# /D3.3 SWOT Analysis of the connected and automated driving ecosystem in Europe

**Darmstadt, 18th September 2018**

Authors:

Heiko Hahnenwald
(Fraunhofer LBF)

Date:

18th September 2018

## Document change record

| Version | Date | Status | Author | Description |
|---|---|---|---|---|
| **0.1** | 29/01/2018 | Draft | Heiko Hahnenwald | Creation of the document (Introduction, Chapter 2.1) |
| **0.2** | 14/02/2018 | Draft | Heiko Hahnenwald | Chapter 2.2 |
| **0.3** | 20/02/2018 | Draft | Heiko Hahnenwald | Chapter 2.3 |
| **0.4** | 20/04/2018 | Draft | Heiko Hahnenwald | Chapter 2.4 and 2.5 |
| **0.5** | 16/06/2018 | Draft | Heiko Hahnenwald | Chapter 3 and 4 |
| **0.6** | 18/06/2018 | Draft | Heiko Hahnenwald | Some corrections, Conclusion |
| **0.7** | 19/06/2018 | Draft | Heiko Hahnenwald | References, Figures and finalization |
| **1.0** | 10/07/2018 | Final | SCOUT Project Management | Final Redaction |
| **2.1** | 11/09/2018 | Review | Heiko Hahnenwald | Revision of text, adding SWOT-Schemes |
| **2.2** | 11/09/2018 | Review | Steven von Bargen (NXP) | Review and minor changes |
| **2.3** | 11/09/2018 | Review | Adrian Zlocki (ika) | Review and minor changes |
| **3.0** | 13/09/2018 | Review | Heiko Hahnenwald | Review integration and SWOT-Table |
| **3.1** | 18/09/2018 | Final | Heiko Hahnenwald | Overworking of Threats, redaction and finalization |

## Consortium

| No | Participant organisation name | Short Name | Country |
|---|---|---|---|
| 1 | VDI/VDE Innovation + Technik GmbH | VDI/VDE-IT | DE |
| 2 | Renault SAS | RENAULT | FR |
| 3 | Centro Ricerche Fiat ScpA | CRF | IT |
| 4 | BMW Group | BMW | DE |
| 5 | Robert Bosch GmbH | BOSCH | DE |
| 6 | NXP Semiconductors Netherlands BV | NXP | NL |
| 7 | Telecom Italia S.p.A. | TIM | IT |
| 8 | NEC Europe Ltd. | NEC | UK |
| 9 | Rheinisch-Westfälische Technische Hochschule Aachen, Institute for Automotive Engineering | RWTH | DE |
| 10 | Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e. V., Institute for Structural Durability and System Reliability FHG | FHG | DE |
| 11 | CLEPA aisbl – The European Association of Automotive Suppliers | CLEPA | BE |
| 12 | Asociación Española de Fabricantes de Equipos y Componentes para Automoción SERNAUTO | SERNAUTO | ES |

## Table of contents

**1 Introduction and process description ........ 3**

**2 SWOT-Analysis on technical layer ........ 4**

2.1 Sense ........ 4

2.1.1 In Vehicle Sensing ........ 5

2.1.2 Sensor Set-up / Environment perception ........ 6

2.1.3 Navigation and Localization ........ 7

2.2 Think ........ 8

2.2.1 Sensor Fusion/E-E-Architecture ........ 8

2.2.2 Artificial Intelligence ........ 9

2.3 Act ........ 10

2.4 Security ........ 11

2.5 Connectivity ........ 12

**3 SWOT-Analysis on legal layer ........ 14**

**4 SWOT-Analysis on human factors layer ........ 15**

**5 General Conclusions ........ 18**

**6 Bibliography ........ 19**

**7 Annex: Overview on SWOT for all investigated layers ........ 20**

# 1 Introduction and process description

Within the SCOUT-Project the state of the art of connected and automated driving in Europe has been investigated by the use of a 5-layer model[1] to illustrate the complexity of automated and connected driving and the interaction between different areas of influence. These areas respectively layers are

1. Technical Layer
2. Human factors Layer
3. Economics Layer
4. Legal Layer
5. Societal Layer

Within each layer the vehicle, driver and at least the environment influence each other and have to be considered by introducing automated and connected driving functions.

The economics and societal layers have been addressed in other work-packages dealing with user expectations, goals, ideas, reservations and requirements on one hand and on the other hand with investigation of suitable business models.

The state of the art investigation, which had to be further investigated in case of strengths and weaknesses, was well as opportunities and threads with this Deliverable, is concentrating on the remaining technical, legal and human factors layer representing the most important aspects of connected and automated driving in public awareness: technical feasibility, regulatory framework and user acceptance.

For the elaboration of the above mentioned SWOT-Analysis the following steps of investigation have been gone through:

1) Deriving requirements on technology as well as on legal regulation with respect the definition of SAE definition on Automation-Level 4 and 5
2) Comparing the state of the art results on technology and legal regulation with these requirements
3) Set up a SWOT-Scheme for each technical and legal regulation area as well as on human factors especially regarding the acceptance of automated driving
4) Finding interdependencies between the three layers and deriving overall topics to be addressed in further investigations of connected and automated driving concerning technology, legal framework and human acceptance.

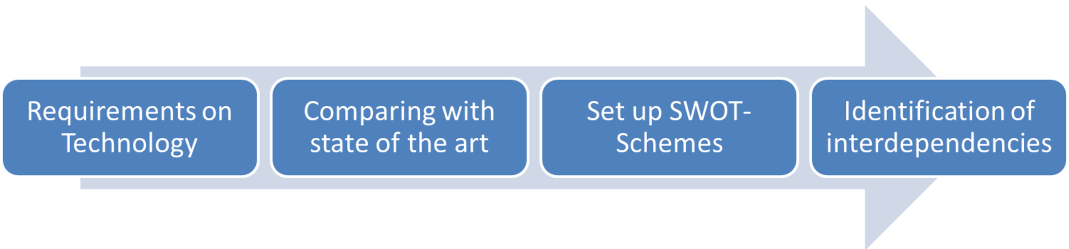


Figure 1: SWOT-Analysis-Approach

[1] Prof. L. Eckstein, ika, RWTH Aachen University

# 2 SWOT-Analysis on technical layer

Basis for the analysis of strengths weaknesses as well as opportunity and threads for the technical layers are the reference requirements for Level 4+ (Level4/Level5), which represents high and full automation levels where no driver interaction is needed. In detail Level automated cars will be able to handle driving from point to point in most use-cases. However, the cars will include functional driving apparatus (wheels, brakes and gas pedals). Therefore humans can manually drive when conditions are not adequate to predefined use cases (i.e., off-roading,) or when the „driver" actually wants to. In contrast Level 5 Automation means the cars are completely autonomous. With prototypes of Level 5 vehicles having no steering wheels, gas or brake pedals there is no need for a human driver anymore even in critical tasks like monitoring the environment and the identification of unique driving conditions.

To realize that a broad range of achievements has to be realized in several technological areas inside and outside automated and connected vehicles. Within the state of the art report five technological areas have been investigated and described: Sense, Think, Act, Communication/Connectivity and Security, (see Figure 1). Each of this will be represented by specific technologies in hard- and software that need to perform specific requirements. In the following chapters these requirements have been defined based on the reference functions of level 4+ automation of vehicles. Also they will be categorized by the description of internal and external factors like the description of current strengths and weaknesses as well as possible future opportunities and threads with respect to automated and connected driving.

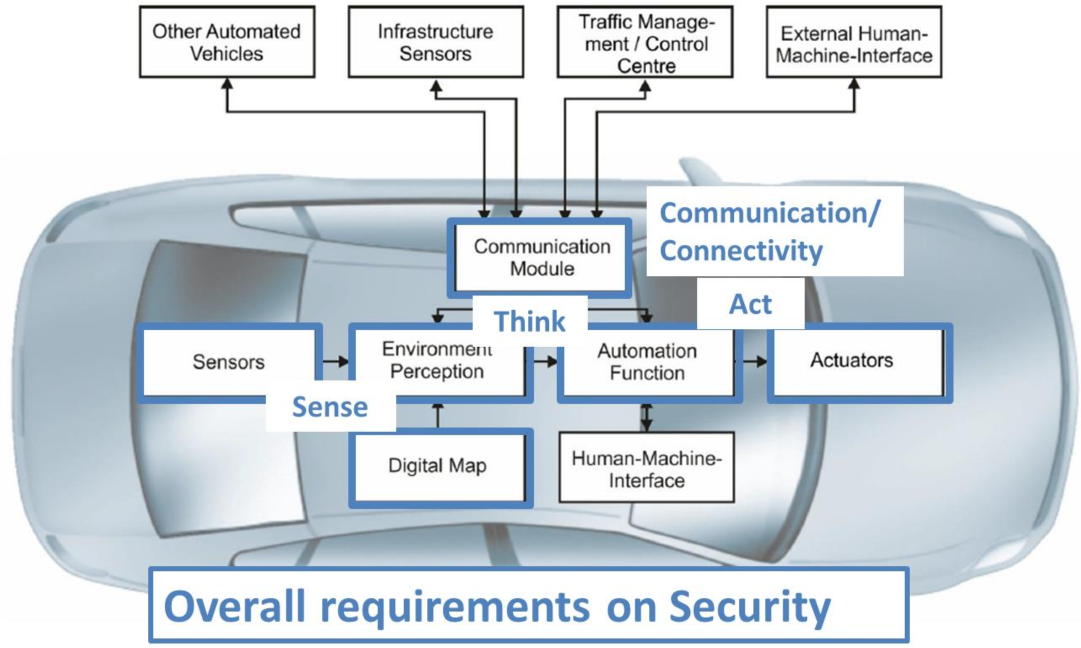


Figure 2: Observed technical elements of connected and automated driving (Source: DLR)

## 2.1 Sense

To provide safe and secure automated driving on level 4+ all automated features had to operate on any weather or environmental conditions, e.g. heat, rain, ice and snow, fog as well as under all traffic conditions regarding traffic density, traffic speed and road type. To achieve that, adequate and precise environmental sensing and localization information is needed. Although current technology readiness of sensing technology is quite high there is still some research to be done but mostly important for future automated driving are broad variety of manufacturer specific set-ups and missing standardization.

### 2.1.1 In-Vehicle Sensing

Already today there is a broad amount of sensors and sensor data available delivering information on vehicle status (tire pressure, engine diagnostics, brake position sensors, steering angle sensor, accelerator pedal angle sensors etc.). Also sensors are available to detect information about driver status, e.g. distracting, tiredness. Although those kinds of sensors have certain market availability their usage is actually limited to premium car features.

The increasing use of sensors leads to continuously sinking costs which already make advanced systems more and more affordable for everyone. The existing in-vehicle sensor network could also be used for advanced automated and connected driving features. The limiting factor for such applications is that actually sensor data is limited to specific sensing tasks. There is no merging of sensor data on meta-information, at once data exchange between the different in-vehicle sensors is mostly missing. To achieve full performance in using this type of sensors available for connected and automated vehicle features standardization is required. This standardization has to take into account sensor set-ups to provide reliable sensing information data base. Beside this also standardization is necessary to provide quality criteria for sensors to ensure long-term durability and data quality.

Beside this, driver status sensors are focusing on driver's attention. But for automated vehicles the driver intention sensing gets even more relevant. In both cases basic research is still needed to improve reliability on one hand and to achieve technology readiness on the other hand.

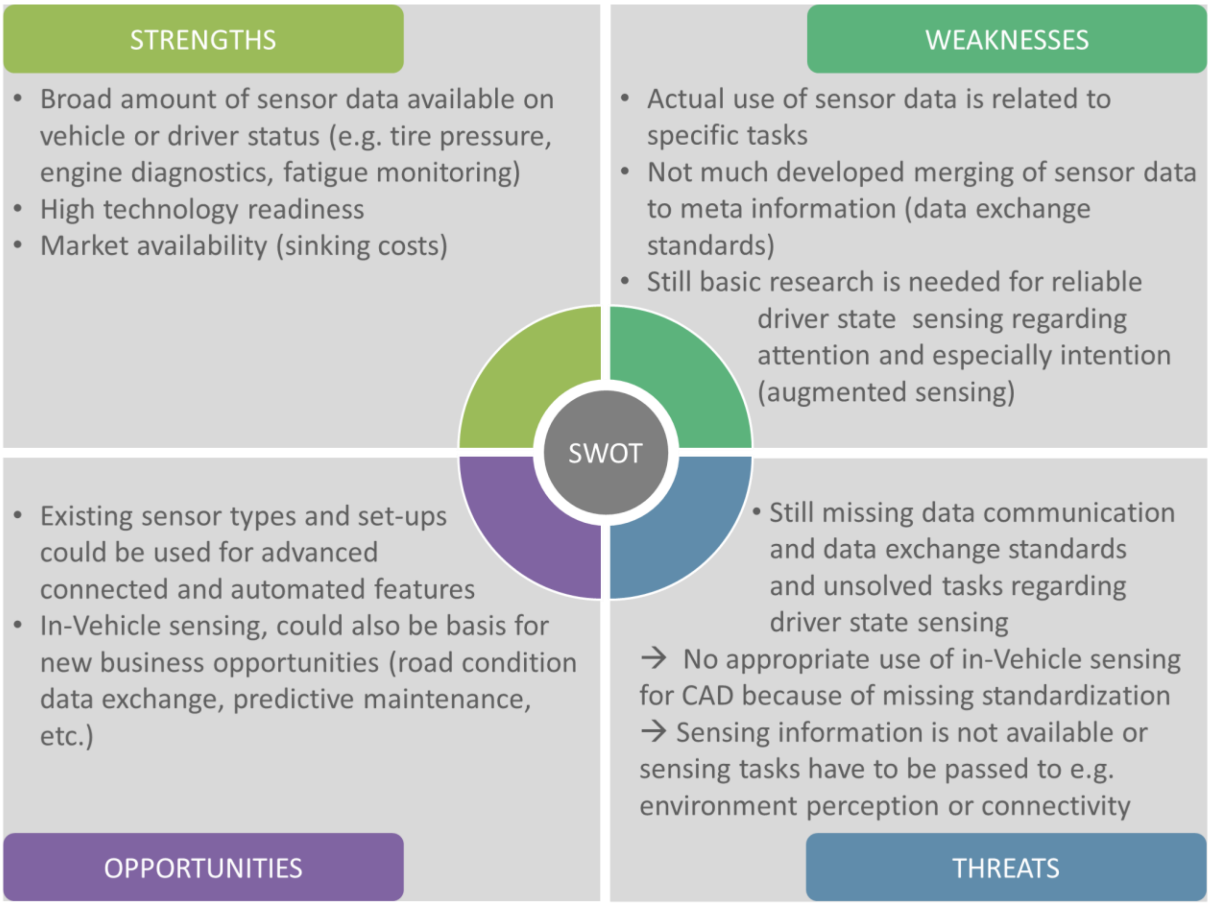

Figure 3: SWOT-Scheme on In-Vehicle sensing

If standardization could not be achieved and driver state sensing could not be improved within the time scope, in-vehicle sensing may not be used as technology basis for connected and automated driving. Therefore market availability of CAD systems are delayed respectively sensing tasks need to be performed by other systems (e.g. vehicle to infrastructure sensing or environment perception).

### 2.1.2 Sensor Set-up / Environment perception

As well as in-vehicle sensing, sensors to detect vehicles environment, like radar, lidar, ultrasonic or cameras are available at high technology readiness levels. On the other hand all sensor types are limited due to coverage, resolution, latency, detection accuracy as well as size, weight or costs. Because of their specific technological advantages and disadvantages they are related to specific sensing tasks. For that high accurate sensor/task combinations can be allocated. This also means that still there is a variety of sensors in use to provide relevant data but also indicates high requirements on sensor data fusion (see 2.2.1) to provide reliable information.

Closely related to the variety of sensor types, is the fact, that there is no common sensor-set-up for environment perception available. Nearly each OEM uses its own set-up for environmental sensing. The range of sensor set-ups lasts from using all available sensors for different sensing tasks over combinations of a few sensor types, to the limitation on camera sensors for all sensing tasks. According to that, standardization may help to reduce sensors and to define a common sensor set-up and system reliability requirements. Standardization also supports scale effects and reduction of sensor costs. Beside possible missing technological reliability missing standardization will system prices will not decrease and therefore connected and automated vehicles will still be expensive and not widely spread.

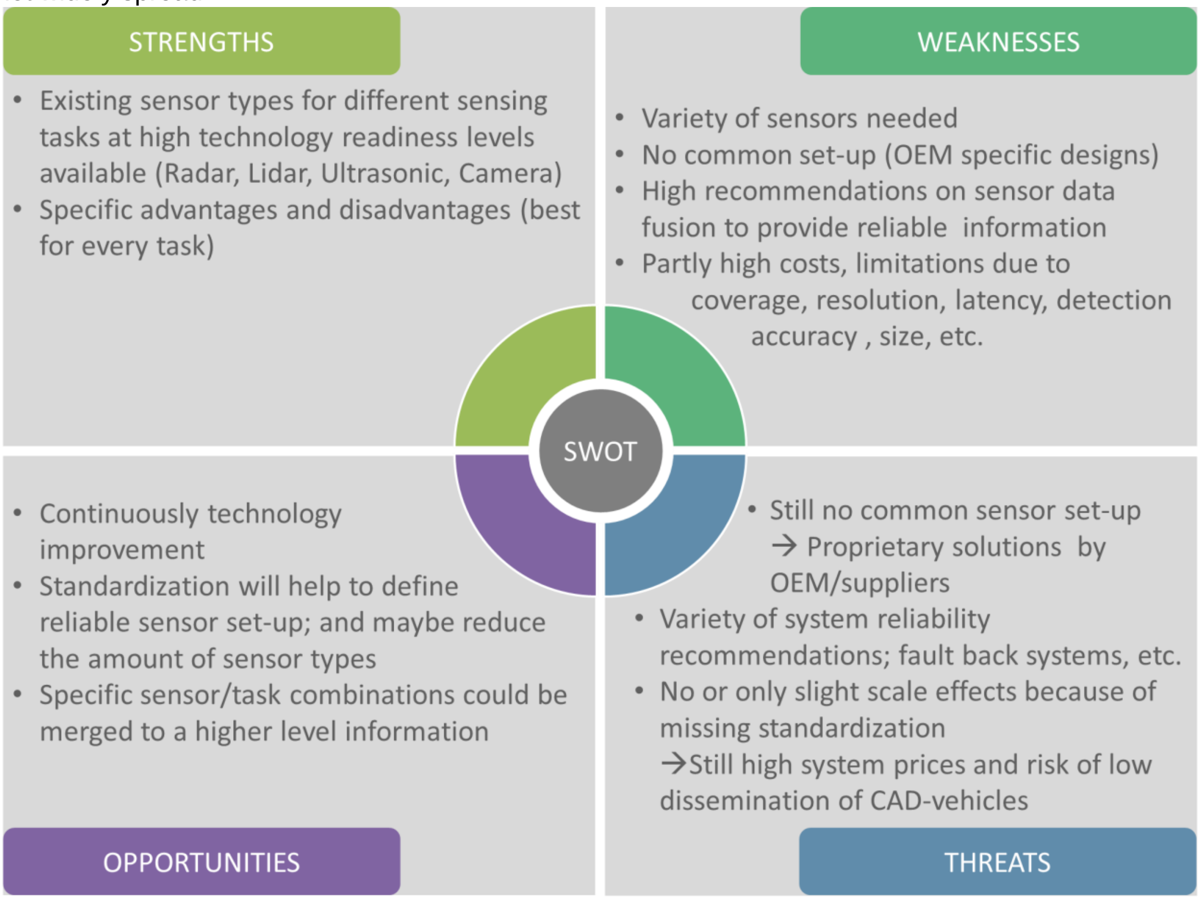


Figure 4: SWOT-Scheme on sensor set-up and vehicle environment perception

### 2.1.3 Navigation and Localization

The availability of High Definition Maps is crucial for automated driving. Comparing to common maps precise information, in range of a few centimeters, is needed to enable automated vehicle navigation. So navigation maps need to provide detailed information e.g. on lane markings, curbs, barriers, poles, overpasses, underpasses and traffic signs. Navigation maps match features, objects and road contours to precise position for automated car guidance.

Although high definition maps with above mentioned feature and more (traffic conditions or location based driver behavior) are available it is questioned if their availability in case of data and price is sufficient to provide safe and secure navigational basis for automated vehicles. Beside this, a set of satellite navigation systems with global (GPS, GALLIEO, GLONASS) or regional (QZSS, IRNSS, COMPASS) coverage, the availability of satellite positioning signals is not comprehensive, depending on the area (e.g. tunnels) as well as certain atmospheric or weather conditions (e.g. heavy rain). Also the accuracy of satellite positioning on lane level without additional sensing is not at all available (especially in areas with high signal reflexing) yet. EU-System GALLILEO actually provides precision in range of meters but with combination satellite navigational systems greater signal coverage as well as accuracy could be increased. Additional sensing (vehicle, infrastructure) in combination with map data also will help to increase signal availability.

Without appropriate and precise navigation and localization, reliable CAD features either had to be performed by even infrastructure sensing (connectivity) and/or environmental perception technology or could not be ensured within the time scope; so market availability of CAD would be significantly delayed.

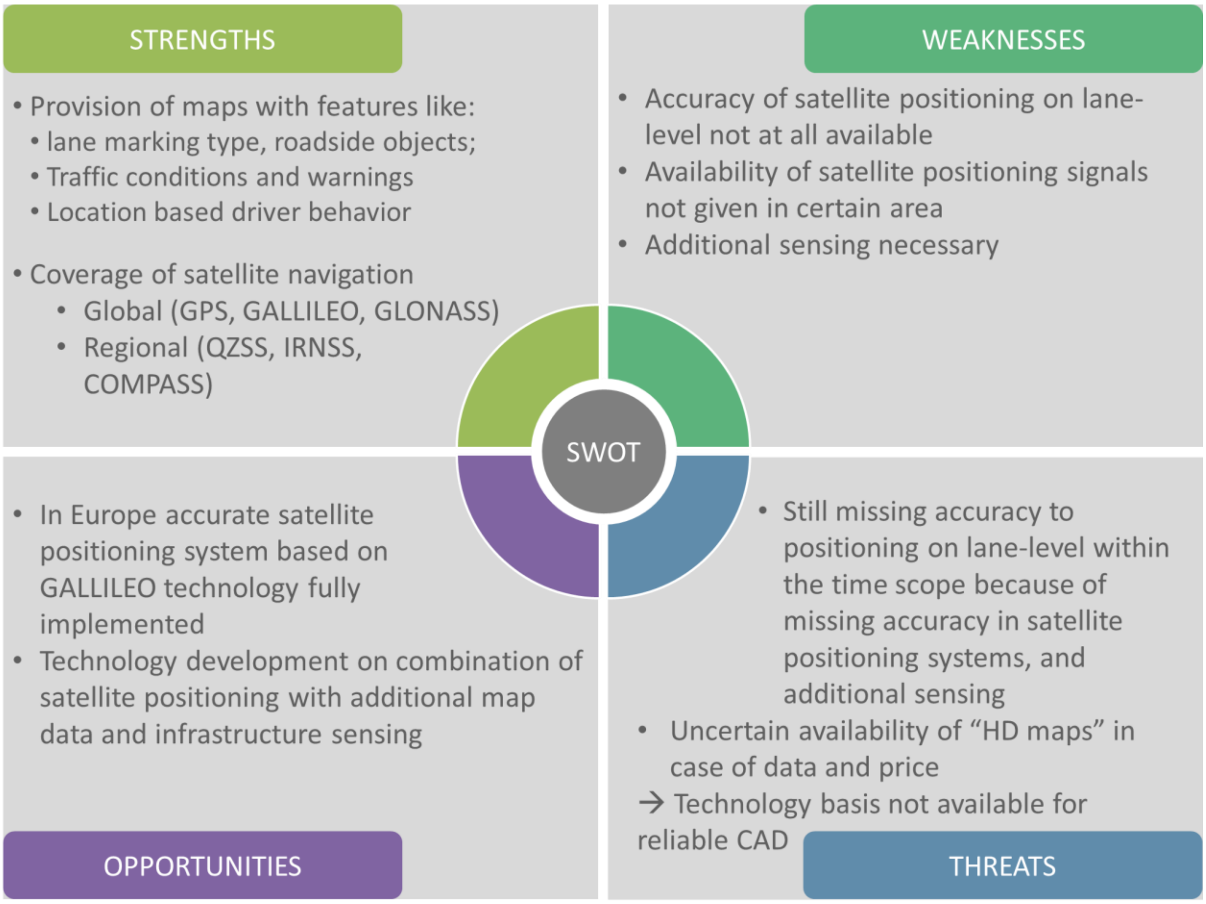

Figure 5: SWOT-Scheme on navigation and localization technology

## 2.2 Think

The sensing framework described in chapter 2.1, delivers various information about the vehicle and its surrounding environment. But the single sensor data can provide a full understanding of the automated vehicle environment. The single sources need to be merged to create a common 360° representation of the environment. To provide automated driving the scene understanding is the basis for behavior generation, real-time decision making and trajectory planning. Therefore efficient and effective data processing hard- and software is needed, as well as adequate system architecture.

### 2.2.1 Sensor Fusion/E-E-Architecture

The use of complementary sensor types is quite established to perceive the vehicle environment. For example the fusion of distance measurement sensor data with camera information is well developed. Algorithms are established to allow sensor fusion for observing dynamic objects but they still need to be improved. Areas of improvement cover object detection, classification and detection rates. Although the fusion of image and non-image data is generally well studied there is a certain risk that this could not be solved accurately until the anticipated time scope.

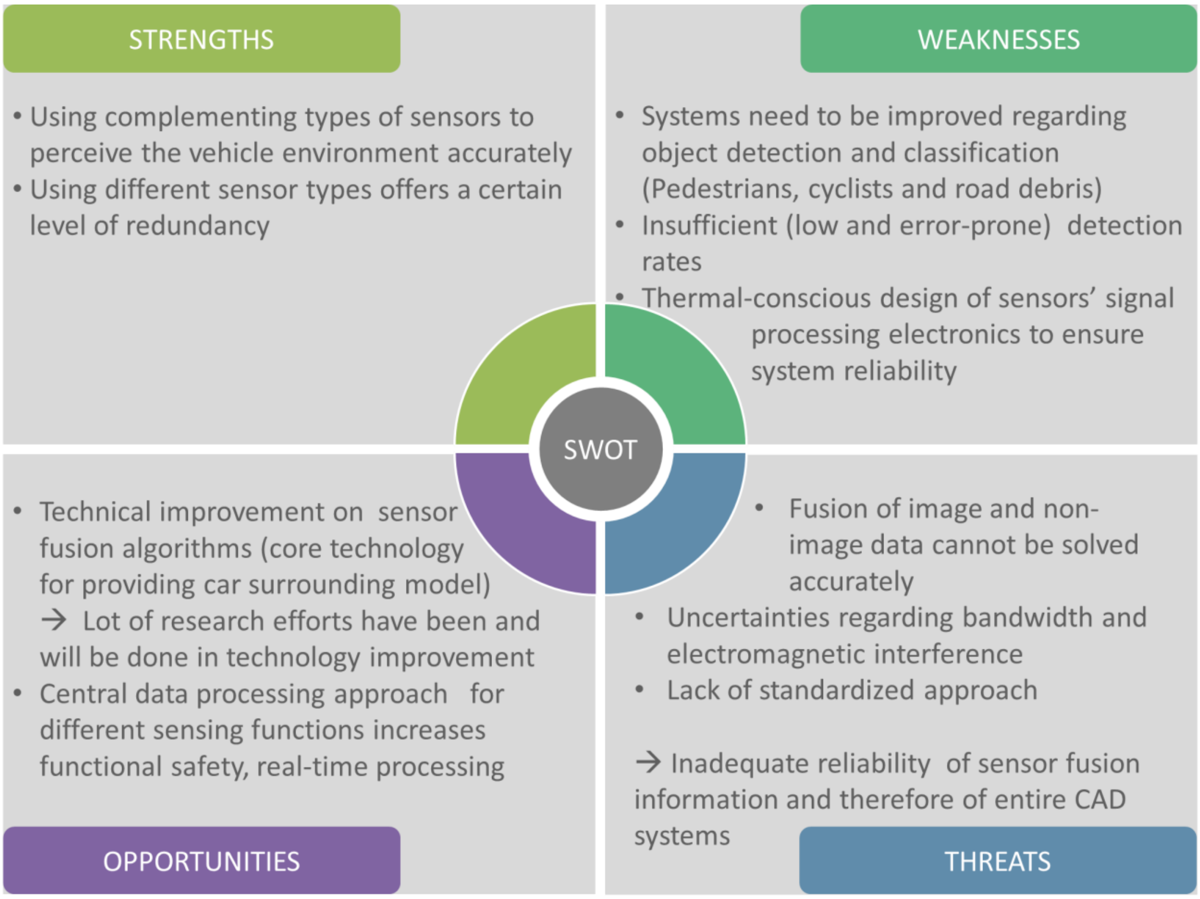


Figure 6: SWOT-Scheme on sensor fusion and E/E-Architecture

Beside sensor fusion algorithms there is no common system set-up has been established yet. While the state of the art in E/E-Systems-Architecture is represented by distributed systems which require processing capable sensors, more space, power and functional safety and they are also expensive. Regarding the future scope of a 360° perception of the vehicle environment and the accompanying challenges in processing power the integration of numerous functions within a central processing unit will be the next step. But there are also some uncertainties regarding wide-bandwidth communication to handle the amount of sensor data in real time and also there will be a possible higher electromagnetic interference to be addressed.

Closely related to sensor fusion is the field of trajectory planning to provide secure and comfortable driving maneuvers. Therefore the fusion of localization information based on high definition maps and environment perception sensors is proposed. But within common trajectory planning methods and algorithms, coming from robotics, perception errors often are not taken into account properly respectively are only locally optimized for the vehicle.

Because of the fact that sensor fusion and derived from that trajectory planning are some core technology for providing vehicle surrounding models the missing of standardized approaches carry the risk of parallel development and proprietary solutions that will complicate compatibility and reliability of automated vehicles. Because of the high importance of sensor fusion for connected and automated driving research efforts concentrate on this topic.

### 2.2.2 Artificial Intelligence

While sensor fusion is needed to generate a real-time vehicle surrounding model algorithms are needed that will process this environment to generate automated driving decisions. So, lots of investments have been made in research to develop and apply suitable AI-Technology in the automotive industry. Especially the further development of deep learning algorithms, especially the approach of Artificial Neural Networks, and their application to automated driving has to be mentioned in this context.

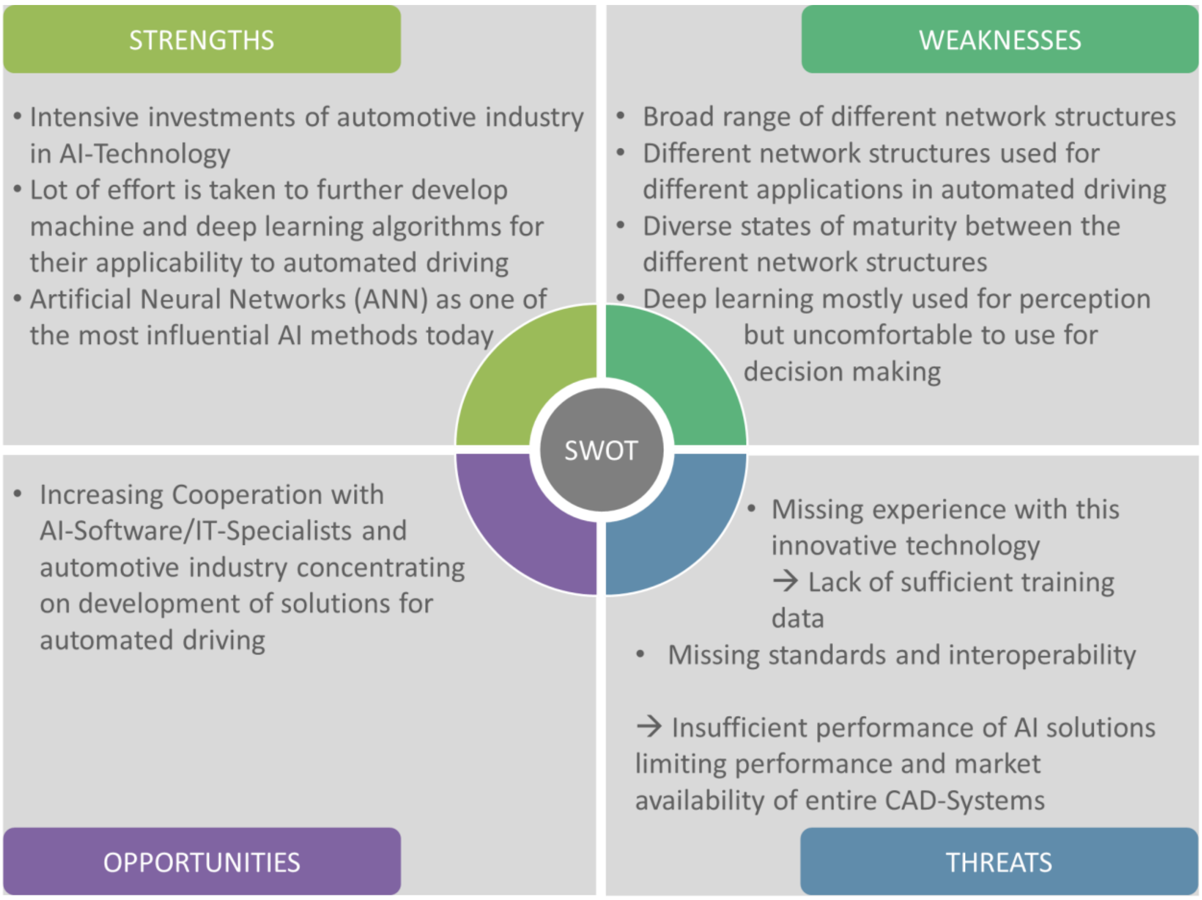


Figure 7: SWOT-Scheme on artificial Intelligence

Nevertheless a broad range of different artificial network structures exist. Because they have specific advantages different network structures are used for applications in automated driving. And also these network structures are quite diverse in state of maturity. Another limiting factor at the moment is the fact that deep learning today is mostly used for perception but uncomfortable to use for decision making in automated driving. So there is still lack of core technology to make the vision of high automated and connected vehicles come reality.

On the other hand high investments and increasing cooperation between AI-Software/IT-Specialists and the automotive industry concentrating on development of AI-Solutions for automated vehicles is speeding up the process and may close the technological gap until the end of the time scope of the SCOUT project. Missing standards and for that missing interoperability between OEM solutions on one hand carrying the risk that benefits of automated and connected driving could not be fully reached. Even worse could be the risk that insufficient performance of AI solutions which are crucial for the reliability of high automated CAD-Systems will significantly delay there market availability.

## 2.3 Act

Actuators in automated driving are used to control the physical operation of a vehicle, e.g. steering, braking. Importantly actuators are limited by physical constraints, including vehicle dynamics and the speed of the actuator itself. Thus, automated driving systems must account for the time lag between issuing commands and the physical response of the vehicle. Regarding Level 5 automation sensor (see chapter 2.1) and actuation technology will replace the driver as observer and physical backup by technical systems.

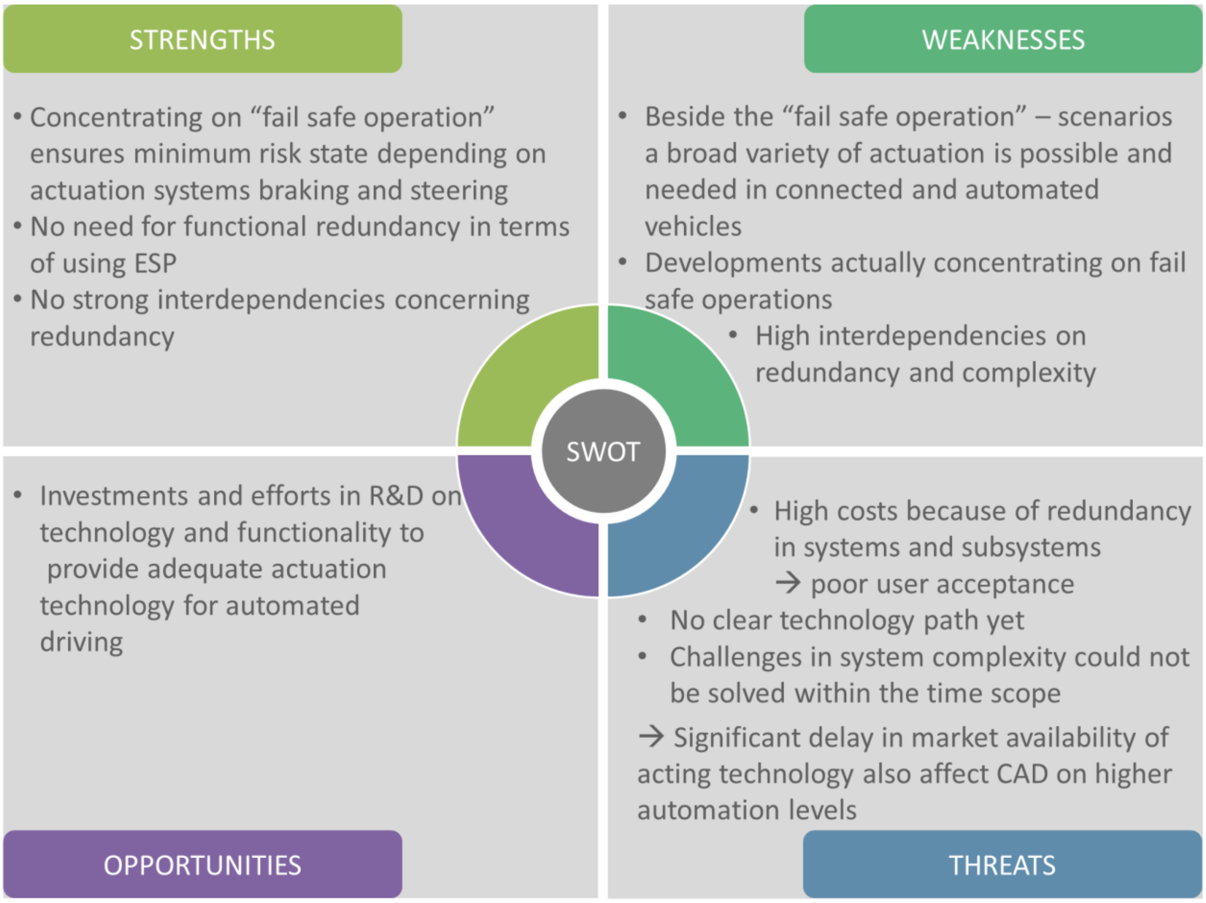

Figure 8: SWOT-Scheme on actuation technology

Beside the existing driving assistance systems, where the driver always is in charge as "physical backup" actuator technology for fully automated driving is concentrating on "fail safe operation" which ensures minimum risk state. Thus the state of the art brake- and steering systems have no strong interdependencies concerning supporting systems as power-net and data-processing net.

But beyond the mentioned "fail safe operation scenarios" a broad variety of actuation, with high interdependencies on redundancy and complexity, is possible and needed in connected and automated vehicles.

Although lots of R&D is going on in developing functionality there is still no clear technology path ahead. There is always the risk of high vehicle costs because of redundancy in systems and subsystems. Other efforts encounter challenges in system complexity may not be solved within the time scope. Summing up, it could be said that there are several risks regarding further development of actuation technology for CAD-systems regarding functionality, safety and reliability which carry the risk that the market entry of full CAD-systems will be delayed significantly respectively are limited to very small user groups because of high prices

## 2.4 Security

With about 85% of vehicles are expected to be connected to the internet by 2020 with more than 50 vulnerable points opening the door for cybercrime functional security of automated and especially connected vehicles is indispensable connected to functional safety. So security has to be designed into the future connected vehicle form the beginning (Security-by-Design). Security should be considered at all levels of the car architecture to provide secure machine to machine authentication, centralized intrusion detection (firewall), distributed intrusion detection and message authentication as well as secure boot, run time integrity and over the air update.

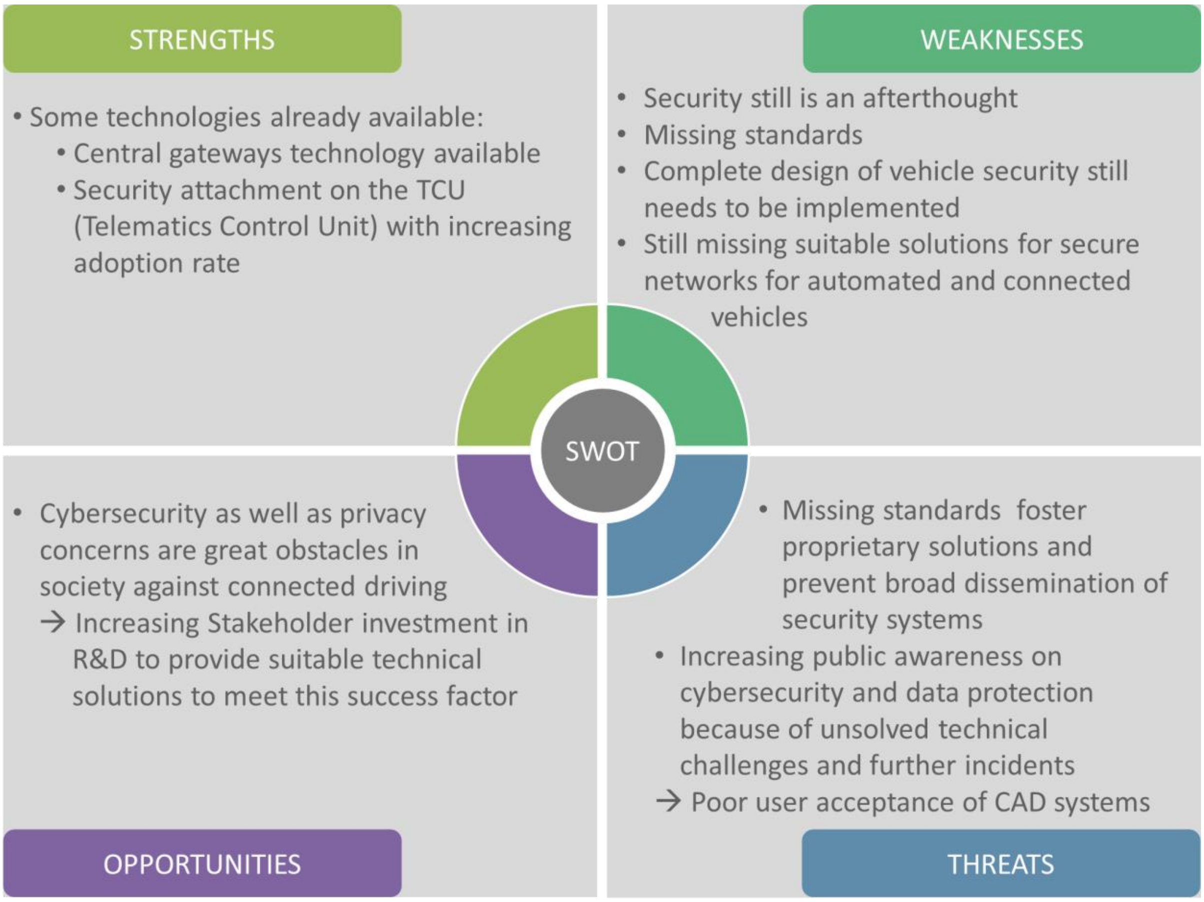


Figure 9: SWOT-Scheme on security technologies

While some technologies regarding central gateway and security attachment on the telematics control unit are already available there is still need for improvement and adoption of technical solutions into the vehicle. So central gateway in vehicles are about 20% today, expected to increase to 50% by 2020 it is still not enough to serve the requirements on safe and secure automated and connected driving. Also security attachments are available for the telematics control unit to provide machine-to-machine authentication.

Security also in cars is still an afterthought. In context of the fact of increasing connectivity suitable solutions for all levels of car architectures are needed especially in the case of network security (message authentication scheme, distributed intrusion detection, etc.). Overall the complete design of vehicle security still needs to be implemented to secure the vehicle throughout the entire lifecycle. Therefore again standards are needed to ensure a technological baseline of security.

As mentioned above cyber-security and functional safety are closely interlinked with automated and connected vehicles by both aspects representing two of the most relevant obstacles in user acceptance concerning connectivity and automation of vehicles. With respect to this societal importance research and development has been increased within the industry as well as public research projects will cover these topics in the future. The provision of technological solutions will be mandatory for the success of connected and automated driving. If not user acceptance will still be poor and therefore market demand and dissemination of CAD will be low.

## 2.5 Connectivity

Beside vehicle onboard sensors and devices described in chapter 2.1 Intelligent Transport Systems (ITS) use technologies that allow road vehicles to communicate with each other (vehicle to vehicle communication (V2V)), with roadside infrastructure (vehicle to infrastructure communication (V2I)) as well as other road users, summarized as vehicle to x (V2X) communication. This concept has been already tested and validated in several large-scale-pilots. The concept behind vehicle to x communication is that connected vehicles become part of a fully connected hybrid communication system including intelligent road infrastructure, distributed sensors, private and public control centers. With each node exchange data with others this creates a cooperative environment building the basis for innovative ICT services for public administrations, mobility related businesses and the end users.

Vehicle to x communication is based on the ETSI ITS G5 standard (based on IEEE 802.11p). It is essential for upcoming developments to ensure interoperability without that safety related functions will not work. The G5 standard is expected to be defined and started to be deployed by the end of this decade. The European Commission is taking big effort and set a high priority in deployment of ETSI ITS G5 standard by concerning regulatory, standardization actions as well as R&D-Projects and pilots to enable a fast move at European scale for implementation.

To support or better ensure safe and secure connected and automated driving the 5G standard defined technical requirements e.g. on latency, reliability, data rate, range, position accuracy. Also it provides use cases on automated overtake, cooperative collision avoidance or high density platooning. Although a lot of *research and deployment* effort has been done yet and will be on the pathway for the near future to provide vehicle to x connectivity support for automated and connected driving, market implementations not yet available. Also infrastructure investments may not be done without additional funding.

But as far as connectivity requirements regarding V2X-communication is seen to be crucial for the provision of efficient and reliable CAD-systems the establishment of the 5G-Standard seems mandatory.

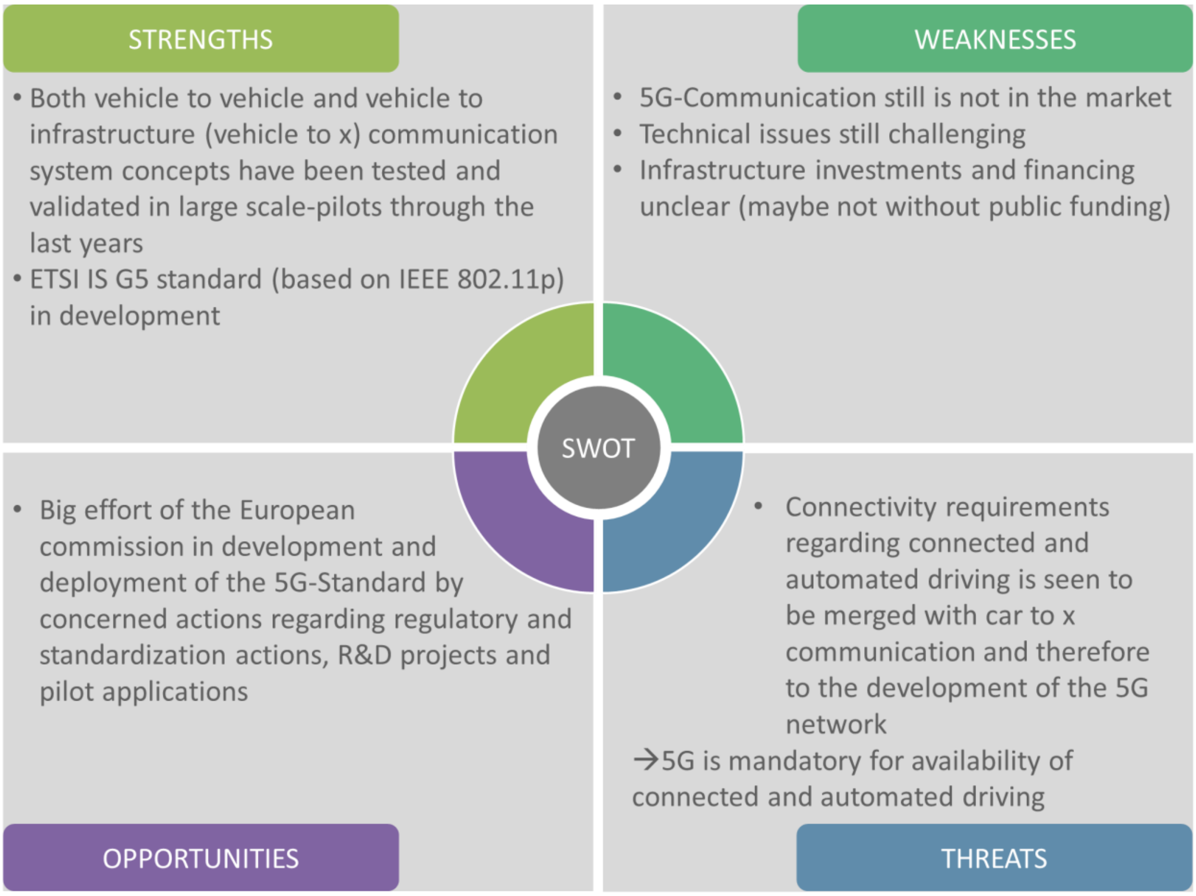


Figure 10: SWOT-Scheme on connectivity technology

# 3 SWOT-Analysis on legal layer

Beside the technical feasibility of automated and connected driving in automation Levels 4 and 5 it is mandatory to adapt legal regulations on traffic and testing, liability, insurance, data security or type approval globally an on a EU-Member state level.

Basis of the European legislation on traffic in general is the Vienna Convention from 1968. It is the main legal basis for regulation in the EU and its member states. Regulations concerning connected and automated driving are the need of a driver to maintain permanent vehicle control, the keeping of a safety distance between vehicles, technical requirements of vehicles and regulation regarding the steering system. Several amendments (Article 8 and UN-R 79) enabling automated driving under certain circumstances (e.g. automate parking systems, lane change by driver initiation, etc.) but development and testing of connected and automated vehicles on higher automation levels is still restricted.

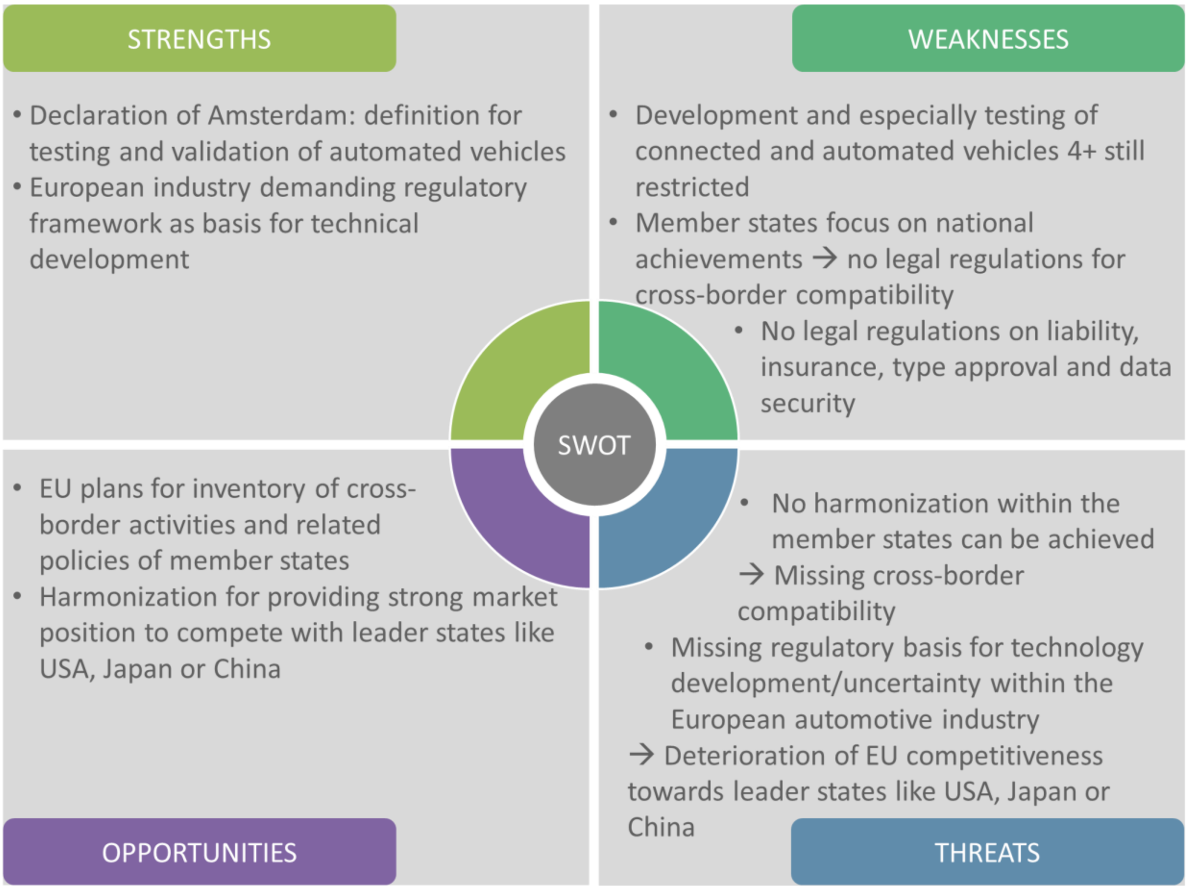


Figure 11: SWOT-Scheme on legal issues

With the "Declaration of Amsterdam" the transport ministers of all member states adopted an agreement how to develop self-driving technology. Therefore national legal authorities defined regulations for testing and validation of automated vehicles.

Despite this progress member states focus mainly on national achievements. There is no harmonization between the different member states. But standardization and harmonization on connected and automated driving is not only mandatory in technology but also in legal regulations to ensure cross-border compatibility of future automated vehicles. This not only includes regulatory framework on development and testing but also regulations on liability, insurance, type approval and data security. None of the last mentioned legal issues has been defined yet. There still is great uncertainty within the European automotive industry with respect to development and testing of connected and automated vehicles and therefore legal certainty is mandatory to create a sound basis for technological development. As a first step the EU plans to initiate an inventory of cross border activities and related policies of the member states.

By achieving a harmonized approach on technology development as well as on legal framework the EU would gain a strong market power in competition with leader states on connected and automated driving like USA and Japan and would be prepared for upcoming competition from China, were actual legal restrictions for field testing of automated vehicle are going to be reconsidered.

# 4 SWOT-Analysis on human factors layer

In the last years several studies have been carried out to analyze the user acceptance of automation levels beyond SAE-Level 3.

Closely related to user acceptance on connected and automated driving are topics like functional safety and data/cyber-security. Although acceptance has slightly increased in the past years there is still mistrust in technology issues, also supported by recent incidents. The Deloitte Global Automotive Consumer Study shows that even in the US which is one of the technological leading countries in automated driving about 74% of consumers feel that full self-driving vehicles will not be safe. (e.g. for Germany there are 72% in contrast to India and China with 64% respectively 62%). The trust in automated technology also depends on the companies providing full automated vehicles. Thus most users will more rely on automated vehicles form traditional OEMs (see Figure 12).

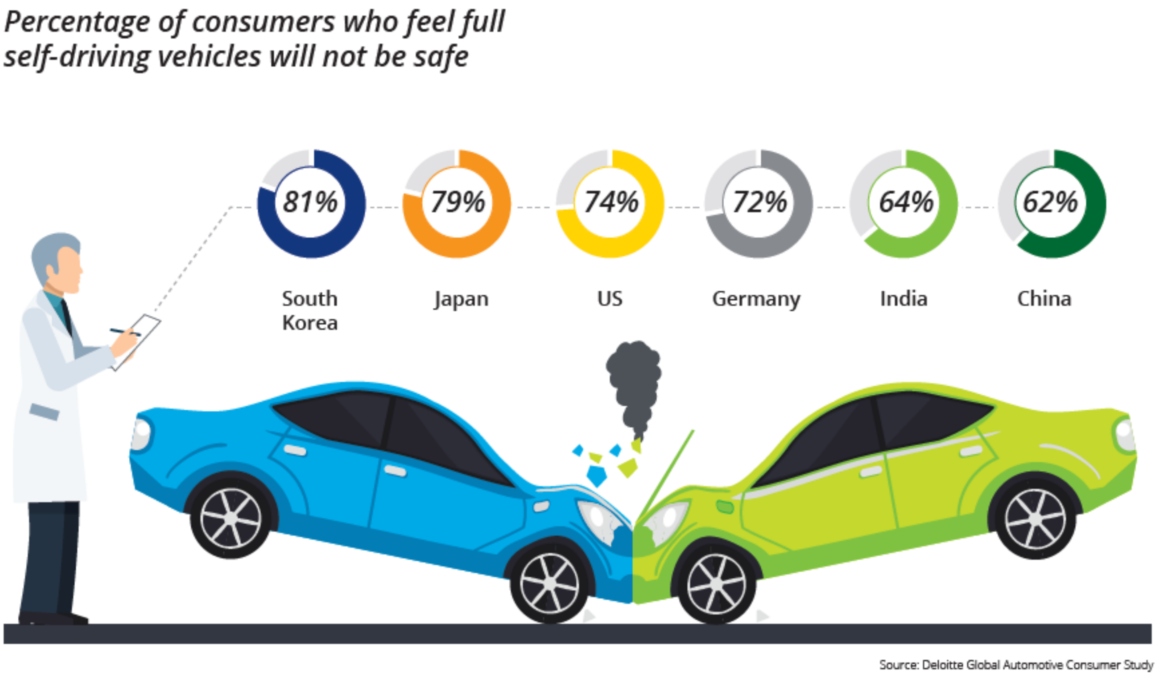


Figure 12: How consumers feel about automated vehicles (Source: Deloitte Global Automotive Consumer Study)

The same study mentioned a decline of the expected price consumers are willing to pay for advanced automotive technologies (also includes automated vehicles).

A study of HERE Technologies on Consumer Acceptance of Autonomous Vehicles also observes the willingness to drive or even buy an automated vehicle which is claimed to be significantly higher if the user has already experience with Advanced Driving Assistance Systems (ADAS) in contrast to users without (see Figure 13).

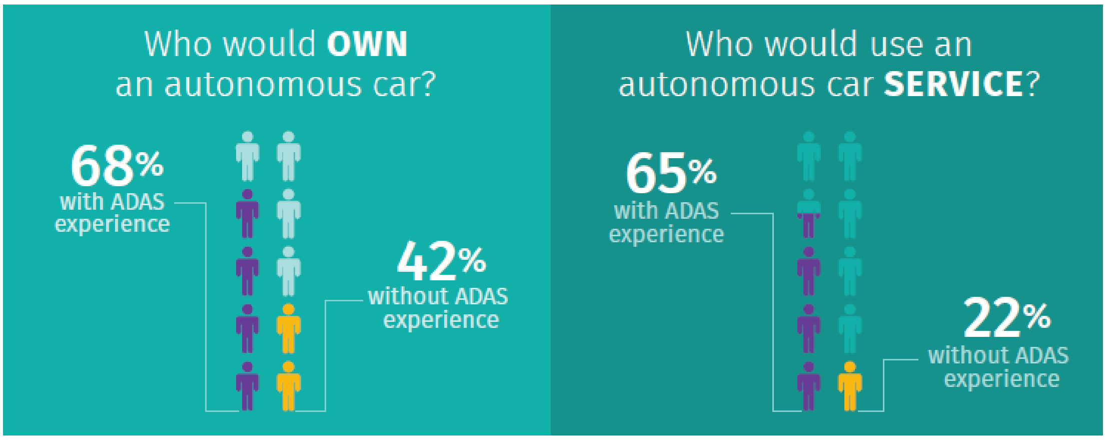


Figure 13: User acceptance on automated driving based on experience with ADAS (Source: HERE Technologies 2017)

Although the hurdle for using a fully automated vehicle for users with experience with ADAS maybe on level 2 automation is lower than for unexperienced users still the possibility for the driver to control the vehicle and the willingness to intervene if necessary (which is quite subjective) seems to be a crucial factor for acceptance of automated driving. (see also Figure 14)

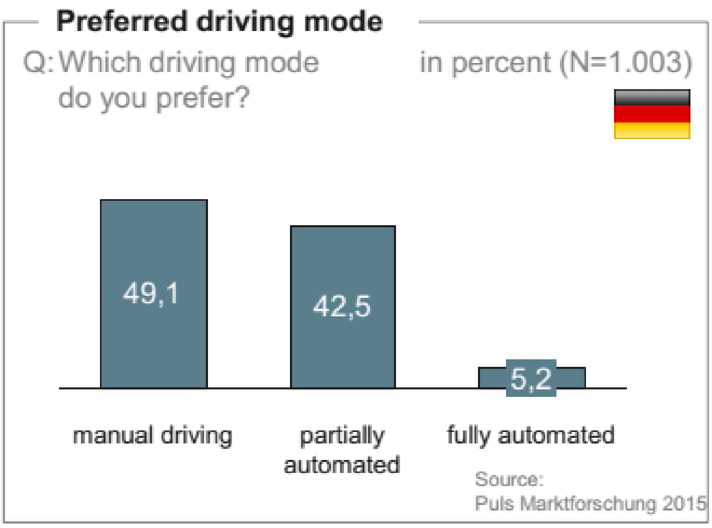


Figure 14: Impression on user acceptance of manual driving vs. partially and fully automated driving

Although there are differences between the member states it could be claimed that people in Europe generally are quite restrained about connected and fully automated vehicles yet. With some deviations most of the people have concerns on passing over vehicle control to an automated system in combination with reservations regarding functional safety. Also cyber security aspects lead to obstacles against high level automation. People fear about systems security against manipulation and data privacy protection regarding the proposed overall connectivity. Actually, all these concerns predominating the proposed advantages of connected and automated driving vehicles which are already known but seem to be “not tangible”. Beside this people also have reservations regarding their willingness to pay respectively estimated prices for connected and automated vehicles and services among them. Without standardization and harmonization in technology and legal regulations these reservations will not be overcome in the upcoming future. According to that the dissemination of connected and automated vehicles will be quite low and therefore the proposed benefits e.g. regarding traffic optimization and increasing traffic safety are still far below expectations.

On the other hand the continuously growth in usage of safety and security automated driving features (at lower automation levels) will also increase the trust and acceptance of higher automation levels. However this will be a slightly increase and depends on positive technology improvement. If this improvement could not be achieved societal reservations will not be overcome and for that dissemination will be quite low so that proposed benefits of CAD also could not be reached.

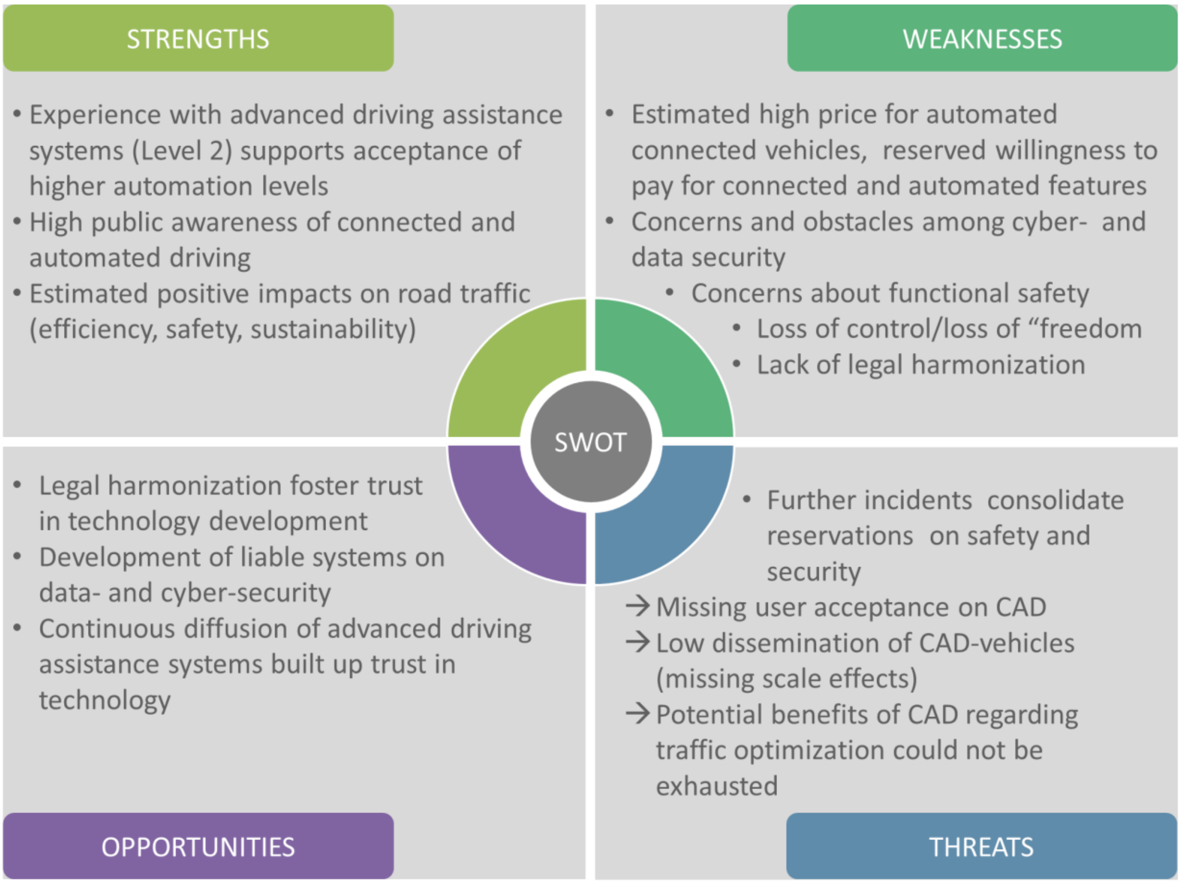


Figure 15: SWOT-Scheme on human factors layer

# 5 General Conclusions

Regarding technology research and development is still necessary to provide reliable systems for fully automated vehicles. Lots of efforts are being made by the industry side as well as by public authorities (funded projects, infrastructure investments, etc.) to overcome existing hurdles and to close technological gaps. But by reviewing the different technological aspects as well as policy and legal issues on connected and automated driving, there is one aspect that runs like a thread as one overall challenge: standardization.

In nearly all the investigated technological developments standardization is needed to create reliable development paths for research and industry as well as to prevent proprietary solutions. This lasts from standardization of data interfaces, data processing, data exchange or decision making parameters, safety and security issues like testing and validation schemes as well as reliability features for components and systems. This affects not only technologies within the automated vehicle itself but also communication technology regarding vehicle to vehicle communication or vehicle to infrastructure communication. To achieve full benefits of connected and automated driving standardization is the basis for all interoperability regarding different OEMs and in cross boarder traffic.

But not only technical standards are needed. Harmonization of different legal regulations is necessary in order to make connected and fully automated driving finally possible. To provide cross border functionality harmonization is mandatory not only in communication technology but also in approval regulations or liability and insurance issues. Besides that, legal regulations need to be harmonized to enable the testing and validation of connected and automated driving technologies under reality conditions. Because these findings are crucial for further development of connected and automated vehicle systems. Although the EU and ahead some Member States like Germany, the Netherlands or Sweden are international competitive in connected and automated vehicle technology it is mandatory to provide a reliable legal framework for all stakeholders from research to industry to keep in position.

Although user acceptance could be improved the trust in automotive industry to provide safe and reliable technology solutions is a sound basis for further developments and to increase trust in connected and fully automated driving technologies, especially when security should be considered as a natural part of the CAD architecture.

# 6 Bibliography

Bundesministerium für Verkehr, Innovation und Technologie. (2016). “utomatisiert – Vernetzt – Mobil, Aktionsplan Automatisiertes Fahren, 2016

Center for Automative Research (CAR) (2016). International Scan of Connected and Automated Vehicle Technology Deployment Efforts,Study on behalf of Michigan Department of Transportation, 2016,

Deloitte (2017). What's ahead for fully autonomous driving - Consumer opinions on advanced vehicle technology. 2017

Eckstein, L. (2014). Aktive Fahrzeugsicherheit und Fahrerassistenz, Lecture Notes, Aachen, 2014

EPoSS (2015). European Roadmap Smart Systems for Automated Driving

Estl, Hannes. (2016). Mehr als die Summe der Teile - Sensorfusion in autonomen Fahrsystemen. Automobilelektronik 05-06.2016, Page 38-41

European Transport Safety Council ETCS (2016). Prioritising the Safety Potential of Automated Drivinng in Europe, April 2016.

Foley & Lardner LLP. (2017). 2017 Connected Cars & Autonomous Vehicles Survey.

Frost & Sullivan. (2014). Cybersecurity in the automotive industry, October 2014 European Commission (2017). Public Support Measures for Connected and Automated Driving, Final Report, May 2017

Fraunhofer IAO und HORVÁTH & PARTNERS. (2016). *The Value of Time - Nutzerbezogene Service-Potenziale durch autonomes Fahren.*

FTI Consulting (2017). A Global Race For Autonomous Vehicles - Views from the United States, Europe and Asia, June 2017

GEAR 2030 (2017). Final Report of the High Level Group on the Competitiveness and Sustainable Growth of an Automative industry in the European Union.

HERE Technologies (2017). Consumer Acceptance of Autonomous Vehicles - 3 Key Insights for the Automotive Industry

KPMG. (2018). Autonomous Vehicles Readiness Index McKinsey&Company. (2015). *Competing for the connected customer - perspectives on the opportunities created by car connectivity and automation.*

Langwalter, Joachim (2016).Künstliche Intelligenz im autonomen Fahren, Automobilelektronik05-06.2016, Page 30-33

Kyriakidis, M.; Happee, R.; de Winter, J.C.F (2014). Public opinion on automated driving: Results of an international questionnaire among 5000 repondents, Transportation Research Part F, Elsevier, June 2015.

Peter Otto (2017). The Future of Mobility - On the road to driverless cars, IPSOS Views #12, October 2017.

The Netherlands Ministry of Infrastructure and the Environment (2017). On our way towards connected and automated driving in Europe, Amsterdam, 15th February 2017

PwC. (2016). *Connected car report - Opportunities, risk, and turmoil on the road to autonomous vehicles.*

VanWashenova, Jeff. (2016). Wegbereiter für autonomes Fahren, Automobilelektronik 05-06.2016, Page 18-20

West, Darrell M. (2016). Moving forward: Self-driving vehicles in China, Europe, Japan, Korea and the United States, Center for Technology Innovation at Brookings, September 2016

# 7 Annex: Overview on SWOT for all investigated layers

| Layer | Technology | Strengths | Weaknesses | Opportunities | Threats |
|---|---|---|---|---|---|
| Technical | In-vehicle Sensing | • Broad amount of sensor data available on vehicle or driver status (e.g. tire pressure, engine diagnostics, fatigue monitoring)<br>• High technology readiness<br>• Market availability (sinking costs) | • Actual use of sensor data is related to specific tasks<br>• Not much developed merging of sensor data to meta information (data exchange standards)<br>• Still basic research is needed for reliable driver state sensing regarding attention and especially intention (augmented sensing) | • Existing sensor types and set-ups could be used for advanced connected and automated features<br>• In-Vehicle sensing, could also be basis for new business opportunities (road condition data exchange, predictive maintenance, etc.) | • Still missing data communication and data exchange standards and unsolved tasks regarding driver state sensing<br>→ No appropriate use of in-Vehicle sensing for CAD because of missing standardization<br>→ Sensing information is not available or sensing tasks have to be passed to e.g. environment perception or connectivity |
| | Sensor Set-up / Environment perception | • Existing sensor types for different sensing tasks at high technology readiness levels available (Radar, Lidar, Ultrasonic, Camera)<br>• Specific advantages and disadvantages (best for every task) | • Variety of sensors needed<br>• No common set-up (OEM specific designs)<br>• High recommendations on sensor data fusion to provide reliable information<br>• Partly high costs, limitations due to coverage, resolution, latency, detection accuracy , size, etc. | • Continuously technology improvement<br>• Standardization will help to define reliable sensor set-up; and maybe reduce the amount of sensor types<br>• Specific sensor/task combinations could be merged to a higher level information | • Still no common sensor set-up<br>→ Proprietary solutions by OEM/suppliers<br>• Variety of system reliability recommendations; fault back systems, etc.<br>• No or only slight scale effects because of missing standardization<br>→Still high system prices and risk of low dissemination of CAD-vehicles |
| | Navigation and Localization | • Provision of maps with features like:<br>○ lane marking type, roadside objects;<br>○ Traffic conditions and warnings<br>○ Location based driver behavior<br>• Coverage of satellite navigation<br>○ Global (GPS, GALLILEO, GLONASS)<br>○ Regional (QZSS, IRNSS,<br>○ COMPASS) | • In Europe accurate satellite positioning system based on GALLILEO technology fully implemented<br>• Technology development on combination of satellite positioning with additional map data and infrastructure sensing | • Accuracy of satellite positioning on lane-level not at all available<br>• Availability of satellite positioning signals not given in certain area<br>• Additional sensing necessary | • Still missing accuracy to positioning on lane-level within the time scope because of missing accuracy in satellite positioning systems, and additional sensing<br>• Uncertain availability of “HD maps” in case of data and price<br>→ Technology basis not available for reliable CAD |

| Layer | Technology | Strengths | Weaknesses | Opportunities | Threats |
|---|---|---|---|---|---|
| Technical | Sensor Fusion/E-E-Architecture | • Using complementing types of sensors to perceive the vehicle environment accurately<br>• Using different sensor types offers a certain level of redundancy | • Systems need to be improved regarding object detection and classification (Pedestrians, cyclists and road debris)<br>• Insufficient (low and error-prone) detection rates<br>• Thermal-conscious design of sensors' signal processing electronics to ensure system reliability | • Technical improvement on sensor fusion algorithms (core technology for providing car surrounding model) → Lot of research efforts have been and will be done in technology improvement<br>• Central data processing approach for different sensing functions increases functional safety, real-time processing | • Fusion of image and non-image data cannot be solved accurately<br>• Uncertainties regarding bandwidth and electromagnetic interference<br>• Lack of standardized approach → Inadequate reliability of sensor fusion information and therefore of entire CAD systems |
| | Artificial Intelligence | • Intensive investments of automotive industry in AI-Technology<br>• Lot of effort is taken to further develop machine and deep learning algorithms for their applicability to automated driving<br>• Artificial Neural Networks (ANN) as one of the most influential AI methods today | • Broad range of different network structures<br>• Different network structures used for different applications in automated driving<br>• Diverse states of maturity between the different network structures<br>• Deep learning mostly used for perception but uncomfortable to use for decision making | • Increasing Cooperation with AI-Software/IT-Specialists and automotive industry concentrating on development of solutions for automated driving | • Missing experience with this innovative technology → Lack of sufficient training data<br>• Missing standards and interoperability → Insufficient performance of AI solutions limiting performance and market availability of entire CAD-Systems |
| | Act | • Concentrating on "fail safe operation" ensures minimum risk state depending on actuation systems braking and steering<br>• No need for functional redundancy in terms of using ESP<br>• No strong interdependencies concerning redundancy | • Beside the "fail safe operation" – scenarios a broad variety of actuation is possible and needed in connected and automated vehicles<br>• Developments actually concentrating on fail safe operations<br>• High interdependencies on redundancy and complexity | • Investments and efforts in R&D on technology and functionality to provide adequate actuation technology for automated driving | • High costs because of redundancy in systems and subsystems → poor user acceptance<br>• No clear technology path yet<br>• Challenges in system complexity could not be solved within the time scope<br><br>→ Significant delay in market availability of acting technology also affect CAD on higher automation levels |
| | Security | • Some technologies already available:<br>  ○ Central gateways technology available<br>  ○ Security attachment on the TCU (Telematics Control Unit) with increasing adoption rate | • Security still is an afterthought<br>• Missing standards<br>• Complete design of vehicle security still needs to be implemented<br>• Still missing suitable solutions for secure networks for automated and connected vehicles | • Cybersecurity as well as privacy concerns are great obstacles in society against connected driving → Increasing Stakeholder investment in R&D to provide suitable technical solutions to meet this success factor | • High costs because of redundancy in systems and subsystems → poor user acceptance<br>• No clear technology path yet<br>• Challenges in system complexity could not be solved within the time scope → Significant delay in market availability of acting technology also affect CAD on higher automation levels |

| Layer | Technology | Strengths | Weaknesses | Opportunities | Threats |
|---|---|---|---|---|---|
| Technical | Connectivity | • Both vehicle to vehicle and vehicle to infrastructure (vehicle to x) communication system concepts have been tested and validated in large scale-pilots through the last years<br>• ETSI IS G5 standard (based on IEEE 802.11p) in development | • 5G-Communication still is not in the market<br>• Technical issues still challenging<br>• Infrastructure investments and financing unclear (maybe not without public funding) | • Big effort of the European commission in development and deployment of the 5G-Standard by concerned actions regarding regulatory and standardization actions, R&D projects and pilot applications | • Connectivity requirements regarding connected and automated driving is seen to be merged with car to x communication and therefore to the development of the 5G network<br>→5G is mandatory for availability of connected and automated driving |
| Legal | | • Declaration of Amsterdam: definition for testing and validation of automated vehicles<br>• European industry demanding regulatory framework as basis for technical development | • Development and especially testing of connected and automated vehicles 4+ still restricted<br>• Member states focus on national achievements<br>→ no legal regulations for cross-border compatibility<br>• No legal regulations on liability, insurance, type approval and data security | • EU plans for inventory of cross-border activities and related policies of member states<br>• Harmonization for providing strong market position to compete with leader states like USA, Japan or China | • No harmonization within the member states can be achieved<br>→ Missing cross-border compatibility<br>• Missing regulatory basis for technology development/ uncertainty within the European automotive industry<br>→ Deterioration of EU competitiveness towards leader states like USA, Japan or China |
| Human Factor | | • Experience with advanced driving assistance systems (Level 2) supports acceptance of higher automation levels<br>• High public awareness of connected and automated driving<br>• Estimated positive impacts on road traffic (efficiency, safety, sustainability) | • Estimated high price for automated connected vehicles, reserved willingness to pay for connected and automated features<br>• Concerns and obstacles among cyber- and data security<br>• Concerns about functional safety<br>• Loss of control/loss of "freedom<br>• Lack of legal harmonization | • Legal harmonization foster trust in technology development<br>• Development of liable systems on data- and cyber-security<br>• Continuous diffusion of advanced driving assistance systems built up trust in technology | • Further incidents consolidate reservations on safety and security<br>→ Missing user acceptance on CAD<br>→ Low dissemination of CAD-vehicles (missing scale effects)<br>→ Potential benefits of CAD regarding traffic optimization could not be exhausted |