5.1
Estimating the impact of barriers of connected and automated driving

SCOUT

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1 Introduction and methodology

This deliverable summarizes the results of Task 5.1 of the SCOUT project, which served to estimate the impact of barriers of Connected and Automated Driving (CAD). During the collection of the state of the art in WP 3 and the market analysis in WP 4 relevant barriers were collected in stakeholder consultation across all of the five layers that unite both technical and non-technical factors that contribute to the advancement of CAD and the assessment will be presented below.
As for all of the discussions and deliverables that will ultimately lead to the creation of the roadmap for level 4/5 CAD, the 5-layer model of Eckstein was used as the guiding framework for discussions and to identify gaps, challenges and barriers for each layer. The risks associated with these gaps, challenges and barriers have been rated by the SCOUT consortium regarding the probability of the risk to occur as well as the severity, detectability and recoverability in case of occurrence.
The method employed to estimate the impact of barriers is the Failure Mode and Effect Analysis (FMEA), more specifically an extended FMEA, which presents an adaptation of FMEA typically used to assess the reliability of products or software as part of quality assurance processes. Extended FMEA was developed as a risk assessment methodology for Advanced Driver Assistance Systems (ADAS) by Bekiaris and Stevens [1] and has already been used to assess risks in technology development, e.g. for future transport scenarios within the Mobility4EU project [2].

To perform an FMEA the factors for risk assessment were rated on a scale of 0-10, from low to high (for probability and severity) and from easy to difficult (for detectability and recoverability). It is important to note that in order to have an indicator for the criticality of a specific risk, detectability and recoverability are in contradiction of their literal sense (i.e. a high rating for detectability marks a risk that is difficult to detect).
To obtain a risk index that enables the assessment and comparison of risks the following formula is used:

$$[Risk\ Index] = [Probability] * [Severity] * \left[\frac{[Detectability] + [Recoverability]}{2}\right]$$

The risk index can thus assume values between 0 and 1000 to capture increasing degrees of criticality.[1]

[1] In this deliverable the risk indices have been rounded to integer values.

2 Risk assessment

The barriers identified in the course of the project are rated across all five layers on the following pages. In addition, mitigation strategies will be presented for the three most critical risks of each layer.

Technical:

Risk/challenge	Probability (0-10)	Severity (0-10)	Detectability (0-10)	Recoverability (0-10)	Index
Lack of data protection & privacy	7	6	5	6	**231**
Lack of cybersecurity	7	9	5	5	**315**
Lack of standardisation (multi-brand)	7	5	2	5	**123**
Validation issues for AI decision making	8	8	4	8	**384**
Harmonization issues e.g. type approval	7	8	2	5	**196**
Big variety of sensor set-ups	8	5	1	6	**140**
Insufficient sensor fusion	7	6	1	5	**126**
Failure of fall back solutions	5	9	2	5	**158**
Low fail operational capabilities of sensors	5	9	2	5	**158**
Lack of robustness & reliability of perception systems	4	9	3	4	**126**
Low recognition of road users and/or traffic situation	4	10	1	5	**120**
Poor performance regarding machine perception	4	10	1	5	**120**
Lack of integration with infrastructure (e.g. connectivity, sensors)	8	8	4	7	**352**
Poor cooperation between telecommunication & automotive	7	7	1	7	**196**
Limited accuracy of localisation	5	8	2	7	**180**
Insufficient maneuver planning	5	8	4	5	**180**
Risk related to artificial intelligence	6	9	3	6	**243**
Insufficient functional safety	5	9	2	6	**180**

The ratings of technical challenges and risks generally exhibit a high detectability (i.e. a high rating value for criticality) and severity, reflecting the role of technology enablers for CAD. The three risks with the highest rating are discussed in detail below:

- **Validation issues for AI decision-making** [risk index = 384]
    - *Risk description*: Due to a lack of transparency and traceability of current AI decision-making processes based on machine learning, their validation poses a major challenge and requires an adapted testing framework. A lack of validation methods also complicates the resolution of legal and ethical issues.
    - *Mitigation strategy*: To reduce the risk for CAD development, AI should be designed for and tested in all conceivable driving and traffic situations using a combination of simulated and real-world test drives. For the validation of AI-

based functions it is thus important to develop reliable simulation and test methods, to ensure reliable system integration and to establish a common testing framework.

- **Lack of integration with the infrastructure (i.e. connectivity, sensors)** [risk index = 352]
  - *Risk description*: Although the level of physical and digital infrastructure required for the successful introduction of CAD is still a point of discussion, an efficient and directed integration of vehicles and infrastructure is required. If the needs for connectivity are not well-defined and not addressed in a timely manner, they risk lacking behind vehicle function development.
  - *Mitigation strategy*: The criticality of this risk can be reduced via the development of integration concepts for traffic control systems, of reliable vehicle sensor systems and of reliable and ubiquitous high-performance communication technologies. Efforts to provide the required digital and physical infrastructure should be launched in the short-term and in coordination with vehicle development, in order to avoid a mismatch between development states and speeds.
- **Lack of cybersecurity** [risk index = 315]
  - *Risk description:* Cybersecurity is a risk for all applications that take advantage of modern communication technologies, but is strongly exacerbated for life-critical applications such as vehicle control.
  - *Mitigation strategy:* The lack of cybersecurity can be obviated by ensuring security by design, developing reliable fallback strategies and protection software as well as monitoring schemes and encryption technologies. A strong monitoring of and exchange with other fields concerned with cybersecurity (e.g. from the IT sector) can provide valuable input for a safety-first approach.

Legal:

Risk/challenge	Probability (0-10)	Severity (0-10)	Detectability (0-10)	Recoverability (0-10)	Index
Lack of clear regulations	5	9	4	5	**203**
Outdated Vienna Convention	6	9	2	5	**189**
Outdated national laws	6	9	2	5	**189**
Lack of universal EU regulations	5	9	2	5	**158**
Lack of insurance	6	8	2	7	**216**
Unclear liability	7	8	3	7	**280**
Lack of standardization	7	7	3	5	**196**
Lack of data protection	7	7	5	6	**270**
Missing support for infrastructure investments	6	7	6	5	**231**
Missing certification	6	8	4	5	**216**
Dynamic changes vs. type approval	6	7	5	5	**210**
No regulations regarding “new driving” licences	5	6	4	3	**105**

For the legal layer several risks cover the lack of regulations on national, cross-border and international regulations. These are marked by a high level of severity and detectability but also medium recoverability, except for the definition of liabilities. The latter is marked by significant uncertainty concerning its resolution, e.g. due to the associated ethical questions, and at the same time has a strong impact on other risks of the legal layer, in particular the lack of insurance which is attributed equal severity and recoverability due to this dependence.

- **Unclear liability** [risk index = 280]
  - *Risk description:* The increasing number of tasks that will be transferred from human to computer control with increasing levels of automation requires clear definitions of liabilities of vehicle manufacturers, providers and users.
  - *Mitigation strategy:* A clarification of responsibilities between stakeholders must be performed and translated into a legal framework that covers the specialties introduced by CAD.
- **Lack of data protection** [risk index = 270]
  - *Risk description:* A lack of data protection can have significant effects on the user acceptance and thus the overall success of CAD (see also the strongest risks in the human factors layer).
  - *Mitigation strategy:* Preemptive creation of a legal framework that assures data protection and provides the necessary security and transparency that can foster user acceptance and guarantee responsible data handling.
- **Missing support for infrastructure investment** [risk index = 231]
  - *Risk description:* A lack of legal basis for both the standardization and deployment of (digital and physical) infrastructure investments creates uncertainty and thereby impedes investments.
  - *Mitigation strategy:* Definition, test and demonstration of clear, safe, sustainable and beneficial use cases in traffic and transport. Creation of a transport policy framework for automated driving as basis for public funding and sustainable private investment decisions and integration/licensing of privately operated services and public-private partnerships.

Societal:

Risk/challenge	Probability (0-10)	Severity (0-10)	Detectability (0-10)	Recoverability (0-10)	Index
Low user acceptance regarding safety	6	9	3	7	**270**
Decrease of employment (e.g. taxi driver)	8	7	2	6	**224**
High costs	6	7	2	6	**168**
Cost of transport is not transparent	6	6	3	7	**180**
Tension between city & citizen	6	8	3	7	**240**
No shared view of future city	6	9	3	7	**270**
Technology push not in line with societal expectations	5	8	2	7	**180**
Ethical concerns	7	8	4	9	**364**

On the societal layer the three main risks received very high ratings, even in comparison to the ratings for risks on other layers. In particular the recoverability of the risks was rated as difficult. The three most critical risks are discussed in the following:

- **Ethical concerns** [risk index = 364]

  - *Risk description:* As many of the other identified risks, ethical concerns are fundamentally linked to the handover of vehicle control to computer (AI) systems. In particular, they focus on vehicle behavior in case of accidents and the potential dilemma of programming choices based on the balancing of injuries and fatalities. First steps toward stabling societal consensus on the ethical guidelines that should govern CAD, e.g. by the creation of an expert roundtable and a recommendation of ethical rules as an initiative of the German government.
  - *Mitigation strategy:* Social debate on dilemma situations, road and system safety, use of data etc. must be continued and regarded with respect to different CAD applications. The outcome of the social debate should subsequently be employed to develop legal regulations. Furthermore, a clarification and resolution of data privacy concerns is required.
- **No shared view of future city** [risk index = 270]
  - *Risk description:* Due to a lack of agreement and certainty but also promotion with respect to the benefits of CAD, the priorities and directions of development efforts are usually not aligned. This is especially critical for city planning, which requires new solutions for traffic management and CAD applications to help combat adverse effects of urbanization.
  - *Mitigation strategy:* Short-term proof of the potential benefits of road safety (beyond hypotheses or unproven marketing claims) to align stakeholder objectives and development directions. Definition, test and demonstration of clear, safe, sustainable and beneficial applications in traffic and transport. Establishment of an urban transport policy framework for CAD as a basis for the implementation of desirable new services and functions. Exchange and harmonization with city and transport planning
- **Low user acceptance concerning safety** [risk index = 270]
  - *Risk description:* The disruptive nature of CAD, the central role of driving in modern life and prejudices relating to AI-based applications, a low user acceptance can prove to be a significant hurdle for CAD deployment. This is strengthened by a lack of promotion of CAD benefits as well as disproportionate media attention for rare accidents involving (partially) automated vehicles.
  - *Mitigation strategy:* Definition, test and demonstration of clear, safe, sustainable and beneficial uses cases in traffic and transport. Promotion of the benefits of automated driving (e.g. proof of the promised increased road safety, efficient use of time use during the trip, efficient integration of service in the overall transport system).

Economics:

Risk/challenge	Probability (0-10)	Severity (0-10)	Detectability (0-10)	Recoverability (0-10)	Index
Slow development of new business models	6	6	3	5	**144**
New players in transport sector replace old player	5	7	2	6	**140**
High barriers for new players to enter the market	5	7	4	5	**158**
Lack of viable business models	6	6	3	7	**180**
Unclear ownership regulations	4	7	3	5	**112**
Cost of digital infrastructure	6	6	4	5	**162**
Low integration with smart city	3	7	4	6	**105**

The identified risks for the legal layer are marked by a high severity, (very) low detectability and, except for the risk associated with a lack of business models, manageable recoverability based on the expert ratings. The most critical risks are again discussed in more detail below:

- **Lack of viable business models** [risk index = 180]
  - *Risk description:* The lack of business models can in part be traced back to challenges on other layers, such as uncertainties in technology development, legal framework and user acceptance. Viable business models could, however, present a considerable driver for CAD development.
  - *Mitigation strategy:* Development business models for different application scenarios and environments. Integration of CAD services with public transport where possible. Determination of possibilities for public-private-partnerships or service licensing.
- **Cost of digital infrastructure** [risk index = 162]
  - *Risk description:* The deployment of CAD will not be possible without the provision of the necessary digital infrastructure that enables reliable and ubiquitous connectivity. However, in connection with the uncertainties described above, the infrastructure costs may slow down CAD development considerably.
  - *Mitigation strategy:* Development of efficient technology, which will inevitably allow reasonable pricing of components and data communication. Foster competition and avoid the creation of a monopoly.
- **High barriers for new players to enter market** [risk index = 158]
  - *Risk description:* The shift from hardware- to software-focused vehicle development has already led to various new players entering the vehicle manufacturing and provision markets in the U.S., while OEMs continue to dominate the European market. The path to market is complicated by existing standardizations and the need to obtain licenses for service provisions.
  - *Mitigation strategy:* Promotion of funded pilot demonstrations, but also integration in the urban and regional transport planning and licensing. Creation of a sustainable transport policy framework and support of new players and services.

Human factors:

Risk/challenge	Probability (0-10)	Severity (0-10)	Detectability (0-10)	Recoverability (0-10)	Index
Low comfort for "driver"	2	8	2	5	**56**
Lack of confidence & trust	6	9	1	8	**243**
Low interaction with VRUs	6	9	3	7	**270**
Low interaction with semi- or non-automated vehicles	4	9	2	7	**162**
Low knowledge of user	6	6	3	5	**144**
No training of users	6	6	3	6	**162**
Low technology acceptance	4	8	5	9	**224**
Low road safety	2	10	2	7	**90**
Accidents by robots	3	10	2	8	**150**

Since the success of CAD will ultimately depend on user acceptance, regardless of the fact whether private or shared vehicles use will prove to be dominant, the severity of risks on the human factors layer was generally rated very critical and the recoverability was further identified as non-trivial. The main risks and the associated mitigation strategies are detailed below:

- **Low interaction with VRUs** [risk index = 270]
  - *Risk description:* Since the lack of intuition and VRU communication is a fundamental drawback of computer-controlled vehicles, the interaction with VRUs has been identified as a central challenge for CAD deployment.
  - *Mitigation strategy:* Further improvement of vehicle intelligence and development of new VRU detection, interaction and communication methods. Inclusion of user feedback and early demonstrations to adapt interaction models.
- **Lack of confidence and trust** [risk index = 243]
- **Low technology acceptance** [risk index = 224]
  - *Risks description:* These risks/challenges are closely related and also exhibit a close link to the societal layer ("Low user acceptance concerning safety"). Trust in CAD technology and acceptance of related service is a prerequisite for deployment, but the disruptive nature of the transition from manual to automated driving has proven to be a central hurdle for development.
  - *Mitigation strategy:* Frequent and detailed user consultation is required and should also be employed to promote CAD benefits and develop a joint vision for the future of transportation. The potential benefits, in particular concerning traffic flow and road safety should be demonstrated or proven as soon as possible, e.g. using living labs showcasing CAD applications, and data privacy concerns must be addressed to reduce prejudices.

3 Conclusion

Overall it can be concluded that relevant risks and challenges exist on all five layers, both technical and non-technical, and each layer features significant hurdles with a high criticality. Since the technology and functionality that will enable the deployment of level 4/5 CAD is still under development, the largest number of risks was identified for the technical layer. The three main technical risks also exhibit large risk indices (> 300) and a large mean value (350). In comparison, the mean values of the three most critical risks on the other layers shows that after the technical layer, the highest criticality was identified for the societal layer (301), followed by the legal (257), human factors (246) and the economic layer (167). The risk analysis did, however, also show that many risks are influenced or exacerbated by developments in other layers or have a noticeable effect on risks in other fields. In the following steps of the SCOUT project, the risks for CAD development will be taken into account for the roadmap creation process as hurdles and the mitigation strategies will serve as input for the derivation of actions on each layer that can accelerate the deployment of level 4/5 CAD.

4 References

[1] Bekiaris, E., Stevens, A. (2005), “Common risk assessment methodology for advanced driver assistance systems”, Transport Reviews, Vol. 25, No. 3, p. 283-292, May 2005.

[2] Report on challenges for implementing future transport scenarios – Deliverable 4.1 of the Action Plan for the Future Mobility in Europe, Horizon 2020 CSA Mobility4EU, January 2001.