” or slow traffic flow caused by automated vehicles?
  - How to reduces mobility costs: “business” costs (automated/driverless trucks, busses, utility vehicles, etc.) and of “personal” cost
  - Society expects offers for individual mobility to handicapped/impaired persons

- Time to market
  - How to speed up “time to market” to enable early market deployment of new solutions?
  - How to manage the fusion of the digital/telecommunication- and the automotive domains?
  - How to carefully draft regulation and limits in order to set the optimum safety focus, not increasing cost and complexity where not needed?

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- How to establish a uniform partnering-approach to address different required safety levels, data formats and business models?
- How to involve insurance requirements, e.g. to maintain black box requirements?

Statements

Throughout CARTRE, stakeholders, including partners and external actors, have had the opportunity to provide input by way of research agendas, conferences, and workshops. Key outcomes are below and could influence/drive future research needs.

Survey responses

- The below highlighted statements received an “agree (strongly agree + mostly agree) of at least 50%. Significance of these remarks is that they serve as indication that the in-vehicle enabler topic and the topics discussed so far on the right track.
  - ⇨ Need for collaboration of maps with in-vehicle enablers; prepare for additional new complexities in the field
    - 86% of respondents strongly agree
  - ⇨ Need for a uniform language for exchange of experiences and learnings (data formats for example) on a European level needs to be developed and managed.
    - 33% strongly agree, 42% mostly agree
  - ⇨ Society expects an increase of safety as well as of traffic and energy efficiency from automated vehicles.
    - 50% strongly agree, 33% mostly agree
  - ⇨ Society expects social-economic benefits such as reduction of traffic jams and pollution
    - 27% strongly agree, 64% mostly agree
  - ⇨ It is necessary to prepare society for possible negative impacts of automated vehicles.
    - 55% strongly agree, 28% mostly agree
  - ⇨ Need to identify niche markets and define pilots in these niche markets. Examples are airports, business districts, university campuses
    - 27% strongly agree, 27% mostly agree
- While the above statements received “agree” votes of at least 50%, there were some survey statements with more uncertainty and mixed responses. The significance is that stakeholders appear to be uncertain about impact, meaning, implementation, etc. Success of in-vehicle enablers and autonomous vehicle adoption could be jeopardized if these uncertainties are not addressed.
  - ⇨ Governments and transportation agencies will be responsible to monitor all risk-related aspects.
    - 36% strongly agree, 14% mostly agree, 36% do not agree or disagree
    - 14% mostly disagree
  - ⇨ It will be the responsibility of the OEMs/suppliers to monitor all risk aspects.
    - 8% strongly agree, 21% mostly agree, 21% do not agree or disagree, 29% mostly disagree, 21% strongly disagree
  - ⇨ Retrofit solutions for non-automated vehicles could accelerate deployment of automated vehicles (e.g. V2X communication)
    - 18% strongly agree, 18% mostly agree, 37% do not agree or disagree, 9% mostly disagree, 18% strongly disagree

2018 Vienna CAD Symposium: In-Vehicle Enablers Breakout Session

- Key takeaway was the interoperability and complexity that is associated with in-vehicle enablers. The high degree of complexity not only impacts technical aspects, but also extends into the legal, policy, and safety fields, to name a few. Recommendation is for systems, components, and partners to work together to master this rising complexity

- Enable harmonization for technical and non-technical fields
- Key poll results
  - Need to accelerate European-wide legal harmonization process and establishment of standards to foster development and deployment
    - Need to develop cutting-edge, reliable, and cost efficient perception, cognition and actuation systems considering redundancy
- Discussion--> term "cost efficient"; should industry be emphasizing savings while safety is not proven at this development stage?
  - Should foster collaboration, standardization, and harmonization between digital/communication and automotive industry

Expected impact: Strengths, Weaknesses, Opportunities, Threats (SWOT)

Strengths
1) The EU is the world's second largest producer of passenger cars, accounting for more than 21% of global car production in 2017 (about 17 million vehicles). Additionally, more than 3.5 million of commercial vehicles were produced in 2017 (19% of global production in 2016). 2) The EU's automotive industry has strong R&D capabilities with experience in ADAS, mobility, and safety systems. 3) The EU has diverse markets in which real market penetration is achieved with a wide spectrum of applications developed by a capable industry from small size vehicles to trucks and logistic services. 4) The EU has a very strong and capable technology development structure, from universities over start-ups and SMEs to suppliers and OEMs. 5) The EU is the home base of more than 90% of premium market OEMs with their leading ADAS offers and the largest suppliers, both having their core development in the EU. 6) The market penetration of ADAS has increased and shall continue to increase with gradual deployment of AD vehicles. Here EU has potential to lead the worldwide market with its in-vehicle technology enablers.

Weaknesses
1) Lacking competencies in Artificial Intelligence (high performance algorithms, big data, etc.), which is thought of as a key technology for automated driving systems. Additionally: also lacking competencies in "applied software science" for the automotive industry. 2) The EU's software and digital-hardware industry is not as strong as in other parts of the world.
3) Local existing expertise not being leveraged to its full extend (at universities and SME competences exist e.g. on cyber security, but high potentials cannot develop easily in Europe and may go to North America where risk-capital culture is different).
4) Overlapping and fragmented responsibilities in digitalization of mobility on European level (digitalization has strong common aspects which have to be handled jointly in DGs). 5) Split regulations: no European single market (long time to unite). 6) Common data availability is low for data-driven Artificial Intelligence; i.e. labelled data are necessary for R&D, but very expensive. 7) The topic of "data" and "data sharing" hinders development since data forms the basis for ML and AI elements, which are building blocks for AD technology.

Opportunities
1) Make better use of knowledge of academic institutions.

2) More efficient collaboration of European institutions on intra-governmental level.
3) Foster collaboration including non-traditional collaborations between network and automotive industry: need for non-traditional collaboration models.
4) Work on the "next step", which enables the deployment of a certain product as e.g. an automated shuttle, automated valet parking, platooning, etc., in order to realise the first step for commercial use.
5) Generate and open data for research and development (labelled).
6) Start an EU wide process for harmonization of verification and validation force to speed up and overcome ADAS hurdles.
7) Create a common "policy lab" that brings together best practices of each countries together and works towards creating a harmonized method and process for all elements like V&V, certification, type approvals, licensing, etc.

Threats
1) Faster technical development in other regions outside Europe. 2) Faster market adoption in other regions outside Europe. 3) Other regions outside Europe could be faster at testing & deployment (depending on regulation). 4) European HQ based global automotive industry invests in R&D in other regions outside Europe, e.g. in California's Silicon Valley region and China. 4) (Lack of) Standardization and political perspective hinders adoption/market entry. 5) Society does not accept technology risks. 6) Potentially disappointing benefits in pilots and early deployment due to still immature technology, e.g. accidents, bad business case, slow vehicles with negative impact on traffic flow, etc. 7) EU needs to build its pool of SW engineers. Tech giants like Google, Apple have an army of SW engineers and with the future vehicle becoming more driven by SW, it is imperative to train current talent or we risk losing the race due to lack of capable talented workforce.

Future research needs

In order to strengthen Europe's position on ART, it is paramount to establish a common future research agenda addressing society, safety, and technology needs. It is imperative to note that there are overlapping interests and opportunities across the three topic areas, and future research should not view these categories as independent research areas but as overlapping opportunities to advance CAD in Europe. These future research needs align with the 2018 ERTRAC Strategic Research Agenda and CARTRE WP 5 Future Research Needs.

SOCIETY - enabling aspects for technology deployment

Without public acceptance, automated road transport will not achieve widespread deployment, or at the very least delay deployment. Therefore, it is necessary to initiate an early discussion. Future research agendas should address the following:

- Study societal benefits, socio-economic impacts, user acceptance and human factors to increase user awareness, acceptance and trust/benefit for CAD
- Learn user behaviour for enhanced vehicle-human system interaction reducing complexity for increased benefit
- Ensure proper user information and assess future skills of users and professionals.
- Evaluate potential business interests of "non-automotive" players and the question of how they might integrate into the value chain. This covers e.g. insurance companies, backend service providers, or mobility service providers, as well as the exploration of new business options & models
- Enhance role and responsibility of road authorities, traffic managers and private fleet operators to support user acceptance

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- Strengthen policy and regulation support (national and EU level)
    - Speed-up regulation for tests and deployment and adaptation/harmonization of traffic rules
    - Coordinate EU research activities related to regulation and policies.
- Assess potential impacts on public transport and integration with shared mobility opportunities, including impact on local (city) and regional (state) governments
- Evaluate the impact of new CAD-enabled services for goods and people
    - Large-scale demonstrations of integrated bundle of shared and automated services (mixed-use traffic scenarios)
- Develop innovative, user-centric, reliable, fair and ubiquitous mobility and transport services. Should also incorporate new concepts for automated services for sharing of transport assets:
    - Includes development and demonstration of concepts for fully automated un-manned vehicles for specific applications for enhanced mobility of people and goods like robo-taxis, bus-trains, innovative freight logistics, confined areas, hub-to-hub automation, and automated modal interchange mobility hubs

SAFETY - enabling aspects for technology deployment

Society will likely not embrace road transport automation without the assurance of the inherent safety benefit. Therefore, it is necessary for future research to cover safety aspects. Likewise, safety needs to be qualifiable and measurable. This especially requires standardization of functional safety aspects, i.e., safety goals, limits and certifications. In order to ensure safe, secure, and resilient CAD, activities should include:

- Develop functional safety requirements/cases, cyber-security requirements and resilience for both technical faults and external threats including cyber security.
    - Includes building up a common set of aligned safety requirements for automated vehicles and infrastructure, including method development.
    - Developing methods to detect and prevent misuse of AVs
        - Raises additional questions on legal responsibility and preventative methods, which go beyond the scope of this paper but which have to be taken into consideration in future work.
- Build up a consistent European wide harmonized regulations and methods framework, which will have to include validation processes and safety requirements. An early start is important because of the inherent interdependence between development, harmonization, and deployment.
    - Harmonize road-network qualities and standards across Europe, including communication and information infrastructure standards.
    - Inclusive approach for all road users, including VRU, for safe interaction with CAD vehicles. Inclusion of Operational Design Domain (ODD) in the validation process to reduce complexity and risks
        - Need to define the ODD to scope the functionality of the in-vehicle system. Needs to take into account different infrastructure, perception, localization, weather, etc. scenarios. It is clear that these aspects will have an impact on the in-vehicle system and how it makes decisions.
- Need to define (legal) responsibility, especially during accidents. However, responsibility cannot solely lie with the technology providers (OEMS, suppliers, etc.) but must also take into consideration driver/owner/user and external actors such as insurance companies and infrastructure providers, who will be impacted by the responsibility debate.
    - It is imperative to have clear guidelines on this matter, which will also have a significant impact on costs (technology and market penetration) and society (deployment and user acceptance).

TECHNOLOGY deployment

During the Vienna workshop on April 19, emphasis was on the necessary development of highly cost efficient, highly available and safe automotive systems in order to reduce costs and achieve a high penetration rate of automation.

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Key will be to create a balanced approach between automation benefits (impacts society) and mastering system complexity (impacts safety). The following suggested research activities will help achieve this aim:

- Real world tests, pilots and field operational tests (FOT) to foster deployment of CAD vehicles (L4).
    - Focused on different sectors: passenger vehicles for private users, heavy commercial freight vehicles in logistics operation, public transportation and pods.
    - Exchange between different vehicle sectors to perform common tests as vehicles will share roads in mixed traffic scenarios
    - Interaction between different types of vehicles with different automation levels
    - Compatibility with changing infrastructures and traffic patterns and include behaviour and interior monitoring
        - Perception, localization, and cognition are imperative and constitute a new system quality. Adequate actuation systems will have to complement. The whole chain sensing-perceiving-acting needs to be extremely reliably and highly available, therefore including the development of appropriate forms of robustness, for example through redundancy.
    - The systems will be subject to shorter life cycles compared to conventional vehicles. Therefore, an ability for adaptation to rapid technology changes will have to be designed in CE cycles.

Digitalization is the foundation of road transport automation and establishing the application of digital competences to the automotive sector, including the development and harmonization of appropriate standards will be essential. Digitalization enables the coping with the inherent complexities by e.g. finding optimized solutions using existing and new technologies. This will also help to reduce "time to market" and should include the following future activities:

- Connectivity and automation technologies development: sensors, software, systems-of-systems, high performance computing and AI
    - Need to address the various aspects linked to connectivity. This includes real-time, secure telecommunication, resilient and reliable telecommunication coverage guaranteed at a certain level all across Europe (5G availability, traffic data availability etc.).
    - Develop algorithms for environmental perception and cognition with minimal computing and power demand, e.g. based on AI methods
    - Includes connectivity and cooperative systems (V2X)
- In-vehicle enablers for reliable perception, resilient systems architectures and on-board decision making
    - Enable high performance simulation, making it possible to transforming real world test into simulation.
- Collaborative driving and human-machine cooperation strategies
- Mastering increased system complexity balancing on-board/off-board computation.
- Data sharing/storage/access, big data, vehicle clouds, privacy and cyber security.
    - The degree of connectivity required by automated road transport will also affect backend safety and security as well as that of the connections themselves, and the reliability of the data provided

References / Link to studies

In order to assess the validity of CARTRE's statements, several other projects, initiatives and studies in Europe were analysed. Key references include:

- 2017 ERTRAC Automated Driving Roadmap: https://www.ertrac.org/uploads/documentsearch/id48/ERTRAC_Automated_Driving_2017.pdf
    - Author: European Road Transport Research Advisory Council (ERTRAC)
    - The ERTRAC Automated Driving Roadmap highlights the following clusters: 'Environmental Detection and Perception', 'Demonstrating Reliability, Safety and Robustness of Technology', 'Legal and Regulatory Framework', 'Users' and Societal Acceptance', 'Driver Attention and Involvement', 'Common Validation

Procedures and Testing Requirements', 'Infrastructure Requirements', and 'Industrialisation'. Interestingly, this roadmap also remarks that the acceptance is linked to a unanimous understanding and agreement of the benefits from automated driving (comfort, efficiency, safety, social inclusion, etc.). It highlights that this will require a better understanding of the impacts on society as a whole (benefits but also potential negative impacts have to be studied). Furthermore, highlights the driver engagement and driver re-engagement for various levels of automation in a safe and conclusive manner. Therefore, the various applications for automated driving at different levels of automation have to consider human factors (visual, haptic and acoustic) as decisive design criteria, since user acceptance for partially and highly automated vehicle is considered to depend on human factors and the intuitive usability.

- Automation: From Driver Assistance Systems to Automated Driving https://www.iaa.de/fileadmin/user_upload/2015/english/downloads/press/Automation-from_Driver_Assistance_Systems_to_Automated_Driving.pdf
  - Author: Verband der Automobilindustrie (VDA)
  - Provides „A to Z" overview of topics and trends which will impact deployment and market adoption of autonomous vehicles
- Self-driving cars: The next revolution https://home.kpmg.com/be/en/home/insights/2012/08/self-driving-cars-the-next-revolution.html
  - Author: KPMG LLP and the Centre for Automotive Research (CAR)
  - The analysis is based on 'Consumer Acceptance', 'Integrity of Technology', 'Market Ecosystem', 'Legislation', and 'Infrastructure Investment'. The main differential points of this study are the focus on convergence of sensor-based systems with those based on connectivity, and the need of higher levels of adoption density to deliver the connected vehicle technology's full value and potential.
- Automated Driving: Safer and More Efficient Future Driving http://link.springer.com/book/10.1007%2F978-3-319-31895-0 ISBN: 978-3-319-31893-6 (Print) 978-3-319-31895-0 (Online)
  - Editors: Daniel Watzenig, Martin Horn
  - Apart from a technology overview, Part VII of this book gives "A Sampling of Automated Driving Research Projects and Initiatives: European and National Projects, European and National Initiatives
- AutoNet2030 project http://www.autonet2030.eu/?page_id=14
  - Developments within the AutoNet2030 project, specifically prototype development and standards enhancements
- AdaptIVe project https://www.adaptive-ip.eu/index.php/deliverables_papers.html
  - AdaptIVe highlights following challenge clusters in its final report: 'System functionality and safety', 'Validation procedures and testing requirements', 'Human factors and HMI', 'Road infrastructure and mixed traffic', 'Data security', 'Legal aspects', 'Social and customer acceptance'. The main factors identified in these clusters overlap with those identified in the CARTRE project. Main additional considerations that have been made in the AdaptIVe project that were not explicitly addressed in CARTRE were related to standardized solutions for key interactions between system and driver, e.g. take-over request, as an enabler for the success of car-sharing systems, which might experience a growing demand with the introduction of AD, and the need for new mobility service concepts and business models, and marketing strategies for how to approach the customers and increase broad user acceptance of the systems.
- Publication "Top misconceptions of autonomous cars and self-driving vehicles" http://www.inventivio.com/innovationbriefs/2016-09/Top-misconceptions-of-self-driving-cars.pdf
  - Author: Alexander Hars, Inventivio GmbH
  - Analysis of 8 misconceptions of autonomous and self-driving cars

- 2018 Global Automotive Executive Survey https://assets.kpmg.com/content/dam/kpmg/nl/pdf/2018/sector/automotive/global-automotive-executive-survey-2018.pdf
  - Author: KPMG
  - Explore future automotive ecosystem
- 2018 Autonomous Vehicle Readiness Index https://home.kpmg.com/xx/en/home/insights/2018/01/2018-autonomous-vehicles-readiness-index.html
  - Author: KPMG
  - Provides an in-depth view of what it takes for countries to meet the challenges of self-driving vehicles, evaluating the preparedness of a cross-section of 20 countries globally.
- 2018 Automotive Disruption Radar https://www.rolandberger.com/de/Publications/pub_automotive_disruption_radar.html
  - Author: Roland Berger
  - Tracking 25 early indicators of disruption, which are happening in each of the most important markets of the world
- 2018 Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee of the Regions "On the road to automated mobility: An EU strategy for mobility of the future" https://ec.europa.eu/transport/sites/transport/files/3rd-mobility-pack/com20180283_en.pdf
  - Author: Commission to the European Parliament, the Council, the European Economic and Social Committee of the Regions
  - With this Communication, the Commission proposes a comprehensive EU approach towards connected and automated mobility setting out a clear, forward looking and ambitious European agenda. This agenda provides a common vision and identifies supporting actions for developing and deploying key technologies, services and infrastructure. It will ensure that EU legal and policy frameworks are ready to support the deployment of safe connected and automated mobility, while simultaneously addressing societal and environmental concerns which will be decisive for public acceptance.
- 2017 Waymo Safety Report, On the Road to Fully Self-Driving https://storage.googleapis.com/sdc-prod/v1/safety-report/waymo-safety-report-2017.pdf
  - Author: Waymo
  - Addresses the U.S. Department of Transportation (DOT) federal policy framework for autonomous vehicles: Automated Driving Systems 2.0: A Vision for Safety.
  - Outline the processes relevant to each safety design element and how they underpin the development, testing, and deployment of fully self-driving vehicles.
- 2016 STRIA Roadmap “Connected and Automated Transport (CAT)” https://trimis.ec.europa.eu/sites/default/files/roadmaps/STRIA%20Roadmap%20-%20Cooperative%2C%20connected%20and%20automated%20transport.pdf
  - This Strategic Transport Research and Innovation Agenda (STRIA) roadmap document addresses the Research and Innovation (R&I) activities and other policy support measures required so that the concepts of connected and automated1 transport (CAT), for all transport modes, may contribute to the Energy Union 2050 goals in the domains of decarbonisation, greater efficiency and competitiveness.
- ERTRAC Strategic Research Agenda http://ertrac.org/uploads/documentsearch/id52/ERTRAC-Strategic-Research-Agenda-SRA-2018.pdf
  - Author: European Road Transport Research Advisory Council (ERTRAC)
  - The Strategic Research Agenda (SRA) is the key document of ERTRAC to prepare the next European Research Framework Programme. The last version was published in 2010 in preparation of the Horizon 2020 Programme. This new version is meant to support the development of the 9th EU Framework

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Programme (FP9): therefore, it provides Innovation challenges and Research and Development topics for the timeframe 2020-2030.

Glossary: Acronyms and definitions

Term	Description
5G	Next Generation Mobile Network
ADAS	Advanced Driving Assistance Systems
AI	Artificial Intelligence
AMAA conference	International Forum on Advanced Microsystems for Automotive Applications
ART	Automated Road Transport
C2X	Car-to-Car or Car-To-Infrastructure communication. Communication of data between traffic participants and infrastructure.
CARTRE	European Commission funded H2020 "Coordination and Support Action" (CSA) project "Coordination of Automated Road Transport Deployment for Europe", GA number 724086
CE	CE marking is a certification mark that indicates conformity with health, safety, and environmental protection standards for products sold within the European Economic Area (EEA)
DG	Directorate General
EC	European Commission
E/E architecture	Electrical and Electronic architecture
ERTRAC	European Road Transport Research Advisory Council
HAD	Highly Automated Driving
HMI	Human-Machine Interface
HW	Hardware
OEM	Original Equipment Manufacturer
ODD	Operational Design Domain
R&D	Research & Development
R&I	Research & Innovation
SCOUT	European Commission funded H2020 "Coordination and Support Action" (CSA) project with the full title "Safe and Connected Automation in Road Transport"
Project intranet web site	A restricted-access website for interaction between registered partners and associated partners. In this case a Microsoft SharePoint site https://ecity.tno.nl/sites/eu-cartre or https://partners.tno.nl/sites/eu-cartre
Public CARTRE web site	Joint website of the two European Commission funded "Coordination and Support Actions" (CSA) projects CARTRE and SCOUT with the URL http://www.connectedautomateddriving.eu/
VRU	Vulnerable Road Users

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