Draft road map and action plan to facilitate automated driving on TEN road network

Workshop report (15–16 March 2017, Utrecht)

“Facilitating Connected & Automated Driving – a Road Operator’s Perspective”

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Authors

Name	Organisation
Tom Alkim	Rijkswaterstaat
Risto Kulmala	Finnish Transport Agency
Satu Innamaa	VTT
Fanny Malin	VTT
Anna Schirokoff	TRAFI

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Preface

The sub-activity 4.2 ‘Facilitating automated driving’ of EU ITS Platform has a scope to prepare road authorities and operators to make decisions on facilitating automated driving and automating their own core business. This is a report of task 3 ‘Road map and action plan’.

This task focuses on the requirements of higher levels of automated driving, and especially the requirements of automated driving towards the road authorities and operators concerning road markings, traffic signs, real-time and predictive traffic information, digital maps, cooperative ITS infrastructure and other aspects. The scope of the task was extended to encompass requirements of automated driving to ensure the safety and the efficiency of the transportation system. This task will work in close liaison with CEDR, vehicle manufacturers, device manufacturers, digital map providers, transport operators and other fleet owners, ITS service providers and maintenance contractors as well as H2020 (2016-17 Call) and other R&D&I projects for wide commitment.

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1. Introduction

The sub-activity 4.2 “Facilitating automated driving" of EU ITS Platform has a scope to prepare road authorities and operators to make decisions on facilitating automated driving and automating their own core business. It has a task to identify requirements. Specifically, this task first focused on the requirements of higher levels of automated driving, and especially the requirements of automated driving towards the road authorities and operators concerning road markings, traffic signs, real-time and predictive traffic information, digital maps, cooperative ITS infrastructure and other aspects. The scope of the task was then extended to encompass requirements of automated driving to ensure the safety and the efficiency of the transportation system.

“Facilitating automated driving" sub-activity organised a workshop entitled ″Facilitating Connected & Automated Driving – a Road Operator’s Perspective″ on 15th–16th March 2017 in Utrecht, the Netherlands. The main objective of the workshop was to examine the challenges and key questions of connected and automated driving (CAD) from the road authorities’ and operators’ point of view. Another objective was to collect input and material for this deliverable.

The purpose of this deliverable is to give an overview of the workshop, summarise the background material and present the workshop results. This deliverable also makes conclusions of the workshop results and presents the processes to create a roadmap and an action plan for the road operators. The next steps are identified in the end of the report. It must be noted that the discussions focused to SAE level 4 automated driving on highways. Therefore, the results are also related to them.

European ITS Platform

2. Workshop organization

The workshop ″Facilitating Connected & Automated Driving – a Road Operator's Perspective″ was organised on 15th–16th March 2017 in Utrecht, the Netherlands. Rijkswaterstaat hosted the workshop at their LEF Future Centre-facility, which is designed for innovative workshops and problem solving (**Figure 1**).

Figure 1. LEF Future Centre (Erik Kottier 2017).

2.1. Objective

The main objective of the workshop was to examine the challenges and key questions of automated driving from the road authorities' and operators' point of view. Another objective was to collect input and material for this deliverable. This was done with different methods such as presentations, focus group sessions, interactive sessions and one-to-one discussions. The results and opinions were recorded to an online system of the workshop venue.

2.2. Structure

2.2.1. DAY 1

The workshop started with introductory exercises where the participants got to know each other and list the key questions that they had related to automated and connected driving (outcome presented in Chapter 4.1). Then the participants got a brief introduction to the EU EIP project and on the current status of automated and connected driving. After that, there were discussions in smaller groups on the role of the road operator in automated driving and on the implications of automated driving on road operators (Figure 2). The first day was wrapped up with a plenary discussion where the main issues were summarised.

Figure 2. Focus group discussion (Erik Kottier 2017).

In one of the interactive sessions of first day of workshop, the help of an artist was used to make a virtual journey from home to the office encountering many different situations (Figure 3, Figure 4). This helped to visualize what kind of impact automated driving can have on the infrastructure. The focus was on the TEN-T network so we considered predominantly highways but we also took into account the first and last mile in urban and rural conditions.

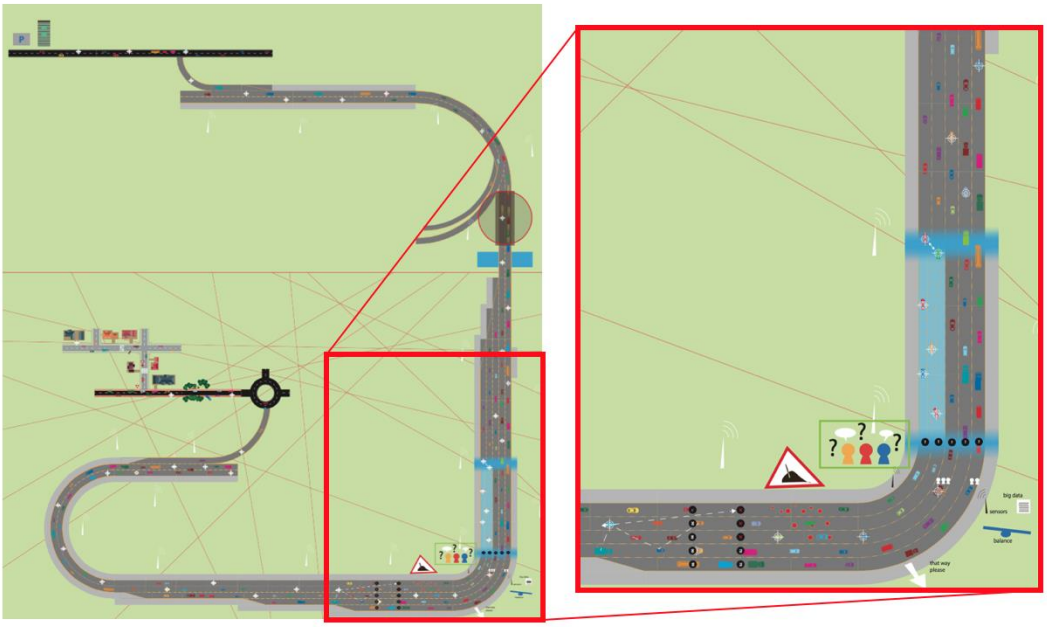

Figure 3. Screenshot of artist's visualization of a home to work drive.

Figure 4. Group session of virtual drive through different scenarios (Erik Kottier 2017).

Some of the situations and conditions encountered were:

- Number of lanes, lane width and curvature
- Presence of hard shoulder or safe havens
- Signage (static, dynamic)
- Tunnels and bridges
- Traffic flow (busy, free flow, congested, percentage of trucks)
- Mixed traffic or not, and if so the percentage (mixed traffic or 100% automated)
- Dedicated lanes for automated vehicles (Physically separated or not? Position? How to enter and leave the lanes? Transition zones?)
- Weather conditions (snow, rain, fog, wind, etc.)
- Road works, lane closures, breakdowns, incidents, etc.
- Transition situations (planned transition of control, e.g. near on and off ramps or weave sections, and un-planned transition of control, e.g. in case of bad snow or sleet)
- Digital infrastructure (connectivity through WiFi and/or 4G, digital maps, clouds)

2.2.2. DAY 2

On the second day, the needs and key questions were examined more thoroughly. In the morning session, there was a round table discussion in smaller groups for four previously selected topics. The selected topics were: (1) Physical infrastructure to facilitate CAD, (2) Digital infrastructure to facilitate CAD, (3) Impact on network operations and maintenance and (4) Traffic management for CAD.

The discussions focused to SAE level 4 automated driving on highways. Each table had a facilitator and one participant acted as secretary and submitted the group's input to the online system (outcome summarised in Chapters 4.2–4.5).

In the afternoon, there was another breakout session with focus group discussions on two topics: (1) improving the road operator relationship with automotive and OEMs, and (2) pros and cons for road operators regarding SAE level 4 driving (Figure 5). The topics were chosen collectively and the participants could choose in which group they wanted to participate. After the breakout session, there were one-to-one-conversations where the participants discussed what they had learned and what the main message of the workshop was for them.

Figure 5. Break-out session (Erik Kottier 2017).

The workshop was wrapped up with a plenary session where the participants had a possibility to share their opinions on the outcome of the workshop and on the next achievable actions.

2.3. Participation

In the workshop, there were more than 40 participants (Figure 6) from 15 different countries: Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Italy, Lithuania, the Netherlands, Norway, Romania, Spain, Sweden and the United Kingdom.

Figure 6. Workshop participants (Erik Kottier 2017).

Most of the participants represented road authorities/operators and the transport research sector (universities and research organisations). There were also many representatives from consulting companies and associations. From the industry sector, there were representatives from only two companies. There were no participants from the automotive manufacturers and OEMs although they were invited. All the participating organisations are listed in Table 1.

Table 1. Participating organisations.

Road authorities and operators	Universities and research organisations	Industry	Consulting	Associations
Danish Road Directorate	Austriatech	DENSO	IBI Group	ERTICO
DGT - Direccion General de Trafico	Federal Highway Research Institute BASt	Dynniq	ICEACSA Consultores	CEDR
Finnish Safety Transport Agency	CEREMA	Siemens	Royal Haskoning DHV	CROW
Finnish Transport Agency	CIDAUT		Sweco	ITS Romania
Highways England	SINA - Società Iniziative Nazionali Autostradal			
Lithuanian Road Administration	SINTEF			
MOW - Mobiliteit en Openbare Werken	TNO			
NPRA - Norwegian Public Roads Administration	TU Delft			
Provincie Noord-Holland	VTT Technical Research Centre of Finland Ltd.			
Swedish Transport Administration				
Rijkswaterstaat				

3. Background material for the workshop

All participants received background material to prepare for the workshop. There was already some knowledge and experience available from various sources. An overview of existing roadmaps and planned pilots, the first deliverable (D1) from EU EIP sa4.2, a Dutch exploration of implications for road design and a state of the art report on infrastructure for automated vehicles. All these documents can be downloaded at the links provided in the following chapters that give a summary of the content.

3.1. Overview of existing roadmaps worldwide

In a recent scan, more than 30 roadmaps were found worldwide and even more pilots. Any attempt to make an overview seems to be outdated the next day, but such overviews are valuable anyhow. Combined with the presentations that were given at the CARTRE workshop “Large-scale automation pilots on public roads in Europe” (December 16th 2016, Brussels) this overview should give a good impression of what is happening in the field of connected and automated driving.

The documents can be downloaded at:

http://knowledgeagenda.connekt.nl/engels/2017/03/09/overview-roadmaps-and-pilots/

3.2. Identification of requirements towards network operators (D1)

The first EU EIP sa4.2 deliverable was produced on requirements towards network operators. This deliverable (D1[1]) describes the state of the art of automated driving, and the expectations that the general public, vehicle and fleet manufacturers and road network operators have on automated driving. The deliverable describes also the identified requirements toward the physical and digital infrastructure. In addition, it discusses topics related to the legal and regulatory framework, requirements on cooperative ITS, and external boundaries of automated driving (including weather conditions).

The summary of the conclusions of the D1 is as follows:

While the general public mostly expects improved safety, comfort and time savings, network operators expect safety and efficiency improvements from the introduction of

[1] Courbon, T., Scharnigg, K., Techner, T., Innamaa, S., Kulmala, R., Alkim, T., Flament, M., Pilli-Shivola, E., Bergareche, A. and Rausch, J. 2016. EU-EIP Activity 4.2 Facilitating automated driving. Task 1 : Identification of requirements towards networks operators. Version 1.01. 31 December 2016.

automated vehicles on their networks. To meet these expectations, car manufacturers and service providers have to collaborate with road network operators in order to define the right balance between comfort, safety and efficiency. Furthermore, network operators need to comply with strict economic constraints while providing equal service to all road users: automated vehicles, manual vehicles, public transport vehicles, bikes and pedestrians alike. Hence, they will not be able to undertake comprehensive network transformations in a short time period to accommodate automated driving.

As automated vehicles will be introduced gradually, the transition phase will be long. It is therefore important to find affordable solutions that also accommodate automated vehicles. Leveraging the advantages of automated driving systems should be done as soon as possible to offset the costs induced by having the different types of vehicles simultaneously on the network.

As long as there is a mix of automated and non-automated vehicles, design parameters for roads are obviously based on the manual operation of vehicles. This means that altering the roads in the sense that elements are taken away (e.g. lane markings, signs) or altering the dimensions (e.g. narrower lanes) is out of the question. However, adding elements to the existing infrastructure to facilitate or enhance automated driving without negatively affecting manual driving is possible (e.g. connectivity, landmarks).

Identified needs towards road network operators

- Consistency and continuity:
    - Car manufacturers need consistency within the network but also between networks
    - Network manufacturers may have to set up some processes to ensure landmarks will be consistently visible and available for automated vehicles to position themselves on the road.
    - Adhering to European standards or guidelines will help to ensure cross-border interoperability and to avoid the replication of work done elsewhere.
- Digital infrastructure:
    - Network operators will have to invest in the digital infrastructure and take a leading role in its development to ensure that the public expectations and objectives are met.
    - Together with relevant service providers, the network operators will have an instrumental part to ensure the availability of data e.g. real-time

information on road conditions, traffic, weather, incident and event. This will have to be done through a single access point.

- Ensure sustainable service provision with long-lasting agreements and contracts with the relevant stakeholders will be necessary for the long-term viability of the digital infrastructure and the safety of all road users.
- Upgrading procedures and quality controls will be necessary for maintenance and network management processes to ensure that the expected level of service is indeed consistently reached on the network.
- Set up asset management and maintenance processes to ensure the visibility of signs and markings even in difficult weather.

- Road classification:
  - If it is chosen to open only some road to automated driving system or to favour routing on certain roads while avoiding other, an extensive inventory and classification of the road network will have to be carried out.

Identified needs towards states and the European level:

- A legal framework to proactively protect consumers and network operator rights and interest before overreaching an “end user agreement”.
- A legal framework to allow independent researchers to analyse and audit automated driving systems without have to risk facing legal action while allowing industry stakeholders to reasonably preserve their commercial interests would help strengthen the security and safety of the automated driving ecosystems.
- A clarification of the repartition between stakeholders to ensure that the industry members have incentives to design automated driving system with road safety as a key and overruling requirement. This should be done preferably at the largest possible level, i.e. at the European level.
- Since type homologation is done at a European level, it should also be done so for automated vehicle type-homologation. Given that procedures will probably be more complex and expansive to design, this would avoid replicating costly work both for manufacturer and public stakeholders.
- Data privacy agencies already exist in European countries. Specific regulation may be necessary for automated driving systems.

The Deliverable can be downloaded at:

https://www.its-platform.eu/filedepot/folder/1077?fid=5833

3.3. Exploration of implications for road design

More know-how and expertise is needed regarding the implications of automated vehicles for the current road design. This need is summarized in two key questions, focusing on both the knowledge gaps and the role of road operators in reacting to, facilitating or stimulating the deployment of automated vehicles:

- Which choices, regarding road design, can already be made when taking into account that automated vehicles are imminent (anticipating that the infrastructure is built to last 40–50 years)
- Which adaptations in the physical infrastructure support the arrival of the automated vehicles (facilitating this, for example by taking into account technological developments in new planning procedures)

The Dutch National Road Authority Rijkswaterstaat and CROW (Dutch technology platform for transport, infrastructure and public space) have initiated explorative research to start answering these questions and asked Royal HaskoningDHV and TNO to provide insight in the needs and challenges to make road design future-proof by facilitating the deployment of automated vehicles. The goal of the exploration is to identify key items and to categorize these items in a research agenda. The starting point is the longer term future vision of 100% fully automated vehicles (SAE level 5) and then reasoning back towards the shorter term situation in which traffic is composed of a mix of vehicles of different SAE levels.

The study provided insights into what the differences between self-driving and manually driven vehicles can imply for road design and the accompanying design guidelines and directives. A large amount of information was collected in a structured way and it was concluded that many changes in road design may be needed and/or are useful in the longer term, when all vehicles on the road are fully automated. However, as long as mixed traffic prevails (i.e. vehicles of all levels of automation potentially present on the road), not much can be changed in the design of the road infrastructure. With mixed traffic, the capabilities of the human driver still determine the constraints in design.

The document (in Dutch) can be downloaded at:

http://knowledgeagenda.connekt.nl/2017/02/01/relatie-infra-en-automatisch-rijden/

3.4. State of the art on infrastructure for Automated Vehicles

Rijkswaterstaat, Ministry of Infrastructure and the Environment in the Netherlands commissioned TU Delft to create an overview on the knowledge and experience currently available on the relation between connected and automated driving and infrastructure. The resulting report “State of the art on Infrastructure for Automated Driving” presents an international literature overview, taking into account both physical and digital infrastructure. In addition recent and current projects, initiatives and test sites for connected and automated driving are listed. A first attempt to map implications for infrastructure per automation level has been done as well as a summary of knowledge gaps and suggested future research directions.

Based on the reviewed scientific literature, projects, test sites, and initiatives, several knowledge gaps with respect to the physical and the digital infrastructure were identified:

Physical infrastructure

- The scientific knowledge with respect to the physical infrastructure is relatively scarce compared to the digital infrastructure.
- There is a lack of research regarding the needed changes in the road geometric design at different penetration levels of vehicle automation and mix of different automation levels.
- From the capacity point of view it is not clear whether the current road network will need to be expanded (adding more lane, road links) to accommodate the traffic demand in the future.
- There are no empirical studies regarding the implications of reducing the lane width, and other cross section elements (such as the shoulder width, median) on the traffic safety performance, and safety perception of drivers/passengers.
- There are few research studies about the implications of automation on pavement rutting under different traffic conditions.
- There is no systematic research regarding the acceleration and deceleration forces that humans can tolerate, or regarding human acceptance of gaps in traffic (such as gaps for overtaking, merging or at intersections).
- No research was found about the implications of automation on the load of bridges, and on the structural safety of bridges.
- Most platooning projects were conducted with few platoons, and with no special conditions, as road work or traffic jam, which require research, especially in sensitive locations, like weaving sections, on-ramps, and off-ramps.

- It is not clear whether the maintenance of lane-marking (retro-reflectivity, contrast ratio, width) and lane-markings in general will be needed in the future for camera-based vision systems, and what their role would be, if precise positioning is further developed.

Digital infrastructure

- Further development and improvement of accurate positioning of automated vehicles. Cheap and accurate positioning technology is critical to CACC (Cooperative Adaptive Cruise Control) implementation but is yet a challenge.
- There is a need to develop accurate and dynamic digital maps of the infrastructure and its surroundings, including details regarding the geometric design of the road.
- There is still no clear picture of the required infrastructure sensors, ITS traffic management, and their role and necessity to facilitate safe traffic operation with automated vehicles, on different types of roads.
- Data quantity and data handling; how to collect, share and store the appropriate data.
- Further research is needed on the fusion of multi sensing and information for scene understanding and prediction.
- There are several studies and projects about connectivity between vehicles, but only few recent projects (PROSPECT, XCYCLE, VRUITS) about connectivity between vehicles and vulnerable road users.

The document can be downloaded at:

http://knowledgeagenda.connekt.nl/engels/2017/02/16/state-of-the-art-on-infrastructure-for-connected-and-automated-driving/

4. Workshop results

4.1. Primary expectations for the attendees

In the beginning of the workshop, the participants listed important issues that they wanted to discuss in the workshop. The resulting list shows the open questions that the participants had identified (before the workshop):

- How can road operators enhance and stimulate the deployment of automated driving?
    - Most important investments in the short- and long-term?
    - What will it cost?
    - To set the scene for cooperation / To define common questions to answer / How can we develop and maintain international exchange of knowledge?
    - As there are many different technologies, how will we know what to invest in? / Harmonisation of technology between national road authorities and car industry.
    - Can a single roadmap be achieved?
- What will be the role of the road/infrastructure operator in the future?
    - Which parts of the current operations are not necessary in the future?
    - Which types of operations are needed more than currently in the future?
    - What is the responsibility of the road operator?
    - Will the public have a responsibility towards the traveller in a more extensive way than today?
    - How to balance the public and private interests?
- What should be changed in the guidelines of roads?
    - What does car industry need from the infrastructure? / What are the requirements of automated driving for the road design? / Should European (high)way design be harmonised to stimulate automated driving? / Does the car industry know what the infrastructure can offer?
    - What do road authorities expect to change in the infrastructure?
    - What are the road weather related limitations and maintenance requirements of automated driving?

- How is pedestrian safety ensured by a road operator?
- How can we facilitate automated driving on rural/regional/municipal roads?

- Opportunities for road operators arising from new technologies of self-driving cars:
  - What is the impact of automated driving in real world traffic? / Is CAD going to be safe? / Can we achieve greater capacity with CAD?
  - When can we see the benefits?
  - Is it possible to get most of the benefits from automated driving by legislating the use of ADAS (advanced driver assistance systems)?
  - What kind of data can be expected from the vehicles?
- Digital infrastructure:
  - V2V, V2I (ITS G5, cellular network), V2X
  - Is connectivity necessary?
- Standards and legislation related to connected and automated driving:
  - The balance between EU / national policy and the industry's agenda
  - How will the technology be harmonized between different regions and countries?
  - What are the impacts of law and regulations?
  - Regulations for test sites and pilots
- Understanding the technology in an environment of mixed connected and unconnected, automated and non-automated vehicles:
  - What is feasible?
  - How to secure open public knowledge from trials and pilots i.e. have openness from car and equipment makers? / How can we improve international cooperation on pilots?
- Truck platoons
- How can we use automated vehicles for public transport?
- How will automation affect driver education?

4.2. Physical infrastructure to facilitate CAD

The round table discussion regarding physical infrastructure to facilitate CAD was moderated by Risto Kulmala, FTA. The discussion was related to the strategic and detailed planning, road and roadside equipment, pilots and test areas, and networking and knowledge sharing.

Strategic and detailed planning

The basic question is whether road infrastructure needs to be adapted for automated driving or whether also the higher-level automated vehicles should adapt to any existing road infrastructure. Nationally consistent road network infrastructure, including temporary and electronic road signage as well as homogenous physical design and easy maintenance would be beneficial for both manual and automated driving.

Higher levels of automated driving could be supported by adjustments of the existing road infrastructure, for example by providing a simplified and logical environment that can support the vehicle to avoid situations of many stops (cross sections, pedestrians-/bicycle crossings, etc.). Strategic transport models will need to consider changed lane/road capacity, perhaps on the basis of sensitivity tests, given the uncertainty about the impacts on capacity. Dedicated lanes for automated vehicles on motorways and high volume arterial roads may be required as the proportion of highly automated vehicles increases.

In any case, the deployment of road network for automated driving will likely be gradual.

Design guidelines for junctions will likely be adapted, considering the co-existence of automated vehicles with other road vehicles, including powered two wheelers and emergency vehicles. There will likely also a need to adapt urban parking, and in general, land use planning.

Specific attention needs to be given to the transition period related to the design, maintenance and operation of road networks.

Common European actions in research and innovation activities, adaptation of the regulatory framework, follow-up of the C-ITS platform as well as the development of a European strategy for highly automated driving were regarded as important.

Road and roadside equipment

The infrastructure performance (visibility, state of repair, etc.) regarding traffic signs, signals and road markings to support higher levels of safe and reliable automated driving has to be agreed upon by the stakeholders.

Road signs and markings need to be conspicuous and legible to the AV sensors as well as to human eyes.

Movable roadside infrastructure is required (for roadworks, special events, etc.), also equipped with communications. Roadside units can be considered to enable V2I communication. Road agencies could come under increasing pressure to develop corridors and precincts that enable vehicles to communicate with infrastructure, which will need to include sensors, transmitters and cabling to enable a connected network.

Railway level crossings may need specific attention to enable safe passing of these.

Positioning infrastructure is essential to highly automated vehicles. In addition to land-based support to satellite positioning to facilitate RTK-GNSS (Real Time Kinematics to improve the precision of satellite positioning), road operators can set up fixed landmarks, post and poles by the roadside, or sensors or beacons embedded into road pavement.

Pilots and test areas

The requirements for physical infrastructure are not yet clear nor do we know about the importance of the different aspects of physical infrastructure for connected and automated transport. The impacts, benefits, and costs are also very uncertain – so far only estimates based on simulation and other models are available, and these model results are strongly affected by the assumptions made in setting up the models.

Hence, it was seen as important to create appropriate testing areas with industry and academia. These testing areas are both closed and open ones. In testing, both driving safety and testing efficiency need to be considered. Each country or road operator likely has their own criteria for designating roads to be used in the testing for automated vehicles, including the equipment requirements for these roads.

Networking and knowledge sharing

The participants repeatedly brought up the lack of knowledge of the technology solutions, infrastructure and communication requirements, and the socio-economy of highly automated driving. It would be very useful to create a network of expertise to share knowledge and experiences, and to enable developers to work together, rather than compete. International cooperation, stronger international networking and collaboration are very much needed.

Moreover, there is a significant need for creating synergies between involved sectors (i.e. vehicle manufacturers, energy, communication services and providers, transport, IT and smart systems sectors, as well as users) that are coming together in the novel value chains for automated vehicles.

4.3. Digital infrastructure to facilitate CAD

The round table discussion regarding digital infrastructure to facilitate CAD was moderated by Satu Innamaa, VTT. The discussion was related to the technology of the digital infrastructure and its harmonisation and cooperation on a national and international level. The outcome of the discussion could be categorised in a following way:

- Data and data sharing
- Cooperation and harmonisation
- Communication technology and digital maps
- Testing
- Liability and regulations

Data and data sharing

To facilitate CAD, the participants stressed the need for high quality and openly available traffic related data such as traffic situation, accident and incident information. Other topics discussed were: data fusion, resources for managing big data, privacy issues and data protection. The availability of data from back-office systems was also considered important.

Cooperation and harmonisation

The participants emphasized the collaboration on a national and international level. The need for a European level strategy was suggested as well as creating a network of experts for facilitating the cooperation and sharing knowledge and experiences on the digital infrastructure. Continuation of the C-ITS Platform could be one option for the latter. Harmonisation of the digital infrastructure, both technologies and processes, was seen crucial for facilitating CAD.

Communication technology and digital maps

The need for sensors and communication technologies was a frequent topic in the discussions. There was uncertainty whether there is a need for special roadside equipment for CAD related services (ITS-G5) or if the communication can be handled through e.g. the 5G network or V2V communication. There was no agreement on who in that case is responsible for the installation and maintenance of the roadside equipment. The importance of V2I and V2V communication was stressed by many participants.

The availability and provision of digital maps was another common topic related to the equipment and technology for the digital infrastructure. Open questions included: What

has to be included in the maps? How can the required quality of maps be ensured? Who is going to pay for the maps?

Testing

The participants agreed upon the fact, that more testing of automated driving and the related digital infrastructure is needed. Investing in appropriate testing areas or roads is necessary. Ensuring the cooperation between the industry and research sector in relation to the test was also seen important.

Liability and regulations

The discussion also concerned the liability issues of CAD. When is the responsibility shifted from the vehicle to the digital infrastructure system? Who is responsible if an accident is related to defects of the digital infrastructure? The responsibility for updating the digital infrastructure was discussed as well as the responsibility for standardisation and certification.

In addition to the above mentioned topics, the participants agreed on that the road authorities and operators should not focus on an ideal situation where all the vehicles are automated. Instead, focus should be on a mixed traffic situation.

4.4. Impact on network operations and maintenance

The round table discussion regarding impact of CAD on network operations and maintenance was moderated by Anna Schirokoff, Finnish Transport Safety agency. When categorising the input from the discussion, six main topics could be identified:

- General topics
- Rutting
- Maintenance of lane markings
- Maintenance of communication
- Road signs
- Data from vehicles

General

Participants assumed that much more maintenance tasks will be needed both for the digital and physical infrastructure and that we will need to be more in compliance with our own guidelines. However, there is no need for higher maintenance standards – automated vehicles should be able to cope with the existing standards.

The discussion also concerned the liability issues of CAD. An agreement needs to be met on standards and responsibilities. OEM's should be asked where they have problems i.e. where their sensors are fading. Are the vehicles designed for new, perfect roads or how much tear and wear can they tolerate and still function properly? Liabilities will be impacted. How much and what liabilities do road operators take? It was suspected that there will be a conflict between road operators and OEM's if there is an accident i.e. was the accident due to the vehicle failing or the road not meeting the required standard?

Rutting

A number of participants mentioned problems of rutting - which grooves from all vehicles following on same track - and the importance of prevention of rutting, as rutting in the road due to truck platoons will impact the driving for automated vehicles. However, all participants were not sure whether rutting will be a problem or not. Therefore testing is needed on questions such as: Can we program the vehicles to minimize wear on the road? Are truck platoons worse than other vehicles?

Maintenance of lane markings

Participants pondered whether better maintenance of lane markings is required or if we should rely more on very accurate mapping. It was assumed that Level 4 vehicles will be more dependent on road markings. This also depends on where automated driving is allowed. However, participants stated that the vehicles should adapt to the roads, not the other way around.

Repainting the lane markings more often will increase the maintenance cost. Road cleaning is also required for fall back.

It was pointed out that there will be different sensors in different vehicles interpreting lane markings: white lines degrading can be seen "better" by some vehicles. Hence standards or regulations for this are needed. Who has the responsibility if a car cannot detect an old or temporary line? This needs to be very clearly understood by all stakeholders and road operators should make requirements to the vehicle manufacturers and to the industry.

Maintenance of communication

Participants discussed the communication infrastructure and agreed that communications coverage is needed on the roads, including both long range cellular and short range communication as well as back-up systems – and all of these need maintenance. They pointed out that data security will also have an impact on road maintenance, responsibility and costs

Road signs

Participants questioned if physical road signs still will be necessary - physical infra might only be the fall-back solution. Other open questions included: Where the digital signing will be controlled? Will it be based on road sensors?

Renewing or cleaning signage more often will increase the maintenance cost. Some signs are less visible during snowfall and even during night time. Maintenance for such signs will incur higher cost. As opposite, the participants stressed the possibility of needing less signage as a positive impact.

Data from vehicles

Possibilities from using the data from the vehicles were discussed and many ideas rose. Information on the road status should be transferred to the vehicles, but the vehicles could also help to collect data. Sensor data from vehicles could be used to improve maintenance and planning. For example it would be very important in winter to receive more accurate road surface temperature data to be utilized in the road salting scheduling. If vehicles would be able to inform road operators where road maintenance is needed faster reaction times on obstacles on roads or damages could also be achieved. Is there a need for greater investments in collecting this data from the vehicles? At least better algorithms are needed to understand the data coming from the vehicles.

4.5. Traffic Management for CAD

The table regarding traffic management for CAD was facilitated by Tom Alkim, Rijkswaterstaat. When categorising the input from the discussion, several main topics were identified:

- Goals of traffic management
- Connectivity
- Traffic management in the transitory phase
- Equipment for traffic management
- Regulations for traffic management
- Characteristics of traffic management for CAD
- Impacts
- Next steps

Nowadays road operators perform traffic management providing information to humans who drive vehicles. How will this change in the future when there is a shift towards providing information to software that drives vehicles. A simple translation of the current messages to humans to messages for machines will not be adequate without rethinking the original purposes of the various traffic management measures. As complex as that may seem, traffic management in a mixed environment may be even more complex when road operators have to consider both (partially) automated vehicles and human driven vehicles. So when considering traffic management for automated vehicles there are two main challenges:

- How will the nature of traffic management change when it is directed at automated vehicles?
- What is the transition strategy from the current situation to future situations that include mixed traffic?

Goals of traffic management

The main discussion in all the groups was related to the goals and purpose of traffic management. What does a road authority or operator want to achieve with traffic management? Today the goal can generally be summarised as 'no casualties, no congestion and no emissions'. The goals are not likely to change with the introduction of automated driving, but the procedures and methods can change.

Traffic management versus mobility management was another important topic. Whether there will be a difference between the public and private traffic management, i.e. whether the focus should be put on collective traffic management instead of individual traffic management? The collective and individual goals have to be combined.

The participants agreed upon the fact that the road authorities and operators have to set the goals for traffic management. The need for a European traffic management system or plan for automated driving was also suggested. The focus should not be on what the impact of automated driving has on traffic management, but to identify the benefits for traffic management through increased automation.

Connectivity

The need for connected automated driving was identified as a key component for achieving the benefits with automated driving for the society. Without connectivity, most of the benefits are on the individual level. Some of the participants were uncertain whether traffic management can work without connectivity. Knowing the origins and destinations of the vehicles was also identified as an important aspect for improving and facilitating traffic management even if it also brings problems with e.g. privacy and data security.

Many automakers and OEMs are developing unconnected automated driving. There is a need for a mutual discussion and form of cooperation between the industry and road authorities and operators was seen as important by the participants. The possibility for road authorities and operators to influence the development was also discussed and whether the road authorities and operators can e.g. set requirements for the vehicles or for using automated functions on the roads.

Traffic management in the transitory phase

There was some uncertainty among the participants, whether there will be a situation when all the vehicles are automated. The transitory phase or mixed fleet situation was in any case predicted to be long. Therefore, the road authorities need to prepare their traffic management for a situation where some of the vehicles are automated and some are not. The instruments and processes have to be developed accordingly, to allow for both manual and automated driving.

Equipment and technology for traffic management

With the introduction of automated driving, new equipment and technologies are needed. Questions arose on whether the road authorities and operators should interact directly with the vehicles or drivers or whether it should be done through service providers?

The need for a fall-back system was also questioned by the participants as well as the characteristics of the fall-back system. Will the fall-back system for instance be a human?

Another need identified by the participants was the need for roadside equipment for e.g. collecting and distributing information or for guiding the automated vehicles to the dedicated lanes. The interlinkage and harmonisation of road signs, signals, telematics systems and real-time traffic information was also seen as an important issue.

Regulations for traffic management

The participants agreed upon the fact that the vehicles have to follow the regulations and instructions that the road authorities and operators set. However, the conditions for allowing automated driving should be defined. Other important questions were: who should decide on the allowed level of automation and what should the decision be based on?

Coherent international, European and national legislation was also seen as important by the participants. The legal framework might have to be continuously adapted and harmonised internationally.

Characteristics of traffic management for CAD

With the introduction of automated driving, new possibilities arise for the traffic management. Will it for example be possible for the driver to choose their route according

to different variables such as duration, length, scenery and environmental impact? Could the drivers be rewarded if they choose a route with low occupation or lower emissions? Are people willing to sacrifice their personal time for the benefit of the society?

The participants also questioned whether it is possible to manage SAE level 4 automated driving without knowing the origin and destination for the vehicles. Knowing the destination is important to facilitate collective routing of vehicles.

Slot management for automated driving was another important issue. What happens if the vehicle misses its slot? Can the automated vehicles give way for a departing automated vehicle to cross the queue if there is a traffic jam ahead?

Impacts

The participants discussed the impacts of traffic management for CAD on public acceptance, demand, business models and services, other road users, other transport modes, congestion and network planning. How will the interface between various modes of transport work? Will there be new business models for traffic management?

In addition to that, some discussion dealt with the human interaction. Will there be impacts on the driver when switching from one level of automation to another? Will there be a need for a human part in the future traffic operations or will everything be controlled by a system?

Next steps

Opening up the discussion and cooperation between the industry and road authorities and operators was seen as the most important step for securing the desired development of traffic management. The need for harmonisation of traffic management strategies and practises, both on a local and international level, was also identified as an important action.

5. Conclusions and steps forward

5.1. Conclusions from the workshop

The objective of the workshop was to identify the open questions related to how the road operators can facilitate connected and automated driving. The workshop indeed succeeded in collecting these questions. Yet, the main conclusion is that there is still a lot of uncertainty among road operators related to the needs of connected and automated driving. There is a clear need to have a dialogue with the automotive industry.

Automated driving is typically described with SAE levels. However, the levels are too general for detailed dialogue regarding the requirements. Therefore, functional descriptions are needed to understand how the connected and automated vehicles operate and what their needs are with respect to road operator services (incl. infrastructure).

Different requirements will arise whether connected and automated vehicles drive in mixed traffic with the conventional vehicles or whether they have a dedicated infrastructure. There are also open questions related to e.g. (physical) transition zones and whether elements should be added or left out because of automation.

Many parties (Member States, road operators, different stakeholder forums, etc.) have already made roadmaps, focusing on topics relevant for them. Before EU EIP makes its own roadmap, an overview of the existing road maps should be done. There is a need to discuss with other stakeholders and to collect more information by studying the results of different pilots and test sites. The coordination and support action CARTRE can help facilitate the sharing of experiences and results. Information will also be gained from EC H2020 research projects.

The time-scale for physical infrastructure is very different from the one for digital infrastructure. Traffic management tools and practices as well as digital infrastructure can be renewed in a few years' time but the physical infrastructure will last for the next 50 years.

5.2. Relation with the CEDR working group CAD

On April 14th 2016 the Declaration of Amsterdam was endorsed by all EU Member States, the EU Commission and the Industry (ACEA). The high-level policy document outlines the specific and joint challenges and actions for the various stakeholders regarding connected and automated driving.

The declaration is very relevant in the context of EU EIP sub-activity 4.2 „Facilitating automated driving". In the conclusion "Impact on road operators, transport operators and traffic management" CEDR is explicitly mentioned:

"Recognizes that connected and automated driving will have a large impact on cities, road operators and traffic management. **Therefore, the participating member states ask CEDR to jointly assess this impact and to provide the HLM with scenarios and concrete suggestions to maximize the benefits and to mitigate negative impact.** Particular attention has to be given to the possible criticalities as well as the potential to achieve overall climate and transport policy objectives."

Therefore EU EIP sa4.2 will cooperate with the recently formed Connected and Automated Driving working group of CEDR (co-chaired by Rijkswaterstaat of The Netherlands and ASFINAG of Austria) to align our efforts

The document can be downloaded here:

https://english.eu2016.nl/documents/publications/2016/04/14/declaration-of-amsterdam

5.3. Process to create a roadmap and an action plan for road operators

When the actual EU EIP roadmap will be produced it should be done in cooperation with CEDR, ASECAP and POLIS. EU EIP's focus is on the TEN-T network and thus the cooperation is strongest with CEDR and the Amsterdam Group but also the link with urban networks is important.

Therefore we will liaise with the Connected and Automated Driving working group of CEDR and discuss how we can collaborate and align our efforts in the next CEDR meeting. Risto Kulmala and Tom Alkim will initiate this process.

Likely, the road map process will cover at least the next steps:

1. Selection of target year (for example 2025 or 2030)
2. Description of the current status of the domain in Europe (development, deployment status and plans, current investments as well as operation and maintenance costs)
3. Agreement on the vision or target state in Europe in the year selected
4. Discussion on the steps and actions needed to reach the vision or target state
5. Descriptions of actions already taking place or under planning

6. Agreement on the road authority/operator related and other important actions as well as the stakeholders involved, the resources needed and the champion for each action
7. Agreement on the timing of the actions

It is essential to involve also other stakeholders than road authorities and operators in the process as otherwise the steps 3-6 will not be plausible.

It's likely to be very difficult to get the commitment from the road authorities/operators to the action plan and especially the resources required, therefore it would be very important to at least aim to get signatures to a common memorandum of understanding or at least a letter of intent. To increase the success factor it will be designed in such a way that it's in line with the Declaration of Amsterdam and the conclusions of the High Level Meeting(s) which have been embraced by most stakeholders.

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