



Conférence Européenne
des Directeurs des Routes

Conference of European
Directors of Roads



Final Programme Report

CEDR Transnational Road Research Programme

Call 2017 Automation MANTRA | DIRIZON | STAPLE

February 2021



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CEDR Transnational Road Research Programme

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Executive summary

The Conference of European Directors of Roads launched a call for proposal in the field of Automation in November 2017. CEDR is an organisation which brings together the directors of 27 European road authorities with the aim to promote excellence in the management of roads. This Transnational Research Programme pools research funding from CEDR members to fund transnational research projects on topics of shared interest to European road authorities and forms a continuation of previous programmes organised under the ERA-NET ROAD brand. The aim of the Automation programme is to investigate what transformational change automation will create for National Road Authorities. Specifically, what new opportunities will automation produce and what core business changes are required to unlock these opportunities?

The call had three sub-themes, which led to the funding of three specific projects on the three specific topics:

- **MANTRA** – Making full use of Automation for National road TRansport Authorities
- **DIRIZON** – Advanced options for authorities in the light of automation and DIgitalisation hoRIZON 2040
- **STAPLE** – SiTe Automation Practical LEarning

All projects started in September 2018 and finalised in autumn of 2020. A final conference was organised on 6th November 2020 as a web conference due to the Covid-19 pandemic. The conference allowed the project consortia to report their results to both the Programme Executive Board as well as to each other and to provide another opportunity to discuss and further elaborate on overarching topics in interactive workshops. During the conference, discussion about the projects themselves, their highlights and the identification of open questions took place. The projects' results presented at the conference are summarized in this report. A brief overview of the projects is given below.

MANTRA responded to the question how automation will change the core business of NRAs. This meant identifying influences of automation on the core business in relation to key policy goals like road safety, traffic efficiency, the environment, customer service, maintenance and construction processes. Furthermore, MANTRA set out to determine how the current core business on operations & services, planning & building and ICT will change in the future. Responsibilities of European NRAs vary, and MANTRA covered the whole spectrum of business areas with detailed assessment for incident & event management, traffic management, road maintenance, winter maintenance, crisis management, traffic information provision, road planning, road building, road works planning, physical road infrastructure, digital infrastructure and ITS systems as well as enforcement and tolling (which are part of the responsibilities of some European NRAs).

The work focused on five use cases: highway autopilot, highly automated freight vehicles on open roads including platooning, commercial driverless vehicles as taxi services, driverless safety trailers and automated winter maintenance vehicles. The work started with the assessment of deployment of automated functions up to 2040 including assumptions for market penetration rates of the specific use cases as well as their Operational Design Domains. Following this, micro and macro simulations were performed for the selected use cases to get results for expected impacts on the NRAs' policy targets. The project also tackled the consequences on infrastructure due to the implementation of automated driving functions. This was done by assessing the impact on infrastructure due to the use of automated driving functions on the one hand and useful adaptations to support the safe deployment of connected and automated driving by providing required infrastructural ODDs on the other. This resulted in a road map providing the NRAs guidance on the expected changes and useful adaptations in their core business.

DIRIZON aimed at assisting the NRAs in moving towards the digitalisation of their road networks and automated driving. The digitalisation of road networks and the rapid developments in automated driving will affect the core activities that NRAs carry out, offer new (business) opportunities and provide NRAs with new and more efficient ways to achieve goals for road safety, traffic efficiency, the environment and customer service. The DIRIZON project's goal was to support NRAs in identifying how these developments will affect their operations and their interaction with other actors. In order to achieve this goal, the project determined the implications of digitalisation and automated driving on use cases, and their consequences on data needs and requirements for both the NRAs and for a data-exchange platform.

The project consortium worked on linking the current and future relationships with other actors in the area of data exchange and how these relationships may evolve in the future in order to understand the current and future roles and responsibilities of NRAs and other actors in respect of digitalisation and automated driving. Following this they determined the requirements for data-sharing platforms and explored business model archetypes for the exploitation of a data exchange platform. All this resulted in a roadmap indicating a step-by-step transition towards full digitalisation of NRAs road networks.

STAPLE addressed the third topic on practical learnings for NRAs from test sites. The overall aim of STAPLE was to provide a comprehensive review of technological and non-technological aspects of the most relevant connected and automated driving test sites in order to understand the impact of these sites on the NRAs' core business and functions. The project provided NRAs with the necessary know-how on connected and automated driving test sites, with the aim of supporting their core business activities, such as road safety, traffic efficiency, customer service, maintenance and construction. The project produced a catalogue of test sites, together with their current activities for future reference by NRAs. This catalogue summarizes what type of technologies are available and will help in identifying existing gaps of current and future operations of these sites as well as the implications for the NRAs' core business areas. Additionally, an assessment was performed on additional considerations such as the NRA-related implications of SAE Level 3 and 4 automated systems on the network, roads with/without physical infrastructure, maintainability and construction as well as the need of roadside equipment.

Following project presentations, the afternoon of the final conference featured interactive break-out sessions. These were dedicated to discussing recommendations for implementation of three over-arching topics of the projects, instead of break-out sessions dedicated to the individual projects. Thereby the discussions could focus on the most pressing matters and unresolved questions, rather than on project specifics. Two break-out sessions were held in parallel twice, allowing all participants to attend both sessions and still engage the participants in smaller groups.

During a more strategic session managerial topics were discussed focussing on the impact of automation on digital infrastructure and reviewing whether or how far the overall research questions of the call could be translated into hands on roadmap items for further take-up. Participants agreed that while a lot has been done in the projects already, definitions and harmonization of requirements for digital infrastructure still need to continue.

The other session focused on three most pressing specific matters: A common ODD & ISAD framework, the necessity for digital twins and the definition of minimum risk manoeuvres. All these topics only evolved in the course of the programme and were not even on the radar at the beginning of the call. Therefore, a lot of work in terms of further research, pilot projects, testing and international harmonization involving all stakeholders still needs to be done.

Summing up, the programme was launched early on in the fast-evolving context of cooperative, connected and automated driving. The projects provided answers on the expected changes to NRAs' core business and what can be done to use the developments to support their policy goals. Not surprisingly, new questions and topics surfaced during the work. In order to stay in the driver's seat further research and international cooperation need to be carried out to realize the full potential of cooperative, connected and automated driving for NRAs.

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Glossary of Terms

ADS	Automated Driving Systems
AI	Artificial Intelligence
AV	Automated Vehicle
C-ITS	Cooperative Intelligent Transport Systems
CAD	Connected and Automated Driving
CAM	Connected and Automated Mobility
CAV	Connected and Automated Vehicle
CCAV	Cooperative Connected Automated Vehicles
CCAM	Cooperative Connected Automated Mobility
CEDR	Conference of European Directors of Roads
CEDR CAD WG	CEDR Working Group for Connected and Automated Driving
CV	Conventional Vehicle
DoRN	Description of Research Needs
DIRIZON	Project Acronym: Advanced options for authorities in the light of automation and digitalisation horizon 2040
EC	European Commission
ENR	ERA-NET Road
EU	European Union
GDPR	General Data Protection Regulation
GLOSA	Green Light Optimal Speed Advice
HD	High Definition
HGV	Heavy Goods Vehicles
HS	Hybrid Scenario (DIRIZON)
I2V	Infrastructure-to-Vehicle communication
ICT	Information and Communication Technology
IDS	International Data Spaces
ISAD	Infrastructure Support levels for Automated Driving
ISO	International Organization for Standardization
Km	Kilometre
Maint.	Maintenance
MANTRA	Project Acronym: Making full use of Automation for National Transport and Road Authorities – NRA Core Business
MDS	Market Dominant Scenario (DIRIZON)
MLP	Multi-Level Perspective
MobiDS	Mobility Data Spaces (DIRIZON)
MRM	Minimum Risk Manoeuvre
NAP	National Access Points
NDS	NRA-Dominant Scenario (DIRIZON)
NRA	National Roads Authority

O&M	Operation and Maintenance
ODD	Operational Design Domain
OEM	Original Equipment Manufacturer
PDI	Physical and digital road infrastructure (WG3 of CCAM Single Platform)
PEB	Programme Executive Board
SAE	SAE International (Society of Automotive Engineers)
STAPLE	SiTe Automation Practical Learning
TM	Traffic Management
V2V	Vehicle-to-Vehicle communication
V2I	Vehicle-to-Infrastructure communication
VAT	Value added tax
WG	Working Group

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1 Introduction

1.1 Background

The CEDR Transnational Research Programme was launched by the Conference of European Directors of Roads (CEDR). CEDR is the Road Directors' platform for cooperation and promotion of improvements to the road system and its infrastructure, as an integral part of a sustainable transport system in Europe. Its members represent their respective National Road Authorities or equivalents and provide support and advice on decisions concerning the road transport system that are taken at national or international level. CEDR is an organisation which brings together the road directors of 27 European countries. The aim of CEDR is to contribute to the development of road engineering as part of an integrated transport system under the social, economic, and environmental aspects of sustainability and to promote co-operation between the National Road Administrations.

The participating NRAs in the CEDR Call 2017: Automation are Austria, Finland, Germany, Ireland, Netherlands, Norway, Slovenia, Sweden and the United Kingdom. As in previous collaborative research programmes, the participating members have established a Programme Executive Board (PEB) made up of experts in the topics to be covered.

This Transnational Research Programme pools research funding from CEDR members to fund transnational research projects on topics of shared interest to European road authorities and forms a continuation of previous programmes organised under the ERA-NET ROAD brand. "ERA-NET ROAD – Coordination and implementation of Road Research in Europe" was a Coordination and Support Action funded by the 7th Framework Programme of the European Commission which concluded in December 2011. The goal of ERA-NET ROAD (ENR) was to develop a platform for international cooperation and collaboration in research areas of common interest. This included the production of an "ENR-toolkit" for carrying out transnational research and trials of the various procedures developed through a series of projects and programmes funded directly by European Road Administrations.

Content wise, the Call 2017 on Automation has built on the findings of its predecessor Call 2014 on Mobility and ITS with the projects ANACONDA, DRAGON and MAASiFiE (Malone et al 2017) as the results of this call provide the research ground for the Call 2020 on the Impact of CAD on safe smart roads which has opened in November 2020.

1.2 General information on the programme

The Project Executive Board (PEB) of the CEDR initiated Programme entitled "Automation" started three research projects in 2018.

The aim of this research programme was to investigate what transformational change automation will create for National Road Authorities (NRAs). The scope of the term 'automation' with regards to this call included both the ongoing development of automated and connected vehicles, leading to an automated traffic system, as well as the automation of maintenance and construction processes and the full range of road operation.

The main reason for this Transnational Research Programme was that NRAs need to understand how to embrace new technology to improve road safety, traffic efficiency, the environment, customer satisfaction, maintenance, and construction processes. In addition to what transformational change automation will create for NRAs the goal was to specifically answer, what new opportunities automation could produce and what core business changes are required to unlock these opportunities?

The research focus was on crosscutting automation up to 2040 that supports:

- Road safety
- Traffic efficiency
- Environment
- Customer service

The call had three sub-themes, which led to the funding of three specific projects which answered the following questions:

- A: How will automation change the core business of NRAs?
- B: What new options do NRAs have from digitalisation and automation?
- C: Practical learnings for NRAs from test sites

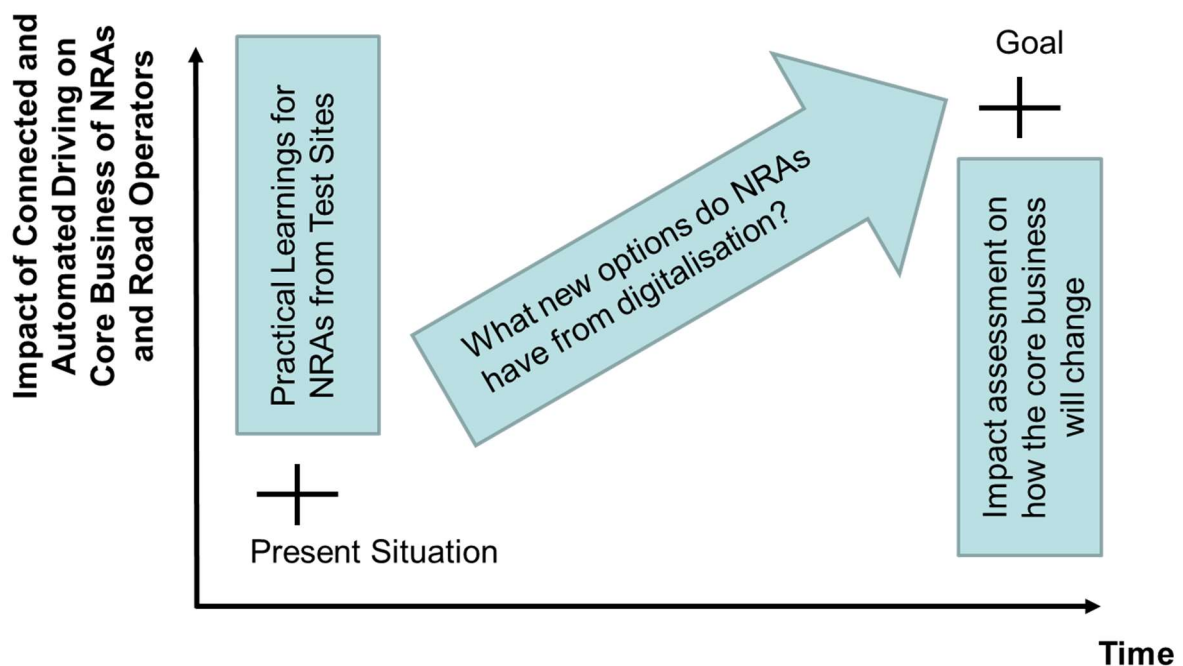


Figure 1. Visualization of the sub-themes in accordance with DoRN

The three projects funded within this call are:

- MANTRA – Making full use of Automation for National road TRansport Authorities
- DIRIZON – Advanced options for authorities in the light of automation and digitalisation horizon 2040
- STAPLE – SiTe Automation Practical Learning

1.3 Approach and Structure

This final report brings together the findings and recommendations from the three projects in a succinct document. It aims to identify synergies between the three projects and illustrate how road authorities can implement the recommendations from each of the projects in an efficient manner. This final programme report contains:

- General information about the programme (chapter 1)
- Executive summaries of all 3 projects focusing on the key results (chapter 2)
- Outcomes, highlights and remarks of the final conference including recommendations for implementation steps and applicability of the projects (chapter 3)
- Overall conclusions and recommendations for NRAs and open questions (chapter 4)

The consortium of writers represents the projects MANTRA and DIRIZON. To ensure that also the STAPLE results and perspective is covered appropriately strong liaison with the coordinator took place. The perspective of each project was initially provided in a succinct manner individually followed by overall conclusions bringing together the overarching results and recommendations focused on the programme goals.

Task	Project Input			Validation, compilation & overall results
	MANTRA	DIRIZON	STAPLES	
General information about the programme	-	-	-	ARNDT
Executive summaries	Traficon	AustriaTech	ARNDT	Hitec, ARNDT
Outcomes, highlights and remarks of the final conference	Traficon	AustriaTech	ARNDT	ARNDT
Recommendations for implementation steps and applicability of the projects	Traficon	AustriaTech	ARNDT	Hitec, ARNDT
Overall conclusions and recommendations for the national road administrations	Traficon	AustriaTech	ARNDT	Hitec, ARNDT
Open questions	Traficon	AustriaTech	ARNDT	ARNDT

Table 1. Work allocation

The summaries on the outcomes of the discussions and interactive sessions during the conference are summarized in this report. Also, the results of the live polls held via the live poll tool “Slido” during the conference are collected in the Appendix.

2 Project Descriptions

2.1 MANTRA

Duration:	August 2018 – November 2020
Budget:	500 000 € incl. VAT
Coordinator:	Traficon (Finland)
Partners:	Hitec (Austria), ARNDT IDC (Germany), TU Delft (Netherlands), University of Leeds (UK), VTT (Finland)
Website:	www.mantra-research.eu

2.1.1 Project overview

MANTRA responded to the questions posed as CEDR Automation Call 2017 Topic A: How will automation change the core business of NRAs, by answering the following questions:

- What are the influences of automation on the core business in relation to road safety, traffic efficiency, the environment, customer service, maintenance and construction processes?
- How will the current core business on operations & services, planning & building and ICT change in the future?

The project's expected outputs were:

- Development and implementation of a road map including identification of core business implementation issues
- Changing roles and responsibilities of the different stakeholders and especially NRA's
- Impact and socio-economic assessment of impacts of different types of automation in different operating environments
- Assessment of impact on NRA's core business and functions including maintenance and construction
- Identification of legal enablers and challenges
- Minimum data requirements for automation to facilitate service provision
- Recommendations for the required digital infrastructure
- Recommendations for road safety, traffic efficiency, environment, customer service, maintenance and construction
- Advice on unintended consequences and mitigation

MANTRA emphasized close liaison towards other actions in the area, building on the consortium members' own involvement in European and national projects as well as the experience working with NRAs. The liaison was especially close to CEDR CAD WG, the members of which are heavily involved in key European and international platforms and working groups.

MANTRA was structured in five work packages as described in Figure 2.

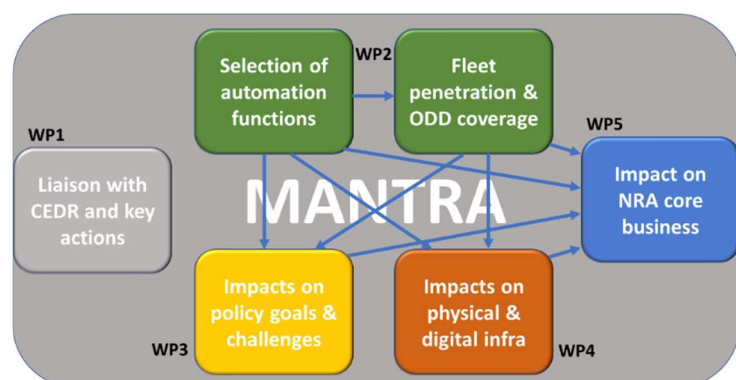


Figure 2. MANTRA project structure

The work started in WP2 by selecting four most relevant automation functions together with CEDR, and then producing predictions of vehicle fleet coverage by vehicle type and Operational Design Domain (ODD) coverage forecasts to determine the spatial and temporal coverage of each function. After this, modelling and other analyses in WP3 focused on the safety, efficiency and environmental impacts of connected automated driving utilizing the vehicle and ODD coverage predictions, based on the likely changes in mobility and driver/travel behaviour of road users. The work continued for each of the selected functions by assessing how the function together with connectivity affects the physical and digital road infrastructure as well as the communication infrastructure, due to

- a) the need to make changes to the infrastructure to provide the required ODD to facilitate connected and automated driving,
- b) the automated function's operation itself, and
- c) the possibility to improve infrastructure related operations as a result from utilizing automated functions or new data provided by these functions.

This also covered the legal framework and affected technical standards, and any needs to make changes in them.

The work concluded by mapping the socio-economic, infrastructure and other impacts of the selected functions against the core business areas of the road operators. In addition, the work contained a comprehensive assessment of the impact of the total change in NRA core business due to connectivity and automation in combination with digitalization, electrification, urbanization, servitization and other megatrends. While national priorities concerning core business emphasis and automation functions vary, MANTRA applied a European transnational approach to facilitate the utilization of the results for all CEDR members.

2.1.2 Main results

A key starting point was the identification of the key use cases of highly automated driving (SAE Level 4) for the road authorities and operators by 2030. This was done at the CEDR workshop at the start of the project and further detailed at a workshop for the CEDR CAD Working Group. The agreement was to focus on five use cases of: (Aigner et al. 2019)

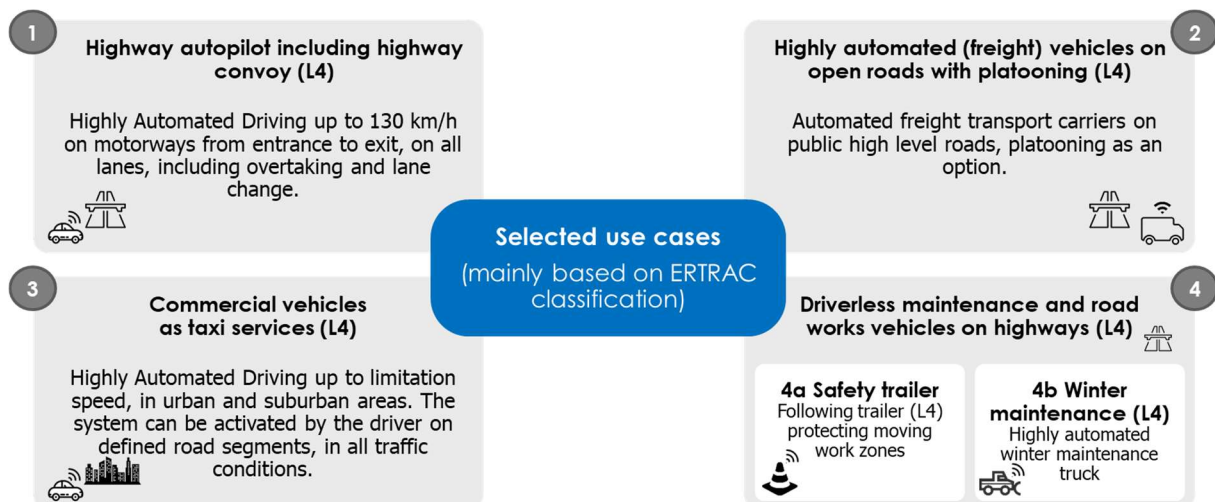


Figure 3. MANTRA use cases

In order to assess the impacts and road operator consequences of these use cases, MANTRA proceeded to estimate the market penetration of new vehicles, vehicle fleet penetration, and vehicle km penetration of the use cases with regard to the relevant vehicle types. The key penetration here is the vehicle km penetration as that describes the situation in traffic flow and thereby is the most relevant for the actual impacts of the use case for traffic and thereby the road authorities and operators. The results on vehicle km penetration are shown in Table 2.

MANTRA Use case	Fleet	Vehicle km penetration (%)			
		2030		2040	
		Low	High	Low	High
Highway autopilot	Cars	1.3	6.6	11.1	47.2
Automated freight vehicles	HGVs	0.8	5.1	12.4	59.5
Robot taxis	Taxis	0.0	8.6	5.7	72.6
Automated winter maint. vehicles	Maint. trucks	0.0	1.3	6.9	24.0
Automated roadworks safety trailers	Safety trailers	3.9	8.9	14.7	39.7

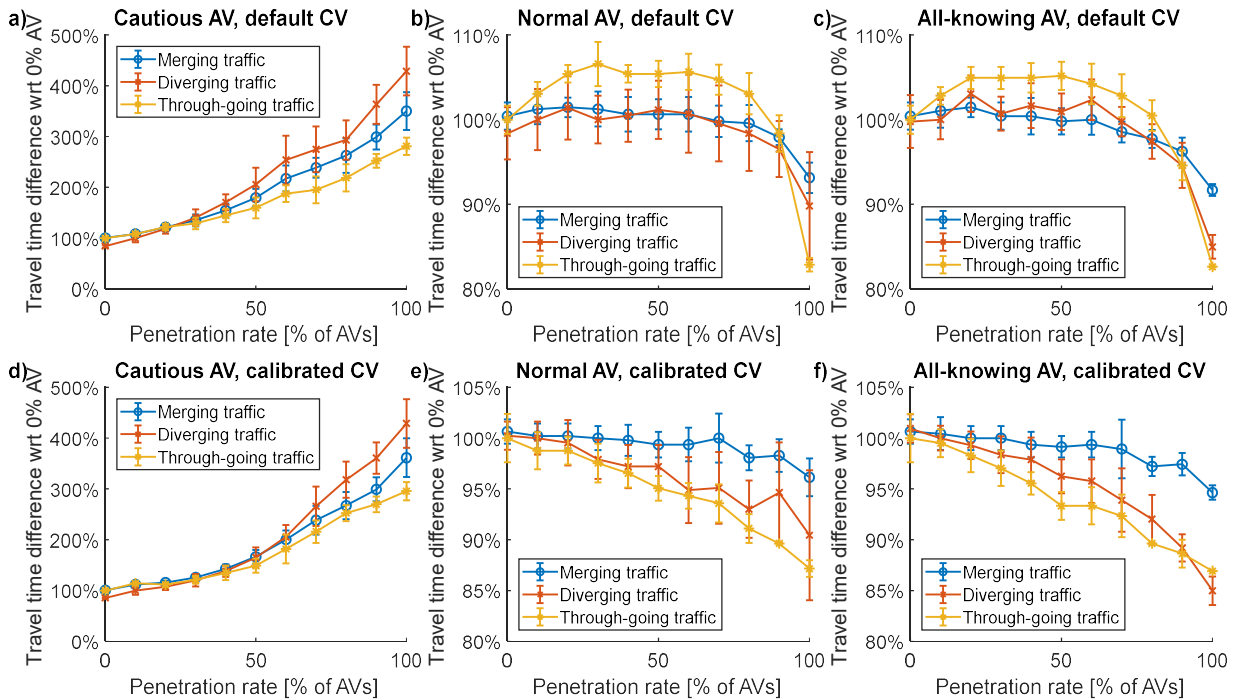
Table 2. Vehicle km penetrations of the MANTRA use cases in European vehicle fleets in 2030 and 2040 in Low and High scenarios. (Aigner et al. 2019)

Above, Low is the “business as usual” scenario, where the automated driving use cases are taken into use as in usual market economy, utilising solutions based on the utility or economic value to the customer or user. The High scenario assumes the acceleration of automated driving use cases via financial incentives such as reduced taxation or via regulatory actions, for instance by mandating automated driving in specific conditions.

Next, MANTRA conducted and summed up comprehensive state of the art inventory (Penttinen et al. 2019) on the impacts of connected and automated driving on travel demand, travel behaviour, traffic flow, safety and energy. The review was based on ongoing and recently completed EU and national projects, and a comprehensive literature review of key publications and articles on the topic.

Most of the impact estimates in the literature are based on either expert evaluation or traffic simulations. The other source for current estimates are available field studies on driver assistance systems. According to literature, the expectations of the magnitude of the impacts vary a lot. Where someone is expecting the traffic safety to be improved by 90%, the others are much more conservative and present only one-digit estimates. The same applies for other impact areas, even fully contradicting estimates exist. (Penttinen et al. 2019)

MANTRA’s own impact assessment (van der Tuin et al. 2020) studied the mobility and efficiency impacts of all five use cases. Figure 4 shows the impact of highway autopilot on a motorway weaving section efficiency. It can be seen that the cautious driving logic with 1.5 s following headway leads to an enormous increase in travel time as the number of automated vehicles on the road increase. The very safe behaviour of automated vehicles leads to large gaps between vehicles and thereby a decreased level of service of the road. Differences between the normal (0.9 s headway) and all-knowing (0.6 s) driving logic are not very large – the travel times for both default and calibrated conventional vehicles are about identical. The main difference can be found in the spread of results (indicated by the error bars), which is slightly lower with all-knowing than normal automated vehicles. (van der Tuin et al. 2020)



Note: CV = Conventional Vehicle.

Figure 4. Comparison of different AV driving logics and different conventional vehicles, modelled on a weaving section with a 300m taper lane and 0.85 flow/capacity ratio (van der Tuin et al. 2020)

The mobility impacts of robot taxis are illustrated in Figure 5.

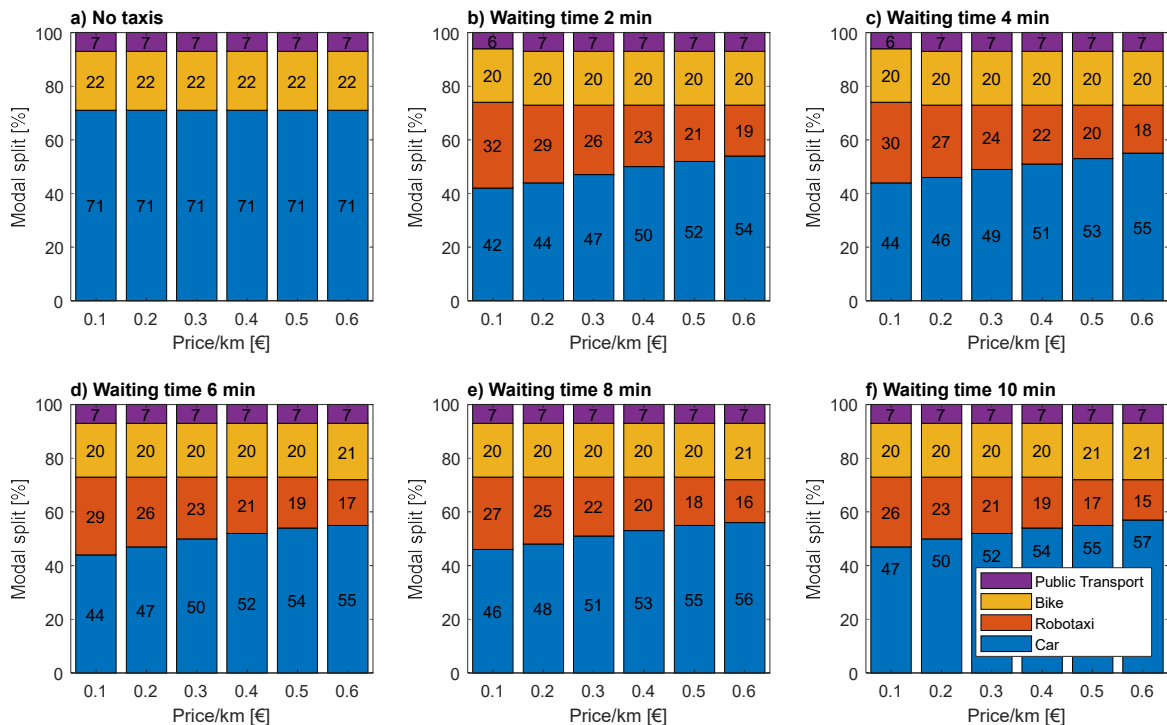


Figure 5. Effect of robot taxi waiting time and price on the number of journeys by various transport modes in the city of Delft (van der Tuin et al. 2020).

Public transport kept an equal share of journeys for each of the simulations: 7% of trips. Transport by bikes decreases a bit from 22% (no robot taxi) to 20% (with robot taxi). The

main influence of robot taxis can be found in the decrease of car usage. With shorter waiting times, more people switch to robot taxis. Also, cheaper prices result in a higher share of robot taxi usage. This leads to a share between 32% (waiting time 2 minutes, €0.10 per km) and 15% (waiting time of 10 minutes, €0.60 per km). The relocation of empty robot taxis – getting back to the origin or a new trip – resulted in many additional kms driven and thereby also leading to additional delays for all road users. MANTRA only looked into private taxi trips, the use of (partly) shared trips might overcome this problem by decreasing the required number of trips. (van der Tuin et al. 2020)

The simulation study examining the impact of highly automated freight vehicles on a major motorway corridor indicated that the impacts on travel time and speed were positive. The benefits generally increased in line with penetration of the automated vehicles, with the most substantial benefits being in congested conditions. In free flow conditions, the benefits accrued mainly to the automated vehicles. Shorter inter-vehicle gaps and a maximum platoon length of four instead of three vehicles both increased the benefits, but only in congested stretches of motorway. (van der Tuin et al. 2020)

The impact of two different types of automated maintenance scenarios was also tested: a safety trailer in front of a slow-moving work zone (15 km/h), and a winter maintenance truck for snow ploughing (45 km/h) and preventative salting (60 km/h). The position of the automated maintenance vehicle was communicated to other automated vehicles only, combined with some advice to move to the other lane. What to communicate and how highly automated vehicles should respond is a point of attention: during our simulations it was shown that communication leads to delays for all types of vehicles, mainly caused by hindering non-automated vehicles not always being able to merge into a lane due to large speed differences. No communication (i.e., only using sensors to detect that the speed of the vehicle(s) in front is low) results in the smoothest traffic flow. The results indicate that communication should be available to either both automated and non-automated vehicles or neither, rather than being given to automated vehicles only. (van der Tuin et al. 2020)

The impact of automated maintenance vehicles was assessed with regard to road safety, traffic efficiency, environment and customer service. The introduction of automated safety trailers to protect work zones caused by unexpected incidents will likely provide the largest benefit to road safety. This will also result in a positive effect on traffic flow efficiency. Automated winter maintenance trucks performing preventative salting works might lead to an improvement in environment due to optimization of the required amount of salt. Last, the customer service is to be expected positively for nearly all automated maintenance operations due to the possibility of detailed information provision. (van der Tuin et al. 2020)

MANTRA used several simulation software packages in its analyses. The OmniTRANS used for macrosimulations of mobility impacts was suited to also automated vehicles but provided no support for their mode choice and travel time functions meaning that such needed to be gained from other research. For the microsimulation package VISSIM there are useful parameters for automated vehicles from other projects such as CoEXist. The AIMSUN microsimulation models were also applied for platooning and proved to be highly usable, particularly since an API to handle the vehicle-to-vehicle communication was available. The principal shortcoming in the version that was used was that it was not possible to visualise the coupling process and thus to see in visual output which vehicles were coupled and which were not. (van der Tuin et al. 2020)

The impact of highly automated driving on the physical and digital road infrastructures was carried out from three different angles as indicated by Figure 6.



Figure 6. Selected angles to assess the impact of highly automated driving on physical and digital road infrastructure (Ulrich et al. 2020).

With regard to the different use cases, automated freight vehicles were expected to have the biggest impact on infrastructure due to their operation. The following areas were identified as most crucial: (Ulrich et al. 2020)

- Pavement
 - > Faster deterioration due to higher loads and convoys
 - > Focus on complex areas of highways (junctions, merging lanes)
 - > Need for additional emergency bays and safe harbours
 - > Changing requirements/standardization for road marking
- Tunnels
 - > Need for additional guiding functions (tunnel wall finishing)
 - > Lighting in exits/entries
 - > Total emergency systems: new requirements
- Road equipment
 - > Most effects on ITS and telematics
 - > International standardization of road signs – machine & human readable
 - > Toll plazas need automated lanes

MANTRA provided a list of Operational Design Domain attributes for the highly automated driving use cases. This is shown in Table 3. MANTRA also provided a detailed list of the sub-attributes to the physical and digital infrastructure attributes relevant for connected and automated driving (Ulrich et al. 2020). These have been utilised since in e.g., the CCAM platform of the European Commission.

The physical and digital infrastructure are closely connected. For instance, in the case of road markings and traffic signs the automated vehicles benefit from a "hybrid" combination of both the physical markings and signs as well as their digital twins in HD maps.

Looking at the unit costs of the various infrastructure changes proposed, the largest costs per road km were estimated due to: (Ulrich et al. 2020)

- provision of safe harbours (in case of ODD termination)
- signs and barriers for access control (in the special cases where needed)
- adaptation of traffic centres and systems
- up-to-date HD maps
- trunk communications with fibre optics cabling
- game fences alongside roads

ODD attribute	Physical / Digital infrastructure	Static / Dynamic
Road	Physical	Static
Speed range	Physical	Static
Shoulder or kerb	Physical	Static
Road markings	Physical	Static
Traffic signs	Physical	Static
Road equipment	Physical	Static
Traffic	-	Dynamic
Time incl. light conditions	-	Dynamic
Weather conditions	-	Dynamic
HD map	Digital	Static/Dynamic
Satellite positioning	Digital	Static
Communication	Digital	Static
Information system	Digital	Static
Traffic management	Digital	Dynamic
Infrastructure maintenance	Physical/Digital	Dynamic
Fleet supervision	Digital	Dynamic
Digital twin of road network	Digital	Dynamic

Table 3. Road operator related ODD attributes. (Ulrich et al. 2020)

The biggest changes will, however, take place in the digital infrastructure required by highly automated vehicles. Many of the changes are related to digitalisation in general and would happen due to the requirements of also other road operator core activities. For instance, the communication infrastructure is needed just for connectivity purposes even without automation to facilitate C-ITS, vehicle industry servicing, and infotainment services. Yet, connectivity also makes highly automated vehicles much better in terms of safety, efficiency and cleanness.

Furthermore, it should be noted that the results reflect the knowledge of the likely function and ODDs of highly automated vehicles in 2020. It is likely that technology, market and policy developments will change the importance, benefits and costs of the individual changes in the physical and digital road infrastructure considerably until 2040.

In the field of road operation, maintenance and traffic management automation can certainly contribute to increase safety of operational workers as well as road users, improve traffic flow and optimize operational cost but only in combination with connectivity. The main conclusion on necessary infrastructure changes to improve operations and maintenance is therefore the need for integrated connectivity of operational vehicles and work-zones with a traffic management centre, equipped to inform automated and conventional vehicles in real time about such works. With such a traffic management, supported by automation and connectivity, smart routing of road users is just a logical next step. All this together will support the over-arching goals 'no casualties, no congestion and no emissions. These goals will remain the same with the introduction of automated driving, but the procedures and methods will need to change as explained. The roles and responsibilities remain the same, and the road authorities and operators have to set the goals for traffic management.

Traditional highway operations and maintenance works (inspections, minor repairs, winter maintenance, incident management, etc.) necessary to reach the over-arching goals will also

be crucial in the future. Nowadays they are carried out by operational workers who are always at risk by carrying out their work in an environment with high-speed traffic right next to them. Supporting them in the most critical operational tasks, like work zone protection on fast lane and winter maintenance, with automated driverless vehicles will take away main safety hazards. The good news is that such measures are not assumed to need amendments on the physical infrastructure but rather further development of the technological readiness of the systems and the according legal framework. However digital infrastructure enabling the positioning of the vehicles and according standardized, connected communication with the traffic management centre are key for the safe implementation. (Ulrich et al. 2020)

Overall, the digital part of an operations management centre and the traffic management centre will need to merge and have integrated communication standards rather sooner than later. The role of the traffic management centre will become increasingly more important in an automated driving future to enable the NRAs to stay in control and to reach their policy goals. (Ulrich et al. 2020)

Future traffic management of automated vehicles can not overlook the ODD issue. Traffic managers need to be aware of the limitations of the highly automated vehicles operating in their networks so that they can prepare for the possible problems at road locations where the ODD of a number of highly automated vehicles will terminate due to static or dynamic conditions affecting the ODD. ODD-aware traffic managers can also provide information of likely ODD termination risks due to events, incidents, weather forecasts or other issues to the automated vehicles and their automated driving systems. Traffic management of the future may also contain ODD management as one functionality. (Ulrich et al. 2020)

The MANTRA work concluded with a road map up to 2040 regarding adaptations to be made to NRA core business and responsibility areas. The following core business areas were used in the analysis: (Kulmala et al. 2020)

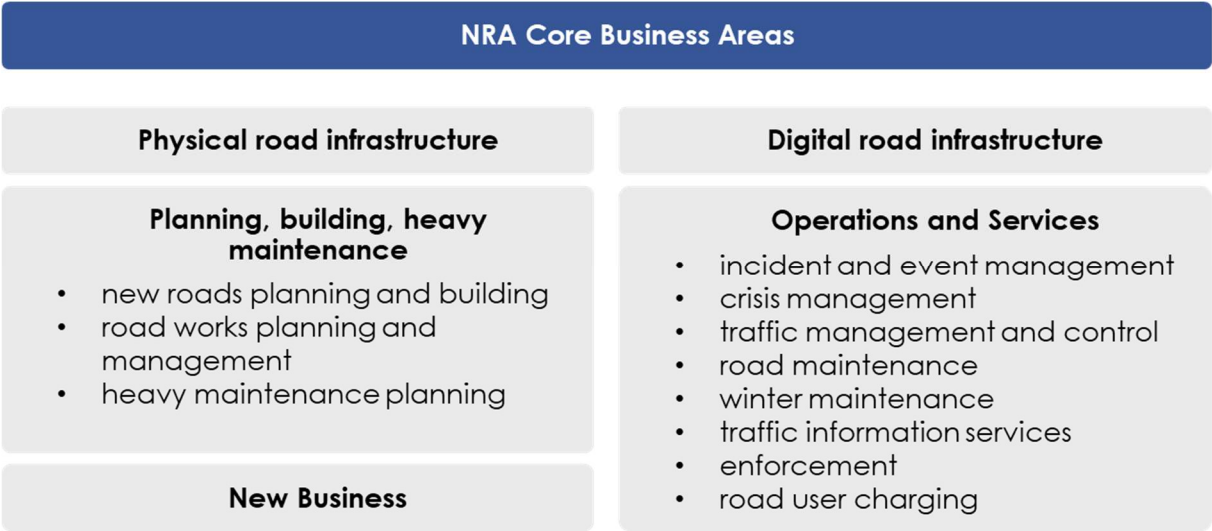


Figure 7. NRA Core Business Areas (Kulmala et al. 2020).

The Multi-Level Perspective (MLP) theory was used to analyse the transition. The MLP conceptualizes overall dynamic patterns in socio-technical transitions. The theory views transitions as non-linear processes that result from the interplay of developments. The core business of the NRAs can be understood as one socio-technical regime which is developing continuously but the structure of the regime is quite stable.

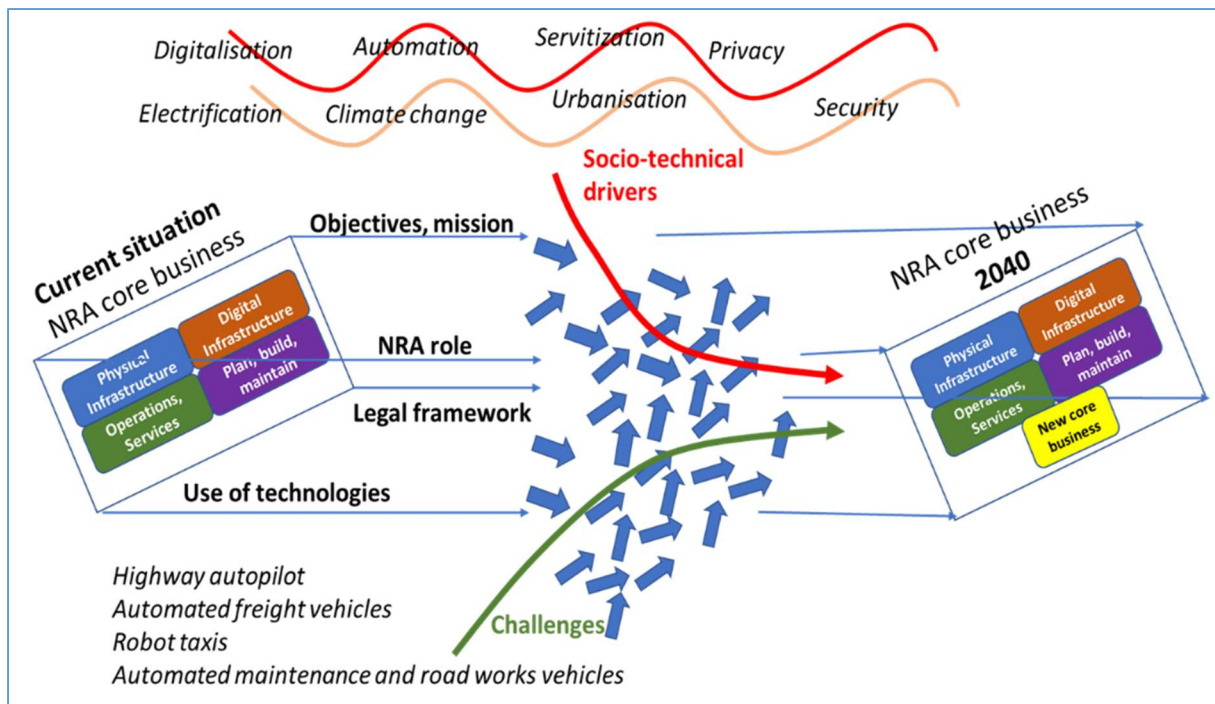


Figure 8. Application of MLP on NRA core business evolution (Kulmala et al. 2020).

The road map addressed the main core business implementation issues, and an indicative timing for national road authority and CEDR relevant implementation and other actions as well as a tentative recommended action plan for 2020-2024. This work was carried out by first preparing draft results which were then validated and elaborated on in a CEDR workshop in March 2020. (Kulmala et al. 2020)

The road map consisted of tables describing actions in different areas of the national road authority core business areas up to 2040. The 92 actions of the roadmap tables were then prioritized via a web survey to road authority and other experts on automated driving, which resulted in 22 priority actions. The actions were specified using a common template describing the business area, the content and timeframe of the action, the automated driving task and stakeholders affected, the legal prerequisites, the responsible stakeholders and their responsibilities, the roles of CEDR and NRAs, and the possible risks. (Kulmala et al. 2020)

The emphasis of the priority actions was on studying and learning more about highly automated driving, its potential benefits and costs, restrictions, ODDs and requirements towards NRAs including the physical and digital infrastructure, traffic management, maintenance and other operations. An important result was that there is a number of no regret actions that can be carried out even without roll-out of highly automated vehicles. However, there are a few key actions linked to actual roll-out and deployment where immediate action is needed. (Kulmala et al. 2020)

2.1.3 Recommendations

Concerning impact assessment of highly automated vehicles, most of the results available are from studies utilising modelling and simulation as their main source. It is thereby very important to pursue empirical studies in this area, to complement the results when on-the-road testing of automation in real traffic with other road users present, and data received from those tests, is available in large scale.

Moreover, even the models to estimate impacts, e.g., traffic microsimulation models, still need adjustment and parameters designed specifically for automated vehicles. The current vehicle behaviour models are based on the behaviour of human drivers. In addition, the behaviour of human drivers might also change when interacting with automated vehicles. The development

of the technology will also have great impact on the area and conditions where automation can be used (ODD), and hence can have impacts in. The variety of impact mechanisms need to be kept in mind when considering the potential impacts of connected and automated driving not only to traffic safety, but also other impact areas.

With regard to infrastructures, a highly developed digital infrastructure without an appropriate physical infrastructure is not sufficient to fulfil the mobility needs neither of manually operated nor of automated vehicles. Investments for further development of physical infrastructure need to be made considering the potentials of digitalization and the requirements of future vehicles with various degree of auto-mated functions.

There are some inherent difficulties for the road authorities and operators to prepare for facilitating and making use of highly automated driving. These are mainly related to technology evolution. The ODDs of highly automated vehicles depend on the capabilities of the sensors and software including artificial intelligence (AI), and these capabilities are improving quite quickly with the evolution of related technologies. Thereby it is important for the road authorities and operators to closely monitor the technology evolution and actively participate in constructive dialogue with the automotive industry to maintain their own preparedness and level of knowledge.

With regard to the actions recommended to the national road authorities as well as CEDR, the MANTRA road map (Kulmala et al. 2020) contains detailed recommendations for different road authority business areas.

2.2 DIRIZON

Duration: September 2018 – November 2020

Budget: 623,745.64 € incl. VAT

Coordinator: TNO (Netherlands)

Partners: Roughan & O'Donovan Consulting Engineers (UK); AustriaTech – Gesellschaft des Bundes für technologiepoltische Maßnahmen GmbH (Austria); AlbrechtConsult GmbH (Germany); HERE Technologies (as associated partner)

Website: <https://www.dirizon-cedr.com/>

2.2.1 Project Overview

The digitalisation of road networks and the rapid developments in automated driving will affect the core activities that NRAs carry out, offer new (business) opportunities and provide NRAs with new and more efficient ways to achieve goals for road safety, traffic efficiency, the environment and customer service.

Completed in November 2020, the goal of the DIRIZON project was to assist NRAs in identifying how these developments will affect their operations and their interaction with other stakeholders and relevant parties, culminating in a Roadmap, which provides recommendations for a step-by-step transition towards the full digitalisation of the NRA road network in an EU wide interoperable system. In achieving this goal, DIRIZON focused on three core topics (or Use Cases) relevant to the topics of Digitalisation and Cooperative Automated Driving as follows:

1. Provision of High-Definition Maps for Automated Mobility

This core topic deals with High-Definition maps meaning the provision of detailed mapping in a machine-readable format to support a cooperative, connected automated vehicle's ability to understand its precise positioning, plan beyond sensor vision, possess contextual awareness of the environment and local knowledge of the road rules.

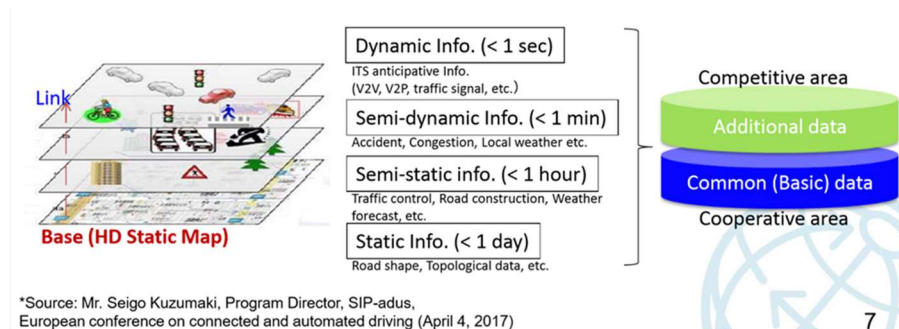


Figure 9. Visualisation of the layers and data types for a HD map (Shibata 2017)

2. Distribution of Digital Traffic Regulations

The distribution of digital traffic regulations becomes more and more relevant for Connected and Automated Mobility (as well as for other areas e.g. smart cities). The core topic breaks down the process for the distribution of digital traffic regulations from the triggering event to the provision to the connected automated vehicle.

3. Infrastructure Support for Cooperative Automated Driving

Infrastructure support for Connected and Cooperative Automated Driving (ISAD) is digitized information, on top of the HD map and the digitized traffic regulations, to support Connected and Automated Driving functioning.

The objective was achieved through a series of work packages, each contributing to the evolution of the project, as depicted in Figure 10, from gaining an understanding of NRA's and stakeholder's current position future thoughts in respect of digitalisation and CAD. The steps towards the final roadmap included determining the data requirements and data issues related to the core topics, defining a data exchange concept based on the IDS concept to enable a collaboration between NRAs, OEMs and Service Providers and exploring appropriate business models.

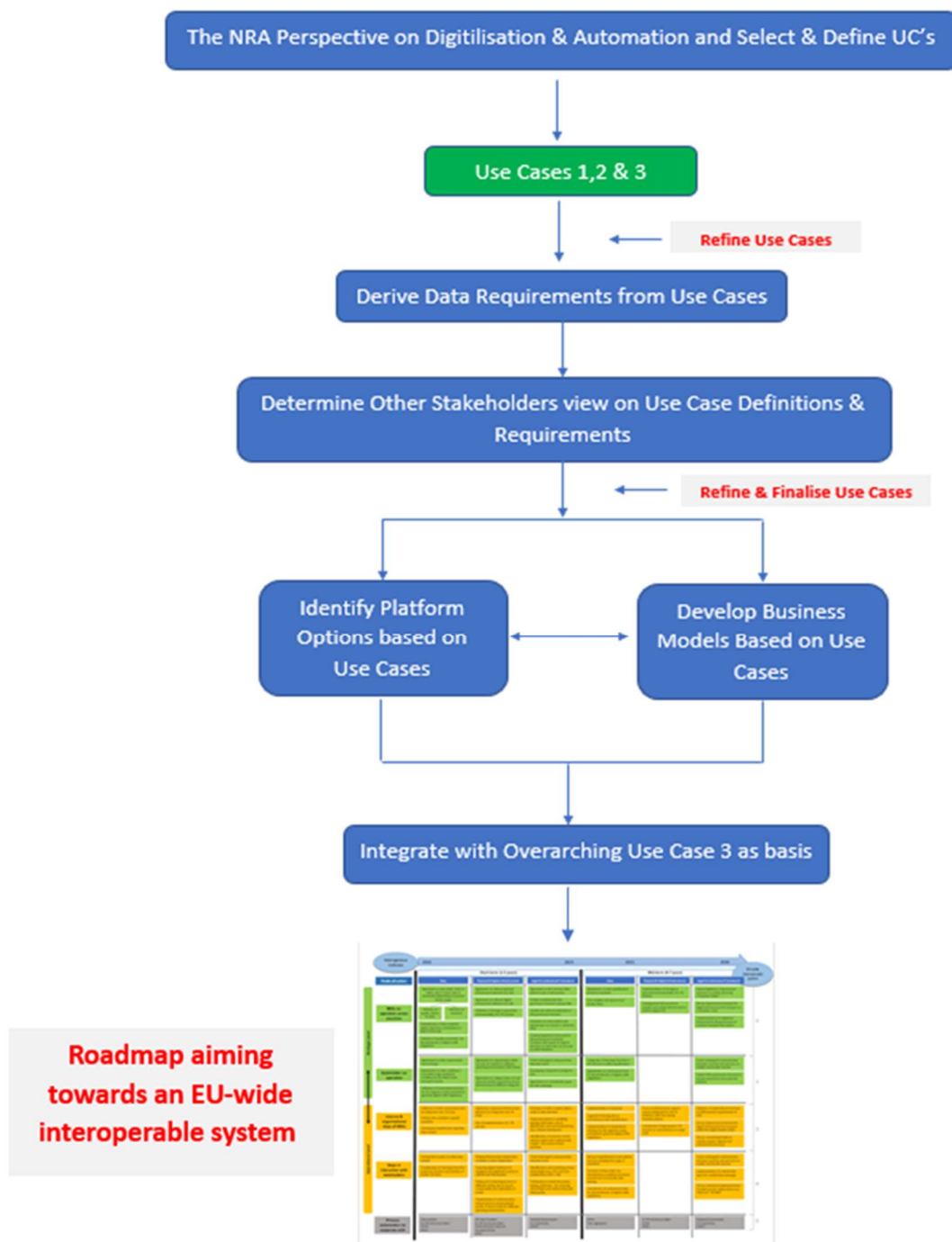


Figure 10. Work streams within the DIRIZON project

Following, the most important outcomes from the individual work packages are described. As this is just a small portion of the findings, reading the full deliverables will provide more detail and give greater understanding of the recommendations.

2.2.2 Main results

2.2.2.1 WP2 - NRAs and Digitalisation

The goal in WP2 (Tucker et al. 2019) was to identify the current level of digitalisation and automated driving of NRAs and to explore their plans. This was done by conducting a literature review, conducting interviews with representatives from relevant actors, primarily NRAs, and selecting use cases for further evaluation and elaboration in subsequent work streams. WP2 also identified the main risks and challenges to achieving full digitalisation of the road network and automated driving and categorised them (e.g., financial barriers, legal/regulatory issues, data issues, public acceptability).

Although NRAs lack clarity on their role and responsibilities whether they see themselves as enablers or service providers, in relation to data, they generally feel that there should be a joint responsibility in providing data. Interviewees agreed that the NRA's role is in infrastructure data provision to service providers as well as the provision of information on construction sites etc. to OEMs.

Equally, NRAs need to agree on the kind of digitalisation and connectivity needed on the road network. It is important that NRAs have connectivity at all relevant points of the road network, to ensure they have adequate radio coverage. As such, NRAs need the telecommunications providers, especially the mobile network operators, to improve services and develop robust communication technologies.

In respect to automated driving, NRAs see themselves ensuring that everything is compatible with regulations and legislation, although these are set at government level.

As all countries are at different stages of deployment, exchange and communication between different countries will be necessary. Moreover, it was acknowledged that most risks can be minimised through participation in research projects, testing, platforms etc.

While the availability of data may not be an issue, dealing with and processing the increased volume of data available will require a shift in operation procedures in respect of managing this data. This will also require staff to be trained to acquire new skills or a shift in the staff demographic (i.e., more software developers).

At present, all of NRAs' work is aimed at the people driving on their road network. Their interfaces are all aimed at people and NRAs need to start preparing their interfaces for engaging with digitalised systems in vehicles and a greater number of third parties. This step requires close cooperation with the automotive industry. NRAs will need to introduce appropriate C-ITS services on their road network to support the relevant stakeholders such as road users and OEMs to have a smooth transition from limited automated vehicles to fully automated vehicles operating on the network in the long term.

2.2.2.2 WP3 - Implications for use cases, Identification of Stakeholders and Data Needs and Requirements

Within WP3 (Malone et al. 2019), the three use cases selected in WP2 were expanded by developing a future view of the process flow in each use case and identifying the data requirements and data quality criteria in providing the use cases.

For **Use Case 1 HD Maps**, one of the main milestones defined in WP3 is the establishment of National Access Points or processes for data provision. Profiles, formats, structures and procedures are needed to handle data streams. This means that there has to be a framework that allows a structured provision of data.

Another important step is to agree on the digitalisation of roads and lanes and to establish localisation. In consequence, relevant physical infrastructure elements, for example roads, lanes and localisation landmarks, have to be digitised and made available to HD Maps. The maps comprise validated data from various sources that are in standardised computer-readable format. This means that already there have to be certain standards in place for the data to be integrated into HD maps. Short-term, there is not much V2V communication, i.e., data sharing amongst vehicles and no extra validation of the HD map data with vehicle produced data from sensors. It is not expected that different OEMs will share fleet-generated data with the exception of pilots.

Medium-term, the evolution of Use Case 1 assumes that most of the physical infrastructure elements have been digitised and are available to HD maps. Moreover, data like static speed limits, access restrictions and other traffic regulations should be available to HD maps. One goal for HD maps is to achieve the data quality levels required for the decision-making process in a CAV. Therefore, feedback loops must be established, and localisation quality has to be reached.

Use Case 2 Distribution of traffic regulations has significantly less milestones at the short-term level than HD maps and stretches more into the medium-term. Short-term, one requirement for this use case is the introduction of appropriate standards which can also extend into the medium term. These have to be agreed upon at least at EU level.

In the medium-term, traffic regulations and relevant infrastructure elements are gradually digitised, while conformance tests of digital traffic regulations and quality parameters have to be introduced. Furthermore, an interface for the regulatory body permitted to generate digital traffic regulations must be defined and implemented.

In the long term, the goal is to have a common platform where real-time traffic regulation data is being shared and stakeholders can exploit that data e.g., in order to provide HD maps enriched with dynamic traffic regulations.

The final **Use Case 3 ISAD Infrastructure Support for Automated Driving (ISAD)** for CAD lies on top of the other two use cases. Therefore, the use of HD maps as well as the distribution of digital traffic regulation are assumed. Consequently, its requirements are the gradual digitisation of physical infrastructure elements and of digital traffic regulations.

Short-term, the introduction of standards pertinent to data format, quality criteria and data exchange is important. There have to be agreements on which data to share, data quality criteria and levels as well as agreements on responsibility for data quality checks. It is also crucial to test these data, quality and processes in pilots. In the medium-term, these can be implemented. This use case makes clear that infrastructure support will not be the same on all roads as there will not be the same level of technology deployed. In terms of infrastructure services. The technological level may change across motorways and local roads will also have different technological levels.

2.2.2.3 WP4 - Stakeholder responsibilities in the areas of data exchange, digital platform, and actions needed for making identified use cases reality

After selecting and finalising the details of the use cases in WP2 and WP3, WP4 (Radics et al. 2020a), using the use cases as a reference, focused on the activities of all required stakeholders and identified the congruent and conflicting views in the present and future with other stakeholders with respect to data exchange. The scope of WP4 was to validate the developed process flow of defined use cases and the included actors, roles and available data not only from the view of “other” stakeholders, but furthermore also from the view of the NRAs (see Figure 11 as the result of refining the Use Cases). A specific focus was on eliciting stakeholder views on data availability, data exchange, roles, security, privacy and governance. This was done by desk studies and collecting data via a web-based questionnaire. The results were the very basis for the further data exchange concept provided by DIRIZON and the formulated recommendations towards the next steps.

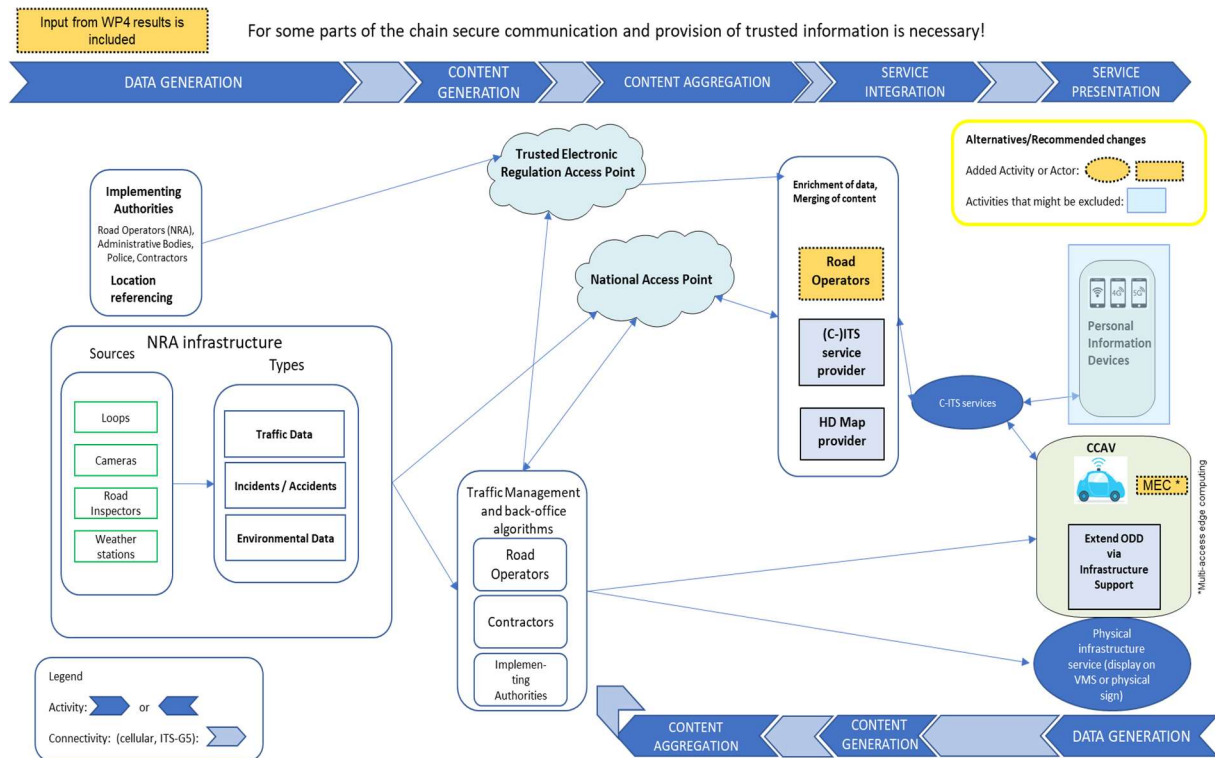


Figure 11. Adapted flow chart of Use Case 3 (Radics et al. 2020a)

One of the core issues of WP4 is the definition and clarification of roles and responsibilities in the area of automated driving. First, it can be emphasised that all stakeholders considered the need for collaboration between the various stakeholders as critical, independent of the core topic. Collaboration is a requirement for all processes and, therefore, might be the biggest challenge. A proposed multi-stakeholder environment can only be successful if cooperation is effective, profitable and transparent.

The results of WP4 show that different data types relevant for CAD can be collected from many different sources and by different parties. Especially when it comes to data storage and accessibility of this data, a clear distribution of roles and responsibilities is needed. Therefore, it is necessary to find a common consensus on data needs (data to collect, data to share, data to standardise) with all relevant stakeholders at an early stage (short-term). The availability of data in a machine-readable format is the very basis to make this reality.

In general, the respondents in WP4 agree on what data is required for CAD, but it has not yet been fully clarified to what extent data exchange/sharing is handled. The results of WP4 show that there is still disagreement about the role of the NAP. The outcomes lead to the conclusion that a common agreement on a shared data space for data exchange, where the role of NAP is solved and clearly specified, is a necessary action in the next years.

A further focus of WP4 was the examination of potential benefits as well as risks and challenges in regard to digitised and automated driving. In future, it will be important to consider security and privacy issues. Therefore, GDPR expectations must be fulfilled. Especially in the area of HD maps cybersecurity is a major topic that will challenge the actors in the future. In addition, legal restrictions may raise when sharing data among non-EU countries. Map providers suppose challenges and uncertainty in the meaning of open data and fees for data in different countries. Next to these, the need for standards and the compliance with standards is of highest importance. Latency issues can be seen as major risks and should be considered in the step-by-step transition towards full digitalisation of the road network.

2.2.2.4 WP5 - Data-exchange concepts for NRAs in the light of connected automated driving

The focus of WP5 (Lüppges et al. 2020) was the development of data exchange options with Use Case 3 “Infrastructure Support for Automated Driving” as a basis since it is the most complex use case, which lies on top of the others. Therefore, research on innovative projects and initiatives related to the topic of data exchange was carried out in WP5.

WP5 started with the thesis that any type of future connected automated driving scenario will generate a need for substantial improvements in data exchange between road authority backend systems, service provider backends and OEM backends (cloud-to-cloud services). Appropriate services would pave the way for providing data services directly into vehicles, mobile devices or aftermarket devices used inside vehicles and, vice versa, providing sensor-data back to the connected backends.

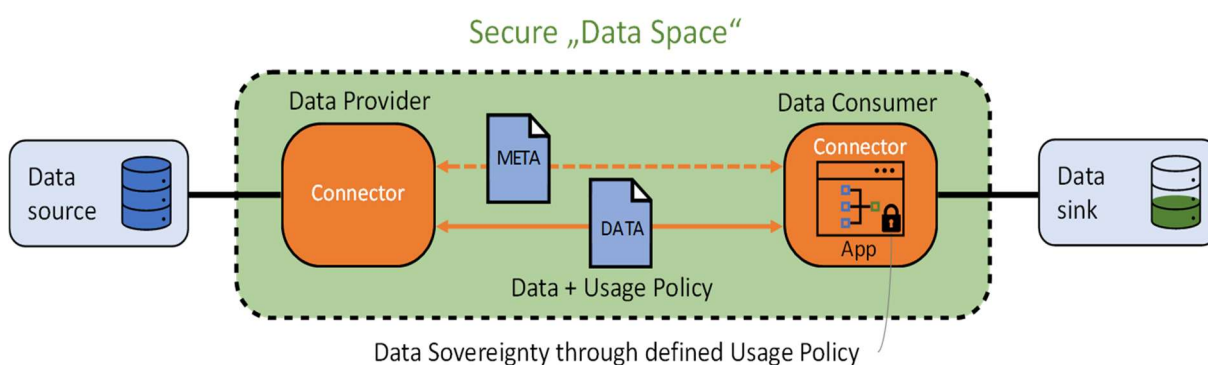


Figure 12. Functional principle to ensure data sovereignty (Pretzsch et. al 2020)

In the deliverable, an overview of data requirements with regard to data exchange options is given as a starting point. This list especially covers technical requirements like latency, refreshment rate and availability. This outcome is essential when it comes to recommendations in the field of needed data types and corresponding quality criteria in respect of CAD.

Based on this introduction, WP5 provided an overview on current data exchange concepts. In this context there was a focus on the introduction of NAPs, C-ITS, Data Task Force and International Data Spaces.

The results of WP4 showed that the role of NAP in the field of automated driving is still not unanimously accepted and unclear. WP5 emphasised, that the European Commission has requested the creation of NAPs as a prerequisite for the standardised handling of mobility data in Europe (see ITS Directive 2010/40/EU). In addition, in the beginning of 2020 the EC adopted the European Strategy for data, which provides in particular for the establishment of EU-wide common, interoperable data spaces in strategic sectors including a Common European mobility data space.

WP5 also looked at current developments and future trends with regard to C-ITS. The communication specifications need to be uniform, at least European-wide. OEMs would certainly prefer even world-wide specifications. In summary, it becomes clear that cooperation with various stakeholders in this area is a decisive factor. As an example, the C-Roads platform, which focuses on vehicle-to-infrastructure and in particular infrastructure-to-vehicle applications, highlights the importance of cooperation and collaboration across sectors.

WP5 also addressed important security and privacy issues in the field of CAD. The deliverable concludes that a secure data space such as the Mobility Data Space would help in respect to sensitive data sharing. This would give data providers the confidence that the provided data is only used in accordance with defined usage and licensing conditions (in IDS terms called usage policy) and that the usage is controlled and verified by the data provider, a measure that has to be considered on the way to full digitalisation of road network in any case.

2.2.2.5 WP6 - Business models options for data-exchange in context of CAD

The goal of WP6 (Berkers et al. 2020) was the provision of business model options for an NRA driven data-exchange platform in the context of future CAD deployment in Europe. The challenge for the business models is how they contribute to move from the current heterogeneous landscape, in which the current deployments of technology as well as policy preferences of NRAs largely differ, to a desirable future landscape, in which CAD-fleets and corresponding public and private data services are flourishing.

Three scenarios were described and further analysed by the consortium along a set of criteria based on concepts from platform business models, governance (e.g. of alliances and collaborations), good governance of commons and collaborative networks. Figure 13 shows the results of the analysis with the colour green symbolising that this criterion would be well taken care of in the given scenario while a criterion highlighted in red would not be met in the scenario. The purpose of these scenarios is to help identify actionable elements from a government centric, a market centric and mixed approach.

The scenarios are:

- NRA-Dominant Scenario (NDS): based on C-Roads example
- Market Dominant Scenario (MDS): based on the Your-Now example
- Hybrid Scenario (HS): A Public-Private scenario based on the Mobility Data Spaces (MobiDS)

	NRA-Dominant (NDS) Based on C-Roads	Market-Dominant (MDS) Based on Your-Now	Hybrid (HS) Based on MobiDS
Traffic	Traffic Knowledge Authority	City-level servicing collaboration	Local to global by interoperability
Convergence	"Agree first"	"Big Markets First"	By design Enabling
Governance	NRA-centric	CEOs at Joint Ventures Local coordination	Local public private collaboration
Business	Passive: agreed standards	OEM driven Big Tech driven	Local to global by interoperability
European Values	Not in contradiction Limited mandate at NRAs	If market demands	By design Enabling
Innovation	Pilot to standard Pre-competitive & R&D heavy	Customer centric Unknown traffic effect	Decentralized, yet replicable

Figure 13. Summary of evaluation of the three studied scenarios (Berkers et al. 2020)

In summary, the following recommendations were derived:

1. Further "institutionalise" the governance structure from NDS. As C-Roads was taken as a basis example for the NDS, it makes sense to build forward on this establishment.
2. Ensure pilots are "IDS-ified", for replicability and sovereignty.
3. Include sub-national authorities in the governance structure. The MDS reveals that automotive and bigtech are interested in servicing and collaborating in the urban domain
4. Ensure commercial implementations in public-private collaborations (e.g., cities) are "IDS-ified". It is important that also local deployments become aligned in this principle.
5. Expand legitimacy of governance structure to include advancing "European Values", e.g., data sovereignty. In order for a union of NRAs to form the nucleus in a CAD-fleet-as-a-service scenario, they must have mandates to go well beyond the traffic, infrastructure and safety. This could imply that national ministries have to be involved.
6. Extend governance structure to include automotive and small tech.
7. Actively profile and monitor regional and national infrastructures and actively broker upscaling / replication of IDS-ified pilots and (commercial) best-practices.

2.2.3 Recommendations

The most important outcome of the last work package WP 7 (Radics et al. 2020b) is a guide for a step-by-step transition towards full digitalisation of the road network for NRAs. The roadmap was developed by integrating all findings from the other work streams within DIRIZON (WP2-WP6) and comprises the most relevant recommendations each of the work packages has found. It gives an overview over the tasks that NRAs need to achieve over the course of the next years in order to reach an EU interoperable system (see Figure 14). The recommendations are explained in full detail in D7.1 of the DIRIZON project, but the highlights will be discussed in chapter 4.2.

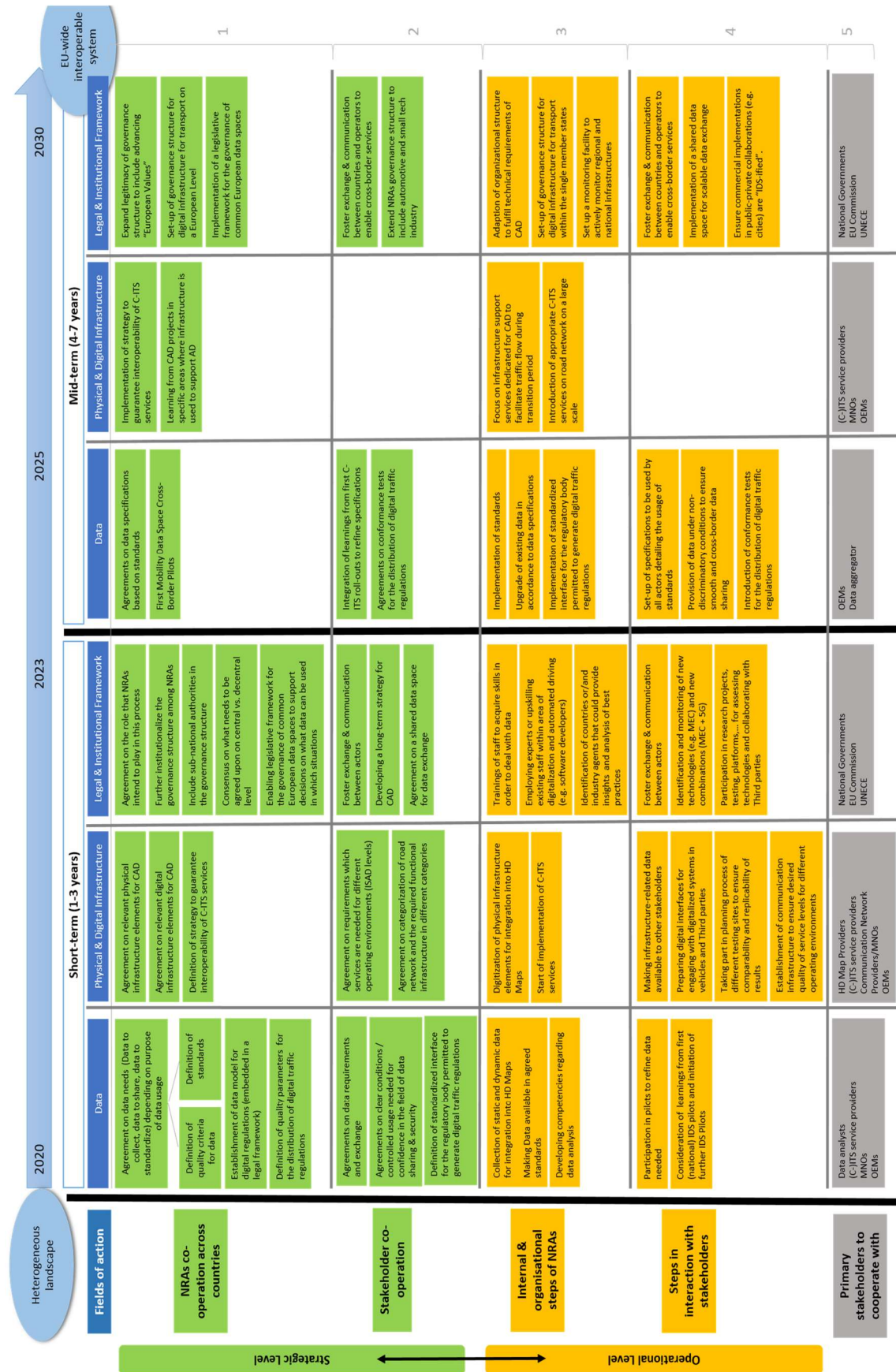


Figure 14. Roadmap for step-by-step transition towards a full digitalisation of the road network (Radics et al. 2020b)

2.3 STAPLE

Duration:	September 2018 – August 2020
Budget:	348.993 € (incl. VAT)
Coordinator:	FEHRL (Belgium)
Partners:	AIT (Austria), ERICA (Poland), Université Gustave Eiffel (France), Maple Consulting (UK), VTI (Sweden)
Website:	https://www.stapleproject.eu/

2.3.1 Project Overview

STAPLE (SiTe Automation Practical Learning) addresses Topic C “Practical learnings for NRA’s from test sites” of the 2017 CEDR call “Automation”. The overall aim of STAPLE is to provide a comprehensive review of technological and non-technological aspects of the most relevant connected and automated driving test sites in order to understand the impact of these sites on the NRA’s core business and functions. This project will provide NRAs with the necessary know-how on connected and automated driving test sites, with the aim of supporting their core business activities, such as road safety, traffic efficiency, customer service, maintenance, and construction.

The project built on previous work by CEDR and others (EU and national level projects) as well as on FEHRLs test sites experience gained through various Scanning Tours organized in recent years. The consortium partners have been involved in a number of relevant research projects (BRAVE, COBRA & ANACONDA, Forever Open Road, SCOOP@F, UDRIVE) and therefore, already had an in-depth knowledge of the methodologies and approached developed in this area of investigation. This pre-existing knowledge was combined with desk research and consultations with selected automated driving test sites to produce a comprehensive catalogue of the latest information and guidance on connected and automated driving test sites in Europe and beyond, with specific emphasis on NRAs' core business influence. STAPLE brought together the results of other projects, initiatives and actions such as C-Roads, Vehicle Platooning or UK CITE and use them to identify how current test sites for connected and automated driving can be used to determine the key areas/priorities for NRAs and the impacts of these test sites on their business and operating processes. STAPLE also embraced the results of these previous and current works via investigation of the key performance areas, where automated and connected driving test sites can influence NRAs operations in terms of new technologies to improve road safety, traffic efficiency, the environment, customer satisfaction, maintenance and construction processes.

STAPLE had the following objectives:

- Provide an overview of test sites in Europe and beyond
- Provide a catalogue of these sites and detail how they contribute to NRA priorities
- Undertake a detailed investigation into a selected number of test sites including visiting a selection of sites
- Assess the implications of the findings of the test sites for future NRA options
- Analyse and report on the practical learnings from test sites worldwide, including gaps where NRA needs are not addressed
- Provide a report and recommendations for future research and test site focus.

STAPLE was structured in six work packages as described in Figure 15.

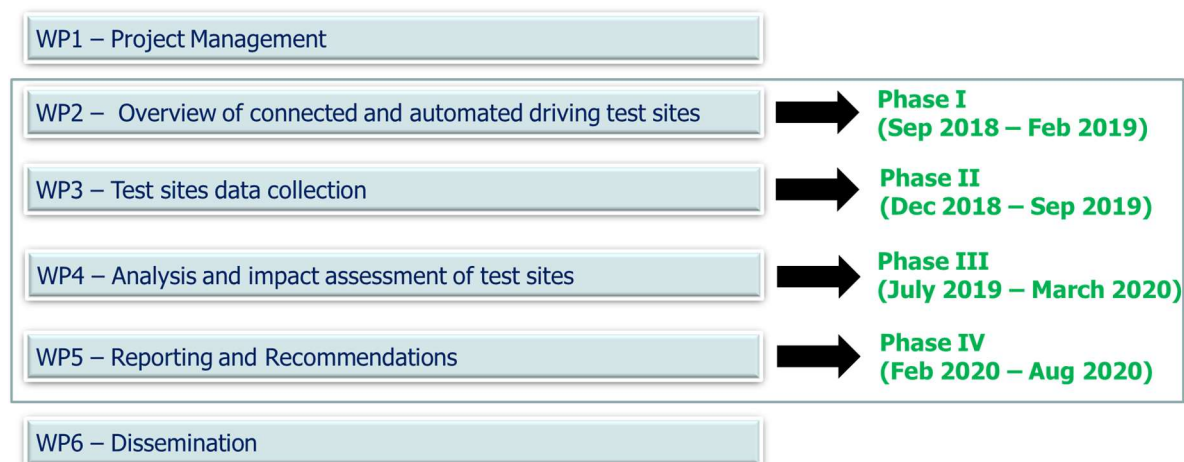


Figure 15. STAPLE project structure

2.3.2 Main results of work packages

2.3.2.1 WP 2 - Overview of connected and automated driving test sites

Over 70 test sites in Europe and elsewhere were identified through personal contacts and knowledge of the project team, web searches and discussion with the CEDR CAD group and industry contacts. The output of this work was a catalogue of connected and automated driving test sites, identifying and categorising 37 test sites in Europe. The sites are also presented in a Google map page which gives the locations of the test tracks and approximate extent of road-based test sites. (Erdelean et al. 2019)

While data on 39 test sites and beds were collected, two sites offered only confidential information and their data is not available in this version of this deliverable. In addition, the initial pre-selection and assessment of sites/beds for further investigation is also described. (Erdelean et al. 2019)

The initial review encompassed a wide variety of sites/testbeds, in terms of location, size, years of operation, experience and other factors. The consortium looked at already existing sites with years of experience as well as new and developing ones. The focus was on test sites and test beds for passenger cars, freight transport operations and shared mobility services. The search yielded over 70 test sites and test beds in 20 countries inside and outside Europe, including the USA, China, Australia and South Korea. (Erdelean et al. 2019)

Based on the consortium expertise and as well as input and feedback from the PEB, a detailed data collection procedure was undertaken for obtaining information on each site, such as location, size, automated use cases tested, type of environment, physical and digital infrastructure support, connectivity employed and other factors. This resulted in a Catalogue of 37 test sites and test beds that can be used as a point of reference going forward but can also be used as a standalone output of STAPLE. (Erdelean et al. 2019)

A preselection of 16 test sites for further investigation was made by the project team and discussions with the CEDR CAD team at a workshop in Tallinn. These sites were prioritised based on factors including provision of information to the team in the first phase, the type of track or roads involved (excluding low speed pods in campus environments for example) and sites or projects that would be operational beyond the lifetime of the project. (Erdelean et al. 2019)

2.3.2.2 WP 3 – Test sites data collection

Stakeholder survey and selected test site visits were performed as part of a stakeholder consultation and site data collection process. An electronic survey of 11 questions was sent to all

test site operators identified by the STAPLE project. All responses received were from European test sites including such countries as Austria, France, UK, Netherlands, Germany, Spain, Hungary, Slovenia, and Greece (see Figure 16). (Zofka et al. 2019)



Figure 16. Map of countries and test sites participated in the Survey (Zofka et al 2019)

Use cases your test site is addressing

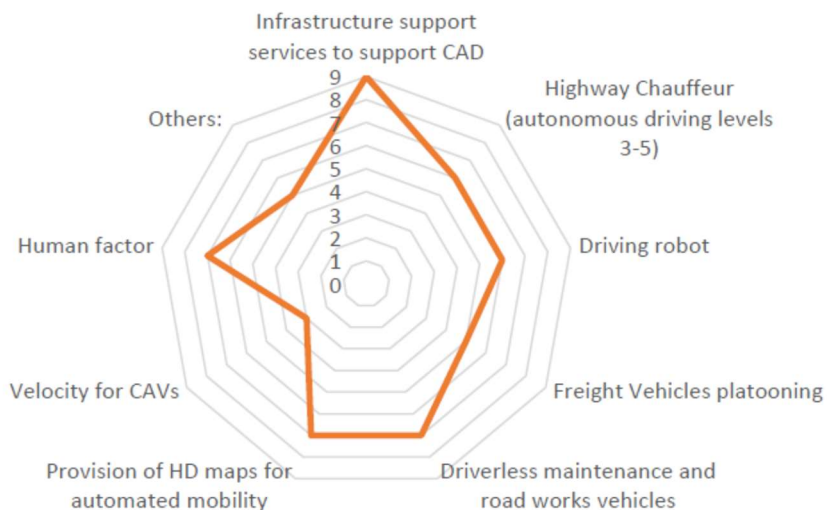


Figure 17. Use cases of test sites overview (Zofka et al 2019)

The results of one of the general questions providing knowledge what use cases are addressed by each site is shown in Figure 17.

Following is an overview of the key findings from the survey: (Zofka et al. 2019)

- most use cases covered, various speeds, human in the loop, physical infrastructure testing and cybersecurity
- moving traffic, congested traffic and incidents, trip optimization based on the real time demand, impacts of different penetration rates, automated vehicle platoons, fuel saving and effects in mixed traffic situation.
- perception of CAVs, privacy and data protection, considering social inclusion, facial recognition as a payment model,
- passive, active, interactive and connected roadworks warnings, real time data collection by maintenance vehicles, using robots for road works

In addition to the stakeholder survey selected test site visits took place. The STAPLE consortium together with the PEB members visited the following test sites and conducted detailed interviews with the site operators of: (Zofka et al. 2019)

- Testbed Midlands Future Mobility, UK
- Horiba – MIRA TIC-IT, UK
- ALP.Lab – Austrian Light Vehicle Proving Region for Automated Driving, Austria
- TRANSPOLIS, France

In the selection process for the interviews and visits the four priority areas were considered; those are road safety, traffic efficiency, customer service and construction and maintenance. During the activities undertaken in WP3, the STAPLE team focused on data collection with the specific emphasis on those priority areas. (Zofka et al. 2019)

The results of this exercise show that there is a lot of potential of using UHD maps in construction and maintenance. Utilising data from sensor fusion can support NRAs in their decision-making process for managing highway performance in terms of traffic management, traffic safety and efficiency as well as digitalization of infrastructure and its roadside furniture. Highways England has also some good experience of customer service so this all be included onto the next step evaluations. Four test sites offered data sharing for road safety, traffic efficiency, customer service and construction and maintenance so further analysis of the most usable case studies in terms of impact and socio-economic assessment can be undertaken. (Zofka et al. 2019)

2.3.2.3 WP 4 – Analysis and impact assessment of test sites

The next phase covered practical learnings, covering an assessment of impacts as well as a socio-economic assessment derived from the previous work. This consisted of test site identification, several electronic surveys, a stakeholder consultation, interviews and test site visits are the results of this work package. (Strand et al. 2020)

Implications for NRAs have been broken down into specific categories as outlined below, with sub-categories detailing individual findings: (Strand et al. 2020)

- Testing environment, such as highway, urban, interurban
- Type of facility, such as open and closed tracks, off-road trials, data trials and simulation trials
- Use cases including highway chauffeur, platoons and HD mapping
- NRA priority areas of safety, traffic efficiency, customer services as well as maintenance and construction, and
- Role of NRAs, such as test site shareholder, if they provide the road for trials, have an involvement with the test site or are a customer

A socio-economic assessment considered potential economic benefits that could be achieved through various connected and automated driving use cases, such as increased productivity through automation or machine assist of various tasks. It also considers potential social benefits, such as using robots to undertake mundane tasks, enabling people to undertake value

added activities, potential safety gains / risk reduction from automation, and the potential for automation to replace jobs, and what this might mean for the future workforce. (Strand et al. 2020)

From the findings developed, a series of recommendations were made. Due to the COVID 19 outbreak they could not be discussed in the intended detail with CEDR in person but rather in three online workshops which were held with representatives of the CEDR CAD group, project officers, research institutes and interested experts and a fourth workshop with the CEDR CAD group only. (Strand et al. 2020)

- The level of involvement of NRAs in test sites significantly influenced the research focus and outputs of the sites. Where NRAs have a strong role, they help steer the results of the sites towards their specific needs. However, they also have the potential to influence the work at test sites where their involvement is weaker, for example through funding of relevant research projects.
- There is highly relevant work conducted at test sites across Europe with clear benefits for NRAs (evaluation of CAVs, testing specific use cases, testing specific technology for pavement markings).
- Digital, test track and live road test sites are useful for different purposes, although combining them in different stages of testing and evaluation can be a useful way of taking projects through various research stages.
- NRAs have to adapt their organisations and strategic work in order to be able to fully realise the potential of different test sites, e.g., through strategic roadmaps to make the right investments, contractual agreements on data sharing to access key data et cetera.
- NRAs also have a significant role to play in cooperating with research projects and making data available for industry to test and develop products and technology solutions, as occurs at Midlands Future Mobility and ConVEX.
- Close cooperation between test sites, NRAs and manufacturers should be encouraged to optimise the impact of the research being undertaken, to explore synergies and to potentially co-fund research where there will be shared benefits.
- NRAs, test-sites and wider industry need to understand each other's motivations and business cases. For NRAs, the business case is not always related to a cost-benefit calculation, but on wider objectives such as accident reduction, environmental improvements and opening up opportunities for employment and economic development.
- What has worked in the past regarding training and qualifications, is unlikely to work in the future.

2.3.3 Project Recommendations

In the areas investigated, there are a variety of simulation, visualisation, test tracks and test beds that address NRA needs across Europe. One area that is possibly lacking is road trials that traverse international boundaries and work on this should be undertaken to ensure interoperability of systems across Europe. Depending on specific NRAs needs there is a variety of testing scenarios available. NRAs can become mutual partners and participate in consortia together with the OEMs and other relevant data and service providers to be able to obtain and exchange data and best practices. Since the test site performance and safety information resulted from specific tests and trials undertaken by each site is typically confidential it is proposed that NRAs join such initiatives or join ventures and become a mutual partner. More open communication from all parties could lead to the development of projects that address common areas of interest such as safety, traffic efficiency and customer service, and help accelerate the deployment of connected and autonomous vehicles. (Lamb et al. 2020)

The following key recommendations were made: (Lamb et al. 2020)

- NRAs, the auto industry, and OEMs could benefit from more open communication to understand priorities, areas of mutual interest and potentially undertaking joint research
- More work needs to be undertaken around privacy on data collected from public roads.
- Work needs to be undertaken on cross-country data sharing and standardisation of testing.
- NRAs should identify the main construction and maintenance operations with a view to robotising tasks and removing road workers from live carriageways.
- Interactions between ODDs should be investigated, and particularly for minimum risk manoeuvres: other than stopping. Useful lessons learned on ODD could be further investigated based the PEGASUS Project results
- Mixed traffic trials at various speeds should be undertaken.
- Provide guidance for CEDR to become involved in EC Research and Innovation projects.
- A roadmap for removal of traditional infrastructure should be prepared, noting the requirement for 100% transference requirement for key information.

3 Outcomes of the Final Conference

3.1 Highlights and Remarks

A final conference was organised on November 6th, 2020 as a web conference due to the Covid-19 pandemic. The conference allowed the projects to report their results to both the Programme Executive Board as well as each other on the one hand and to provide the opportunity to discuss and further elaborate on overarching topics in interactive workshops on the other. During the conference, discussion about the projects themselves, their highlights and the identification of open questions took place. The afternoon break-out sessions were dedicated to discussing common topics over the three sub-themes. Participants involved mainly CEDR members and project representatives but also some members of public authorities and research institutions. To make the most of the final conference and to direct the break-out sessions accordingly to answer the most pressing questions the PEB was involved in the contextual orientation of the interactive sessions.

The conference started with a welcome note from the chair of the PEB, Philip Proctor of Highways England, highlighting the importance of the topic automated and connected driving for NRAs. He also pointed out that the focus has shifted furthermore to cooperative rather than only automated and connected mobility during the course of the programme.

During the morning, the projects presented their results with 30 minutes each. Questions were collected in the chat during the presentation which were answered afterwards. The presentations covered the following topics with a strong emphasis on concrete project results and managerial recommendations, which are also reflected in the project descriptions of chapter 2 in this report:

- Short general project overview including consortium, objectives, work packages
- Main results of each work package
- Key project results and recommendations for deployment

In addition, each project prepared one key poll question related to the project that was raised at the end of the presentation to engage the audience. The project results were overall satisfactory with no critical remarks or questions from the audience.

3.1.1 MANTRA poll and discussion

The MANTRA poll focused on infrastructure investments for CCAM - when and where they should start. A clear tendency towards immediate deployment of infrastructure upgrades and preparations became evident.

While the word cloud on the question about where investments should focus did not provide clear areas this is solely due to the different ways of writing. However, the following areas were considered the most important:

- Major roads / motorways / highway / core network
- Digital infrastructure / digital twins
- Data / data sharing / data exchange / connectivity
- C-ITS

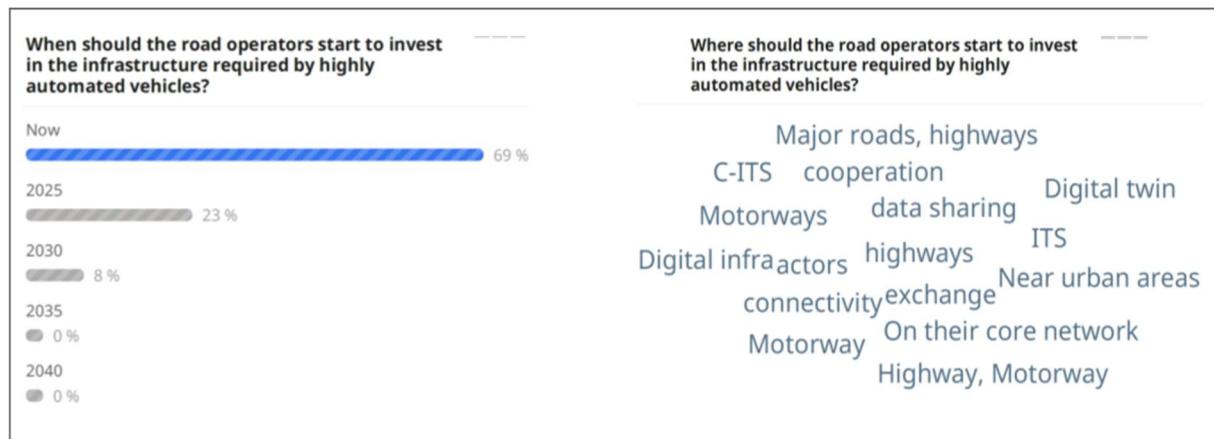


Figure 18. MANTRA poll questions

The MANTRA presentation and results received good feedback and were of great interest to the audience. Questions focused in particular on pick-up/drop-off areas, road marking requirements and considerations of environmental goals.

The first question was whether constraints in terms of pick-up/drop-off areas are expected or if simply next possible stops like e.g., petrol stations are used. MANTRA had looked at two types of robot taxis, the car type with lots of freedom to choose pick-up and drop-off points and the public transport type utilising specific points like bus stops.

Concerning the retro-reflectivity of road markings to keep them visible/readable, a question was made about its minimal value to be maintained on the roads. The response was that MANTRA has not suggested specific values. The reason is that discussions are still ongoing in international standardization groups on this matter. There are no generally accepted minimum values, and in fact even the necessity of road markings for automated vehicles has been questioned lately.

A participant was impressed of the detailed and clear view of the future. The MANTRA comment was that in each case a number of assumptions has been made in order to come to striking scenarios. Those assumptions have been made carefully using the consortium’s experience but also facilitating the knowledge of experts in workshops. However, it has to be clear that those views need to adapt, if underlying assumptions are developing differently.

Regarding the future traffic situation analysis, a participant wished to know whether environmental measures (e.g., reduction of CO₂) and the likeliness that a move to public transport and car sharing could reduce individual traffic were taken into account. MANTRA responded that such developments were taken into account when looking at NRA core business changes, but not in the mobility effects calculations, which are more or less based on the current status. In addition, the current Covid-19 situation has actually led into opposite developments. Which only shows that even the best predictions cannot take every aspect and scenario thing into account.

3.1.2 DIRIZON poll and discussion

DIRIZON used the poll question to validate its recommendations with a good approval rate in particular for the ability to share data in a distributed and interoperable infrastructure to manage traffic flow and safety and services.

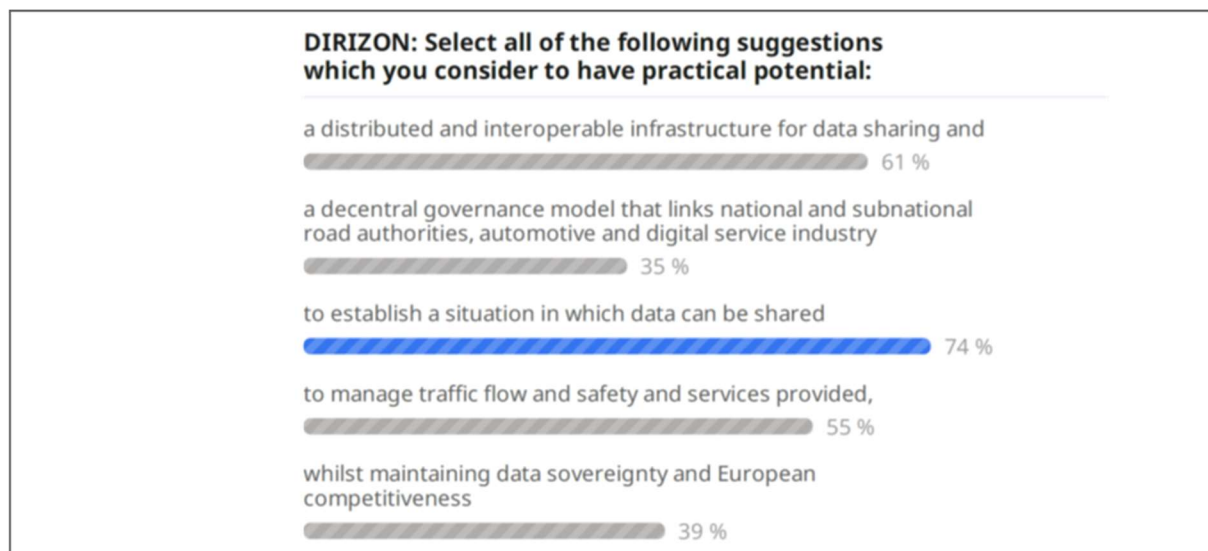


Figure 19. DIRIZON poll questions

The audience appreciated DIRIZON's work and had great interest in the deployment of data sharing for HD maps and infrastructural provisions to be taken to support data connection.

The first question to DIRIZON was on asset management concerning digital maps and cooperation with private sector for digital maps for vehicles. How could cooperation work? Are there synergies? Is it a huge job or quite easily done? How can data which is already available support vehicles? DIRIZON referred to the already existing standard TN-ITS for exchanging NRAs Map Data. Hence, it should not be a huge task. Also, the sharing of data has one of the highest potentials in accordance with the poll results, so data exchange solutions are needed in alignment also with service providers and map providers. This means distributed infrastructure for data is needed.

The next question was raised by the MANTRA consortium making a connection between the projects: Cybersecurity was highlighted as an important issue also in MANTRA. What are the DIRIZON recommendations how to tackle this issue concerning the digital infrastructure in the short term? The use of IDS (intrusion detection systems) is recommended by DIRIZON as it has mechanisms to use sovereignty also in a secure way to exchange data.

One participant wanted to have recommendations on what NRAs can do now in new road constructions to facilitate/support data connection and automation? DIRIZON listed different possibilities to exchange data like e.g., via mobile network (5G) or backbone (internet). After all it is up to the NRA to take the initiative and to make sure that data is available. After that various ways of sharing are available.

3.1.3 STAPLE poll and discussion

Also STAPLE focused on their projects recommendations and asked the audience about their opinion which one would be easiest to implement. The audience found all the recommendations very valuable, however found their implementation rather challenging due to the necessary active cooperation of different stakeholders with different objectives. The improvement of communication between test sites, auto industry and NRAs were considered the easiest to realize.

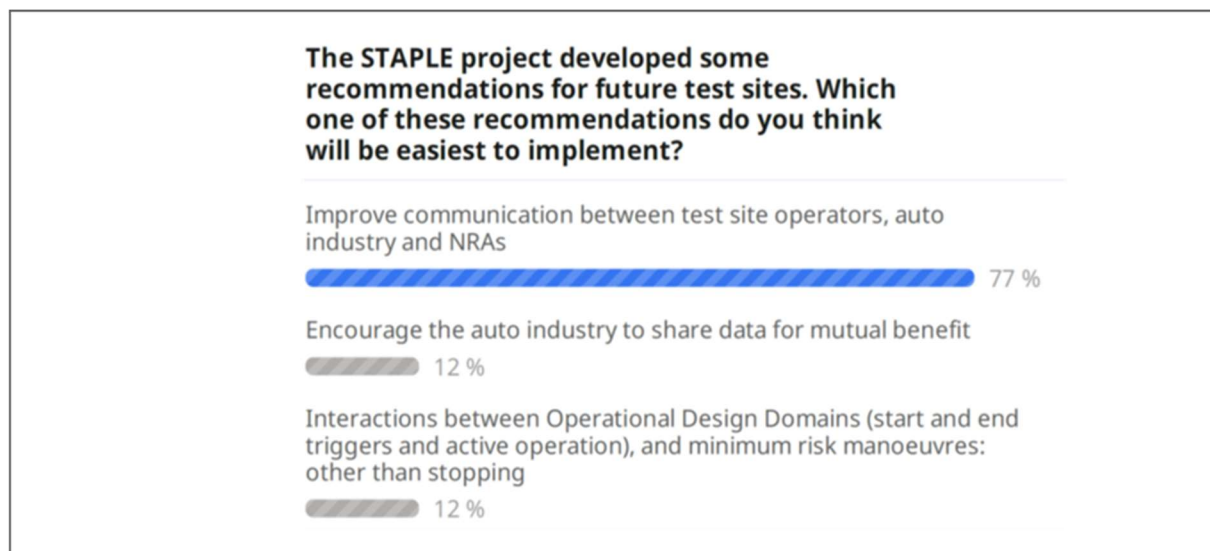
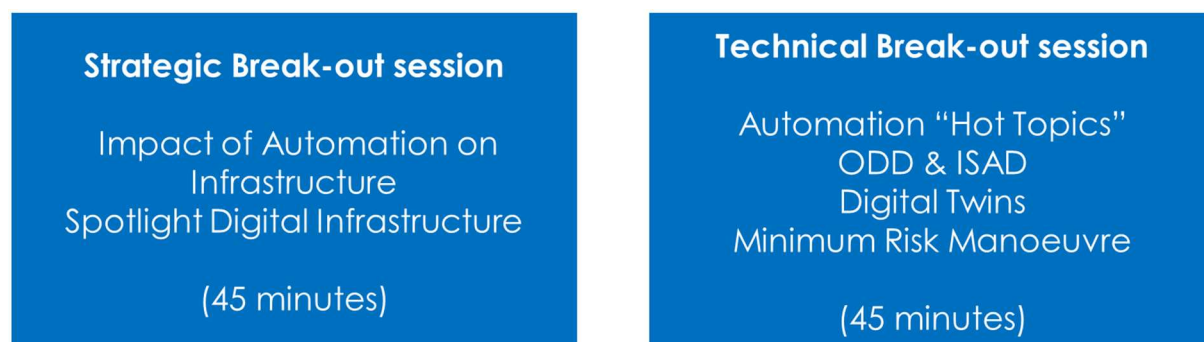


Figure 20. STAPLE poll questions

STAPLE’s collection of test site information was considered extensive by the audience. One additional question was raised on whether also pilot projects were considered or only test tracks. Yes, STAPLE has also considered pilot projects. One example is the ALP.Lab project which is partly on the regular Austrian highways. In terms of the poll question, the answer met the expectation of STAPLE.

3.1.4 Break-out Sessions

In the afternoon discussions were held in two parallel break-out sessions. Instead of break-out sessions dedicated to the projects it was decided together with the PEB to have concrete topics per break-out session that have been touched by all projects. This way discussions could focus on the most pressing matters and unresolved questions, rather on project specifics. Obviously, there would be many topics available that would be interesting to be discussed. Also, the intention was to engage all participants, experts in specific fields as well as generalists. Therefore, it was decided to have one rather general-managerial session and one more specific technical session:



The break-out sessions were held in parallel twice, so groups could switch afterwards, and everyone could attend both sessions. The goal of the discussion groups was to give the CEDR CAD working group the chance to dig deeper in most pressing matters but also to discuss questions that could not be finally solved within the projects and require further discussion and consultation. For active engagement of as many participants as possible live polls and surveys were used also in the break-out session.

Results and outcomes of the break-out sessions are summarized in the following chapters 3.2 and 3.3.

3.2 Recommendation for implementation steps regarding infrastructure

Making effective use of the participants expertise the strategic break-out session focussed on lessons learnt and recommendations for implementation steps with regards to infrastructure. The session was moderated by Walter Aigner from Hitec and Lena Radics from AustriaTech.

After a short orientation towards the framework for this CEDR Call 2017 the purpose of this break-out session was jointly explored. It was prominently mentioned that the DoRN has provided a fruitful and informative framework and excellent preparatory work for guiding the strategic questions (see Figure 1).

Specific focus of the break-out session was to take up the general framework and re-assess new knowledge from the core questions of the Description of Research Needs (DoRN):

- A) How will automation change the core business of NRAs?
- B) What new options do NRAs have from digitalisation and automation?
- C) Practical learnings for NRAs from test sites

Within this framework the session focused on the two following topics:

- Focus 1: Strategic elements focusing on digital infrastructure
- Focus 2: Some open issues from ongoing road-mapping towards digital infrastructure (pre-testing some work in progress from DIRIZON)

Therefore, results and documentation on these two focus areas are reported in the following two separate subsections (3.2.1 and 3.2.2).

3.2.1 Focus 1: Strategic elements focusing on digital infrastructure

One challenge for the months and years to come will be (for each NRA) to come up with a tailor-made prioritisation of impacts to be fed into management layers. As a starting point a bigger picture of NRAs business fields and responsibilities was presented from a section in MANTRA's final deliverable D5.2 (Kulmala et al. 2020) to guide participants towards the history and evolution of this specific focus field "Digital road infrastructure and ITS systems":

1. Physical Road infrastructure
2. **Digital road infrastructure and ITS systems (focus in this break-out session)**
3. Operations and services
4. Planning, building, heavy maintenance
5. New Business
6. Impact on objectives and mission
7. Impacts on operations and use of technologies
8. Impacts on NRA role
9. Impact on legal frameworks

Some representatives from NRAs have signalled that their management would probably prefer to narrow down the priority areas and the according management narratives to an overall number of only three; for some representatives this will be preferably done in different departments while keeping cross-links in mind. It was pointed out that MANTRA Deliverable 5.2 (Kulmala et al. 2020) provided a framework how these management narratives could be effectively grouped into three areas, as well as provided for the nine topics listed above detailed descriptions and a road map for core business adaptation in those nine topic areas.

For developing the respective management narratives, the workshop moderator provided a theoretical framework (see figure 21 below) used in various NRA-related contexts (also used in MANTRA):

Increasing structuration
of activities in local practices

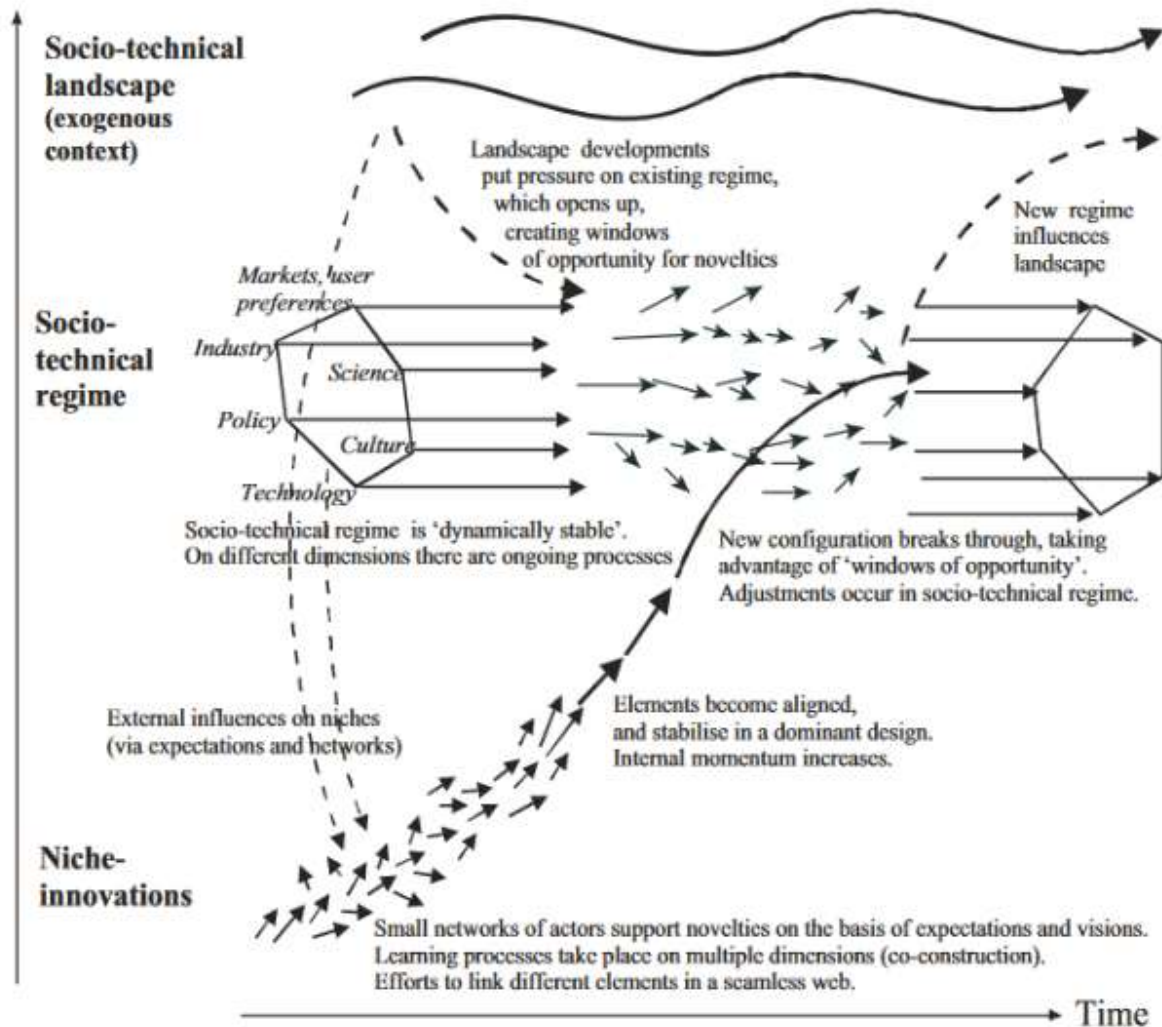


Figure 21. The multi-level perspective on sustainability transitions as basis for discussions

Three warm-up questions for this break-out session were raised to get the discussions started. This was intended as an addition to the in-depth surveys that were done within the project frames:

1. Where would you see the biggest deployment challenge for your organisation in the short term?

Participants' input on the first warm-up question:

- Deployment challenges for organisation → Who does what? Roles?
- Know-how exchange?
- Dependence on parallel developments?
- where to find the required competences?
- We have to cooperate on a global basis

2. Where would you see the biggest challenge towards full digitalization of the road network operation from the NRAs' perspective?

Participants' input on the second warm-up question:

- Who is in the driver seat when it comes to data?
- Lack of clarity on roles and responsibilities main challenge → this is the reason why we had the call and the session; very interesting and result confirms the previous results! It will always be dynamic. Insufficient collaboration between actors can be seen as a barrier.

3. Will NRAs in Europe (your organization) be able to take an active role in digitalization and automation?

Participants' input on the third warm-up question was affirmative but yet also uncertain to some extent. The following are statements collected in the discussion or via the slido tool from different participants:

- Certainly yes & hopefully yes
- Hopefully yes. Because most people from here are from NRAs; so, one known bias is: we know we have to participate; but how would you effectively get involved in a highly competitive market; We have to decide: Should we be involved as a key champion in this value chain? But we have to ensure that we will have a role
- Sharing data depends on the value of it and value is specific to the decision quality; speed is always higher if you do it internally, but it will be a challenge to do all internally or to try to kind of control this highly dynamic field
- "Sharing Value" along the value chain is historically private business; unless we have very stringent agreements several NRAs will face role issues (without this it is not going to happen)
- European Data Task Forces where we are working on first services to exchange data directly from vehicles (exchange with service providers and traffic centers); prevailing impression that this resembles an environment where more warriors are around the table than technical people to make it happen. That is a very strong indication for commercial stakeholders selling data (with some rationale to sell data we as NRAs have gathered from our side...).
- One participant maintained that the question is kind of invalid, because by (his view and his affiliation with C-ROADS) NRAs already have an active role in digitalisation itself; With regards to digitalisation for automation it is quite similar to C-ITS. C-ITS was discussed for many years and in the end, we had the chicken-egg problem: who will invest first? Infrastructure was prepared to enable C-ITS; maybe one could see it quite similar when it comes to automation (not autonomous vehicles but really automation, which includes connectivity). Here hopefully NRAs will have an active role to enable automation along roads, national roads, motorways. So, we definitely need an active role in digitalisation for automation, otherwise it will not really happen in future.
- "Hopefully yes", because I am really not sure. There are two important constraints. Firstly, road operators and NRAs are managed by people with very specific and highly elaborated skills; their skill and expertise is often outside the focus of these digitalisation topics, it is a hard effort to get into these dynamically evolving topics and it takes time. Secondly, even if there is the support by top management, it is difficult to attract skilled people you need.

The session moderator shared his guesstimate that probably the more experienced session participants were the once who answered with something along "hopefully yes".

After jointly discussing some of the Slido results an orientation was provided what the bigger picture might look like and how individual NRAs might approach their digesting of the roadmaps and recommendations.

As a useful context orientation for this break-out session the road map developed in MANTRA D5.2 (table 2, p. 64 Kulmala et al. 2020) was mentioned.

The most important actions in the field of digital road infrastructure relate to digital twins and HD map processes – both co-dependent on large-scale road-mapping and harmonization activities in various corners in the world. Somehow through digital technologies NRAs will face opportunities and challenges in today's coping strategies with errors and risks. Shorter innovation cycles and rather high probabilities for errors in digital maps need to be addressed in potentially new operational strategies.

Cooperation with OEMs and service providers will be one option to mitigate risks and to make full use of digital infrastructure's potential for effective and efficient operation in a transition period towards highly automated driving. Access to digitally excellent human resources will most probably turn out to become a key element in the future transition period. Thinking in digital ecosystems beyond traditional buyer – supplier relationships might become one necessity in coping with this dynamically evolving digital technological field.

The roadmap of MANTRA classified the actions in three major categories to make it most useful for NRAs and CEDR (Kulmala et al. 2020):

- Actions with no regret – actions useful also for human-operated vehicles to be carried out due to present needs and other developments
- Study and learn – actions to find out more about the technology, operation, benefits, costs and implementation issues in order to understand the potential, restrictions and feasibility of automated driving
- Key actions for deployment – actions to safeguard NRA interests and with major future impact on NRA investments and operations.

During the break-out session a Slido question gathered some orientation on: How helpful would you rate this hierarchy for discussing the lessons learnt within your organization? As a prevailing response it has been perceived as helpful.

A big share of actions identified in MANTRA relate to the digital infrastructure. The resulting actions are provided in detail in chapter 4.1.1.

3.2.2 Focus 2: Open issues from ongoing digital infrastructure road-mapping

A second thread in this break-out session related to work in progress (as of November 5, 2020) and wording within the frame of DIRIZON. Several participants hinted towards necessary harmonisation efforts regarding concepts and wording and provided suggestions to the participating presenter(s) from the DIRIZON team.

Given the work in progress status and several participants' feedback that this would need considerable rewording the Slido result (see Figure 22) is considered not terribly relevant for this final conference proceedings and is presented only of documentation purposes:

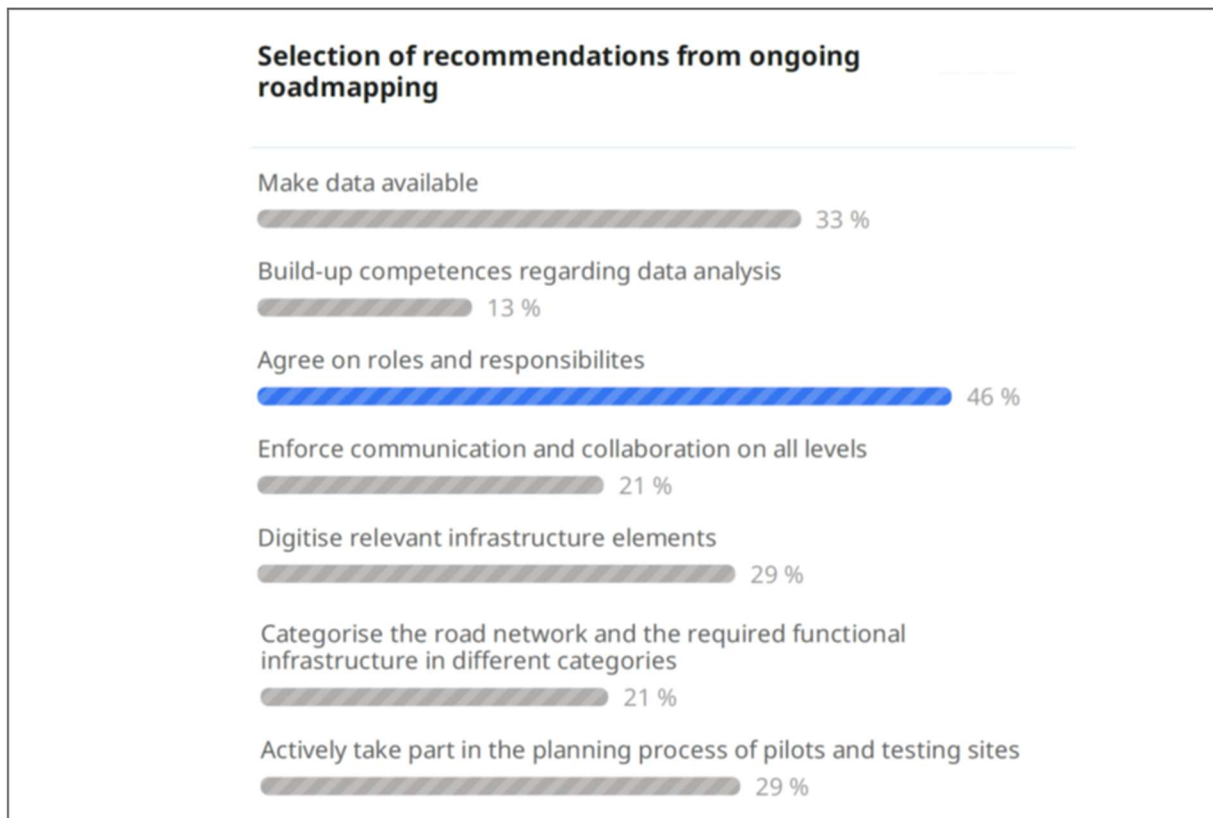


Figure 22. Poll results on recommendations for ongoing road-mapping on digital infrastructure

A fruitful and informative discussion concluded both runs of this break-out session. Key outcome from ongoing dynamically evolving discussions within the CEDR CAD WG context has been on two questions and is seen as a candidate for further implementation activities.

Discussion question was:

- Collaboration with stakeholders
- What hands on actions can you think of to enforce collaboration and build up trust with different stakeholders?

Input from several break-out session participants was that the OEMs need to be brought on board. Explicitly: Joint calls with ACEA also as optional next steps within upcoming CEDR CAD WG calls and tenders. All Slido results can be found in Appendix 2.

3.3 Recommendations for implementation steps regarding crucial strategic topics

The second break-out session focused on specific challenges and topics of automation that have been covered by all three research projects in some way. The selection of these three topics was done together with the PEB during the conference preparation representing most pressing matters and areas of interest for the NRAs. The session was moderated by Risto Kulmala from Traficon and Sandra Ulrich from ARDNT IDC.

3.3.1 ODD and ISAD

At the time of the launch of the call the topic of Operational Design Domains (ODD) was still a concept only known to a very small group of experts in NRAs and outside of the automotive

industry. Vehicle manufacturers and Automated Driving System providers describe the conditions for automated mode use with ODD. This is the description of the specific operating domain(s) in which an automated function or system is designed to properly operate. These attributes include:

- Physical infrastructure attributes (road type, shoulders, pick-up/drop-off, etc.)
- Digital infrastructure attributes (digital map, electronic traffic regulations, satellite positioning, etc.)
- Communication infrastructure attributes (latency, reliability, bandwidth, etc.)
- Traffic and environmental situation attributes (traffic situation, weather, visibility, etc.)

While still a long way from being harmonized, ODDs are the accepted concept of defining the specific operating conditions in which the automated driving system is designed to properly operate. Still, ODDs are the language of the automotive industry to define the requirements of their automated functions towards NRAs and others.

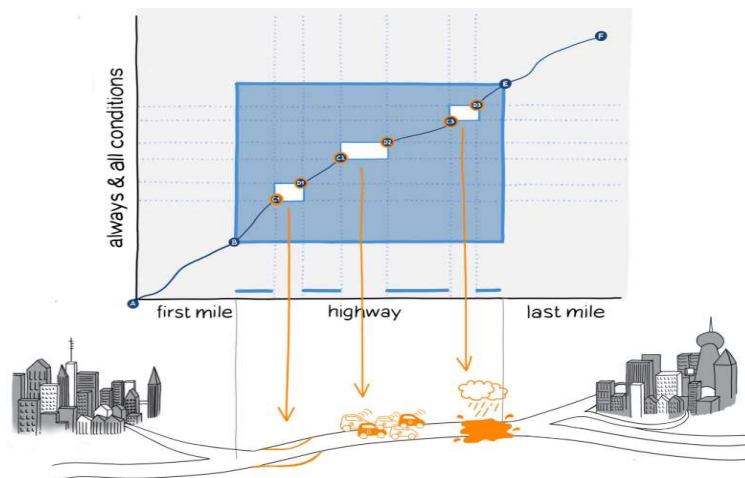


Figure 23. ODD scheme © Tom Alkim 2019

The concept of infrastructure support levels for automated driving did not even yet exist at the time of the launch of the call. NRAs had no universal language of describing the readiness or status of their road networks to provide the required infrastructure support for the automated functions. During the work of the project road operators started to develop their own classification to describe where they will provide the infrastructures in specific service levels for automated driving. A proposal for such a classification is the ISAD levels developed in the INFRAMIX project (Carreras et al. 2018). The ISAD levels could be seen as the NRAs answer to ODDs to provide an orientation.

	Level	Name	Description	Digital information provided to AVs			
				Digital map with static road signs	VMS, warnings, incidents, weather	Microscopic traffic situation	Guidance: speed, gap, lane advice
Conventional infrastructure	E	Conventional infrastructure / no AV support	Conventional infrastructure without digital information. AVs need to recognise road geometry and road signs.				
	D	Static digital information / Map support	Digital map data is available with static road signs. Map data could be complemented by physical reference points (landmarks signs). Traffic lights, short term road works and VMS need to be recognized by AVs.	X			
Digital infrastructure	C	Dynamic digital information	All dynamic and static infrastructure information is available in digital form and can be provided to AVs.	X	X		
	B	Cooperative perception	Infrastructure is capable of perceiving microscopic traffic situations and providing this data to AVs in real-time.	X	X	X	
	A	Cooperative driving	Based on the real-time information on vehicle movements, the infrastructure is able to guide AVs (groups of vehicles or single vehicles) in order to optimize the overall traffic flow.	X	X	X	X

Figure 24. ISAD Levels (Carreras et al. 2018)

The interaction of ODDs and ISAD has still room for improvement and needs further discussions which was done in this first part of the break-out session. Introductory statements for the basis of the discussion were:

- The relationship between ODDs and ISADs should be specified via multi-stakeholder interaction and agreements
- The ODDs depend on specific automated driving use cases and ISADs on specific road environments
- CCAM platform WG3 on PDI is working towards infrastructure attribute consensus

The discussion started with the question on the basis for requirements of an ODD-ISAD framework. Participants agreed that a combination of views is preferred while it also became clear that it is not an option to let users/driver have a say what is safe and not safe as it is not their expertise. Perceived safety was considered an important aspect as trust is crucial to get users acceptance. One participant pointed out that the CCAM platform and the following CCAM partnership are the ideal setup for further elaborating on an ODD-ISAD framework.

Participants agreed that the focus of the framework needs to be on all aspects of infrastructure and cannot be only on one part of the infrastructure. Rather than excluding particular aspects of infrastructure it is considered more important to allocate priorities and define an order of deployment. In addition, it needs to be considered the road networks are heterogenous where some parts of the network have good communication connections and others are quite bad, so the transition between those areas needs to be bridged. One participant pointed out that traffic management is not explicitly mentioned as an option but is a crucial area in particular when it comes to policy goals like safety, efficiency and decarbonisation.

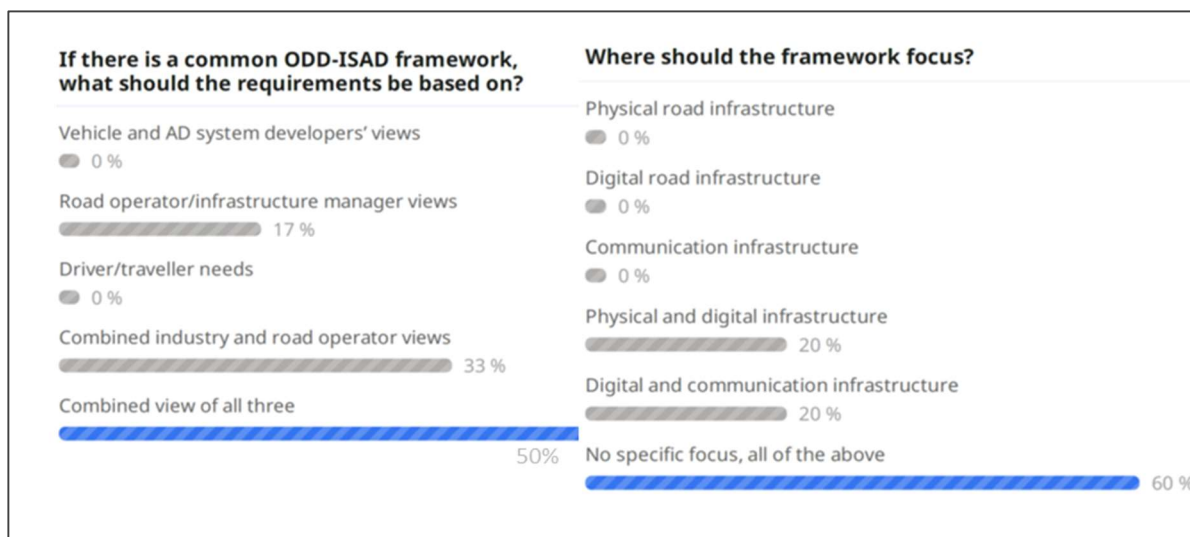


Figure 25. Poll on requirements for an ODD-ISAD framework

The final question on who the champion should be of an ODD-ISAD framework sparked interesting discussions. While participants agreed that it would be ideal to have cooperative discussions between all relevant sectors with the various umbrella organisations, they also agreed that this would be very slow and rather unrealistic. NRAs were not seen as the main driver who consults the others as the topic is too manifold. Without a clear idea what the most efficient way could be, most participants chose standardisation organisations. However, discussion showed that this would also not be satisfactory because this way it would also be a very slow process. Agreement was that action is needed now and that this topic goes beyond the borders of the European Union.

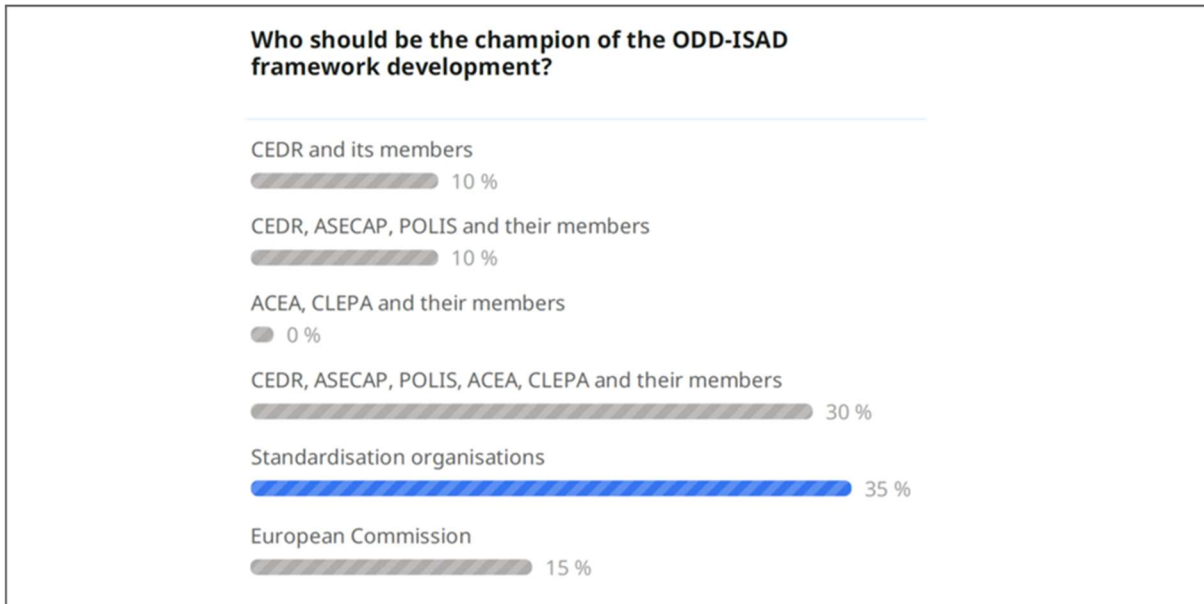


Figure 26. Poll on champion of an ODD-ISAD framework

The link of ODD and ISAD in a combined framework is still a very fresh topic. Discussions were fruitful but came to no concrete answers yet. In research projects of the future this concept has to be considered together with other important topics like digital twins. Moreover, the CCAM partnership was considered a good platform for carrying this topic further.

3.3.2 Digital twins

The term „Digital Twin“ is widely used throughout industries to describe a digital replica of a physical entity with varying detail or functionality, dependent on its intended use. A digital twin of the road network to support CAD is seen a bit like the holy grail for the successful (traffic) management of CAD deployment.

Digitalisation is – in one way or the other – based upon promises from having a digital representation of what happens in real world and the promise that automated decision making or automated preparation of decision making have the potential to fuel entirely new mechanisms for NRAs. However there have been significant concerns that in an exceedingly complex world of sensors and automated interactions the technologies for effectively coping with this complexity have yet to be invented and it remains to be seen whether and how these new technologies can be effectively absorbed by NRAs (concept of absorptive capacity). Requirements are still to be defined and subject to ongoing discussions.

Some introductory statements to fuel the discussion were made by the moderators:

- A digital twin is purely a model of some aspects of the physical entity
- A digital twin should support decision making (i.e., in traffic management)
- A digital twin is solely the basis for decision making but does not decide itself
- The requirements for a digital twin strongly depend on the use case it supports

One participant immediately added that a digital twin can be more than a digital duplicate of the physical infrastructure when used i.e., for geofencing.

The development of a digital twin touches manifold areas and considerations are necessary in all those fields by NRAs.

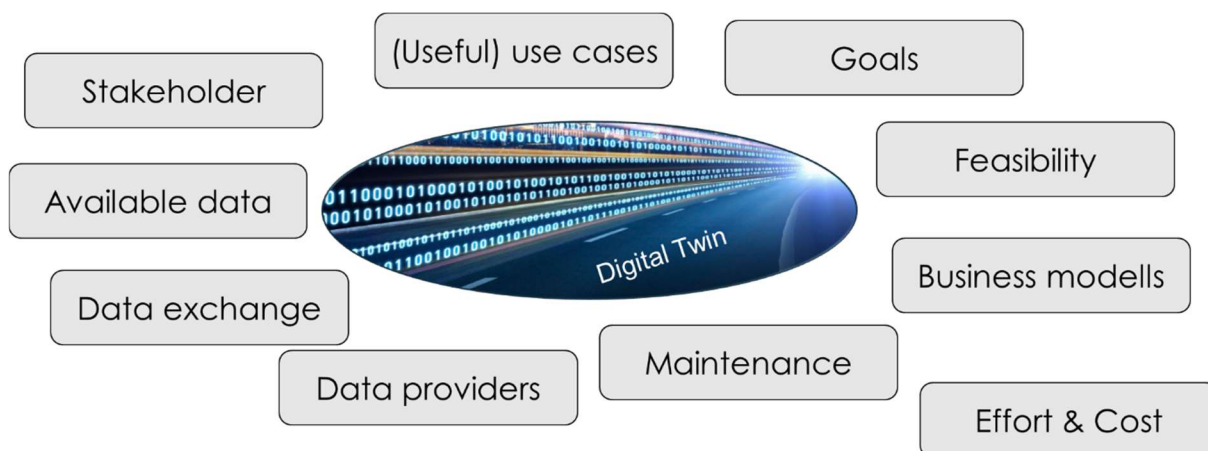


Figure 27. Areas to be considered for a digital twin

The initial poll question was a great discussion starter: Which real-time data is available for a digital twin from NRAs that is considered reliable enough to support decision making automatically? Participants were hesitant in answering because honest statements made it clear that actually at this point in time none of the data is ready for automatically decision making. Therefore, discussion evolved around the proposed list of options and which of those were considered most likely to be ready and useable soon. The following poll results (Figure 28) therefore rather answers a different question – instead, which data is already available it can be more considered as a ranking of which data is expected to be ready first.

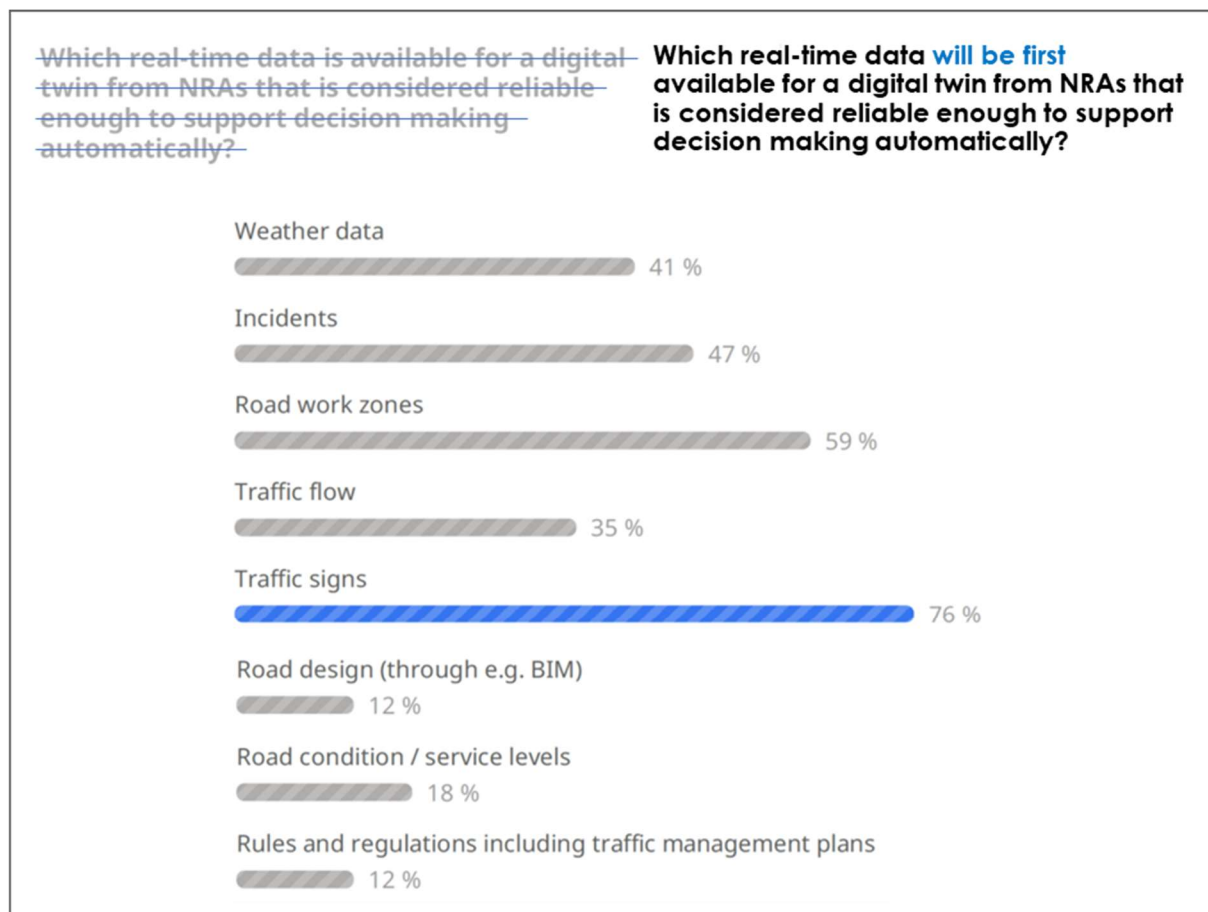


Figure 28. Poll on available data for a digital twin

The discussion then shifted towards how the data can be made available. One participant pointed out that the way forward should be on making data available through backbone and defined interfaces. International data spaces seem far away but the exchange of data between stakeholders needs to be enforced.

Some data should be available via C-ITS and also via internet using the viable interfaces. This is a starting point for sharing the data.

Participants agreed that purely real-time data is not a sufficient definition for most use cases. More important is the definition of the required reliability of the data and to answer the question: What quality is good enough to operate in a sufficiently safe way? A quality assessment framework needs to be put in place before the use of data for AV support is possible. Additionally, also the legal framework is needed to make such data binding rather than being of informative character.

As the results showed that traffic signs would be the first go to data, participants again agreed that this is a good starting point. Most important that the exchange and sharing is started to push the discussions around data quality and reliability.

The necessity for pilot projects, tests and simulations was again emphasized. Discussion was vivid on this matter and the moderators decided to use the momentum rather than to push for sticking to the poll results. The second question on which use cases are considered most valuable to be supported by a digital twin evolved mainly around one proposed use case: Co-operative traffic management based on real-time simulation utilizing current traffic flow and incident situation (data from NRAs and vehicles) would support many different NRA policy goals like safety, traffic flow and decarbonisation all at once. Participants however also agreed

that this is the opposite of a low-hanging fruit. Other use cases that were mentioned as interesting opportunities for a digital twin were improvement of asset management and support for maintenance in order to improve the management maturity level.

Using the available time for the lively discussion the further poll results were partly only answered in writing by a small number of participants. The discussion provided more insights and content than the actual poll results wherefore results are only included in Appendix 2 for documentation. The vivid discussions underlined the importance of the topic for NRAs. However, the difficulty of finding concrete answers also showed that a lot of work is still to be done. Research projects, pilot projects, tests and simulation will need to be pushed forward to accelerate developments.

3.3.3 Minimum Risk Manoeuvre

When the ODD end is approaching, the automated driving system requests the vehicle occupant to take over vehicle control. If the occupant does not, the vehicle makes a MRM. One example is the Automated Lane Keeping System (Highway Jam Chauffeur, SAE Level 3) which has the minimum risk manoeuvre of stopping on lane – natural choice due to system design. There is a concern by NRAs that minimum risk manoeuvres could cause a lot of safety and throughput problems for the road operators, unless such manoeuvres can be accomplished in a safe and efficient manner considering the road operator concern. One scenario would be when large numbers of vehicles carry out MRMs at the same time and location, the result is a total standstill. It should also be noted while the minimum risk manoeuvres are expected to be quite rare events, the probability of their occurrence is still quite uncertain. The issues with minimum risk manoeuvres need to be solved also in situations involving connectivity and digital infrastructure. Currently MRM standardisation is going on in ISO but by industry stakeholders, not road operators.

Participants widely agreed that in case of no other option stopping on lane is an unacceptable MRM (Figure 29).

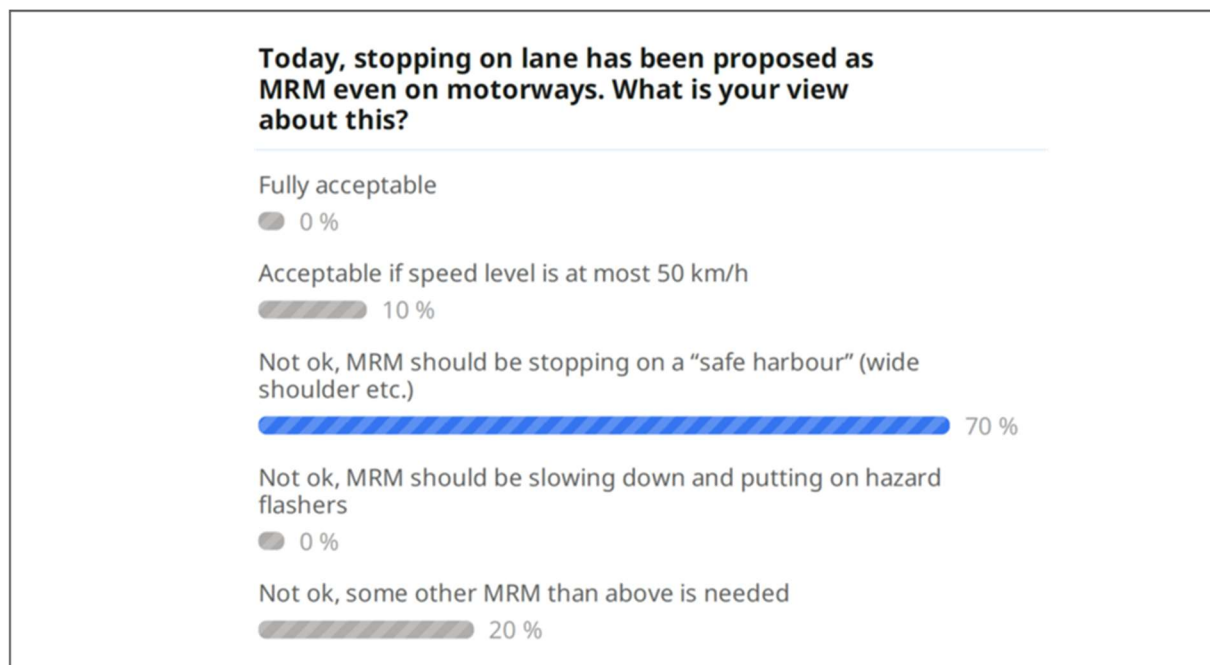


Figure 29. Poll on stopping on lane as MRM

The answers were not as uniform in the second poll question dealing with the responsibility for determining the allowed MRM on a specific road section. There is more or less a tie between road operators, type approval authorities and a cooperative decision of OEM and road operator

being the determining institution for the MRM. On the one hand the road operator is clearly responsible for the road, but the appropriate deployment might be challenging for OEMs. On the other hand, if type approval authorities are responsible for it this would mean a consistent approach throughout Europe.

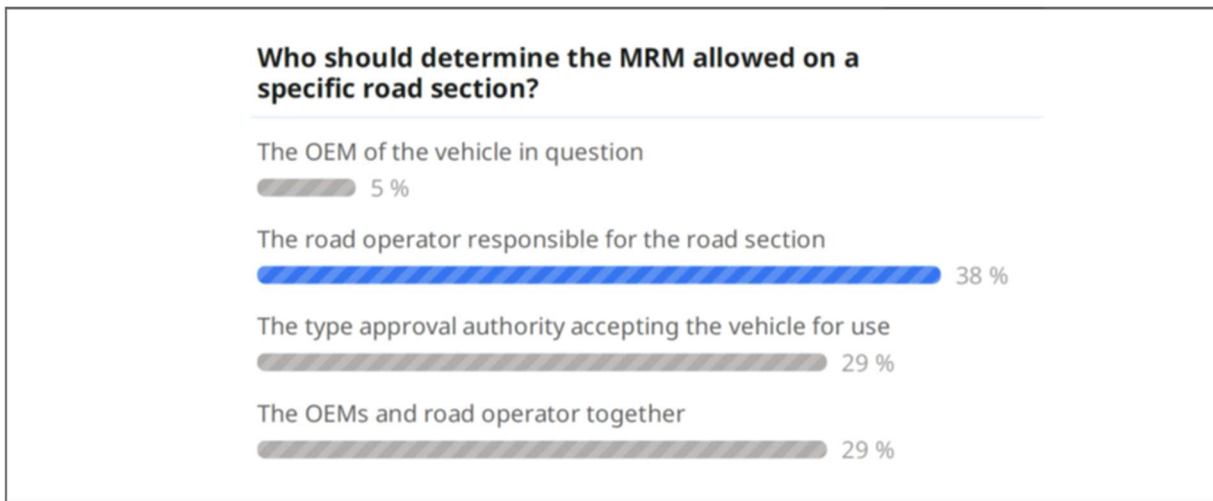


Figure 30. Poll on determination of allowed MRM on a specific road section

The final question on the cost coverage for the provision of infrastructural MRM amendments was again answered rather clearly putting the NRAs in the driver seat or rather having them pay for it.

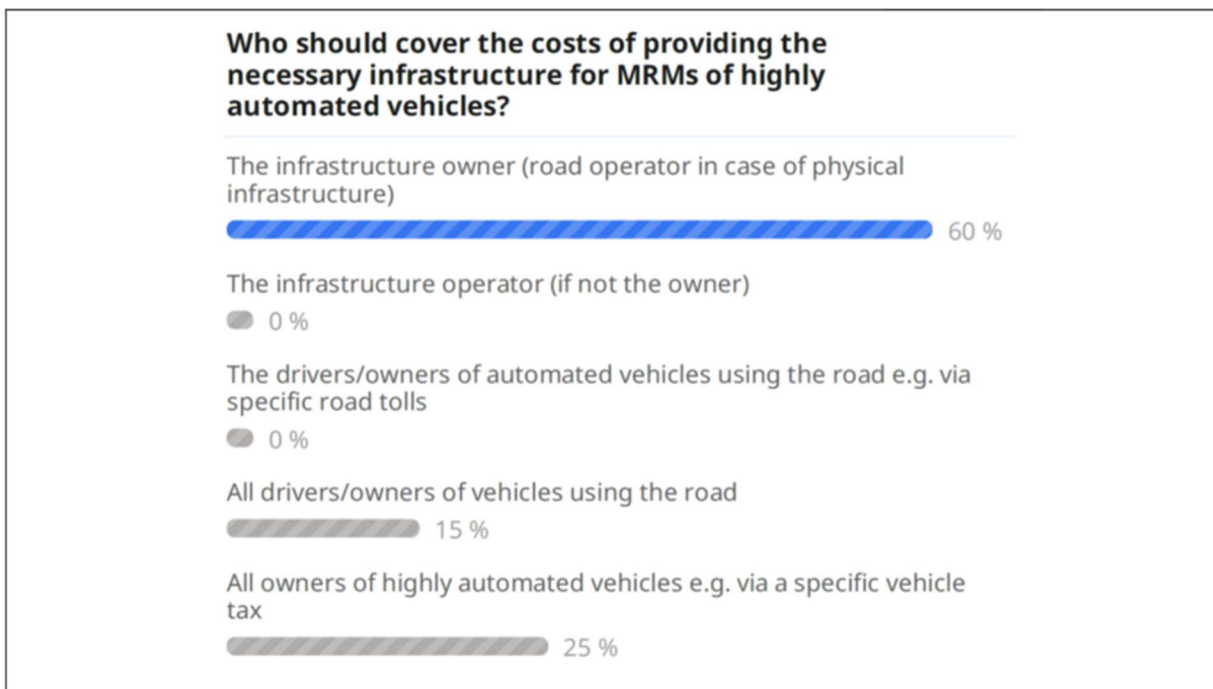


Figure 31. Poll on cost coverage for proving MRM

Discussions on MRM were a bit tricky as the potential problems threatening are like a Sword of Damocles over the policy goals of NRAs. Provisions might be very costly so decisions cannot be taken lightly without clear indications.

4 Applicability of the projects and recommendations for implementation

4.1 MANTRA

4.1.1 Overall conclusions and recommendations for the NRAs

MANTRA classified the actions in three major categories based on our own expertise as following: (Kulmala et al. 2020)

- Actions with no regret – actions useful also for human-operated vehicles to be carried out due to present needs and other developments.
- Study and learn – actions to find out more about the technology, operation, benefits, costs and implementation issues in order to understand the potential, restrictions and feasibility of automated driving
- Key actions for deployment – actions to safeguard NRA interests and with major future impact on NRA investments and operations.

None of the actions purely belong to only one category. All of the actions include elements of study and learn, for instance. The classification relates to the most essential nature of the action.

The actions with no regret contain the following actions: (Kulmala et al. 2020)

- Machine readability and digital twins of road signs
- Road markings of sufficient retro-reflectivity in different conditions
- Provision of road network related data to HD maps
- Human resources with digital expertise
- Digitalisation of incident and traffic management plans
- Digitalisation of traffic management centres

The actions listed above are recommended to be carried out even with no highly automated vehicles as they will be beneficial to service providers, fleet operators and connected vehicles in addition to the NRA's own processes and operations. It needs to be pointed out, that “no regret” should not be mistaken for “involving no risk”. Many digitalisation initiatives involve significant risk both in terms of competing technologies and increasingly ambiguous technology readiness levels. Depending on the strategic position of some NRAs, a focus on only this first set of actions might involve additional risks of losing or not attracting highly qualified staff with digital proficiency. Therefore, the risk of not facing some of the tricky challenges might come through the back door of missed opportunities or high external dependency in not attracting and keeping digital competences. (Kulmala et al. 2020)

Typically, any value added in providing information to partners in a varied ecosystem of stakeholders internally and externally depends on understanding the specific context of those who make decisions on the basis of digital information. Traffic management might involve entirely new roles such as predictive maintenance, contribution to greening Europe, maintaining economic strength in a world with jammed logistic hubs, coping with increasingly severe weather conditions, demographic changes in driver population, counter balancing for a further increase in high intensity mental workload during drivers' resting times due to online gaming and digitally enhanced resting intervals, and travellers avoiding air travel or train travel due to COVID-19 follow-up scenarios. Thereby digitalisation in traffic management is certainly not a trivial issue. (Kulmala et al. 2020)

Studying and learning within several departments in a specific NRA would profit from in depth studying and providing ODD and ISAD specifications for some key priority areas on the road

network and decision algorithms within a specific NRA for early forms of assisted vehicles as an internal preparation exercise on digitalization. The exercise should also aim at mitigating issues with e. g. minimum risk manoeuvres and support future proactive alignment with vehicle manufacturers and service providers. (Kulmala et al. 2020)

Furthermore, it is important to develop a kind of mental model and organisational vision on what a specific NRA wants to grow into in a time of digitalisation and ecologically challenging political goals – even with a slow uptake of automated functions in vehicles. In other words, the individual actions should never be picked solely on the basis of individual projects or organisational silos but also for their contribution to a dynamically evolving vision and mission concerning digitalisation in NRAs. (Kulmala et al. 2020)

The actions of study and learn include the following: (Kulmala et al. 2020)

- Ensuring up-to-date content of HD maps
- Cybersecurity issues for connected and highly automated vehicles
- Information provision on incidents, events and crises
- Harmonised marking of incident sites to be correctly recognised by automated vehicles
- Cooperative traffic management concept
- Digitalise traffic rules and regulations
- Improved information quality for automated vehicles
- Standard communication protocols related to automated vehicles
- Provision of hybrid C-ITS traffic information services
- New infrastructure and regulations for traffic law enforcement
- Environmental enforcement utilising geofencing and other tools
- General physical road design changes
- Harmonised management of road works sites
- Awareness by automated freight vehicles of their own gross weight and individual axle loadings in order to determine ODD

The actions above provide additional information related to the deployment of highly automated vehicles, their function and evolution so that when the roll-out of highly automated vehicles is sufficient to warrant physical and digital infrastructure investments and changes in operational practices, the NRAs have the knowledge needed to make the related decisions and implementations. Some of the actions could commence and benefit immediately even human-operated vehicles, such as improving information quality or harmonised management and marking of incident and road works sites. The contents of such actions would likely be a bit different if the additional needs of highly automated vehicles are considered. Hence, these carry the “regret” element. However, at least some of the regret element can be mitigated by digitally enhanced learning and change detection mechanisms for instance via simulation capabilities in a Digital Twin environment. One tends to learn more if one is committed to doing something – even regrets or forms of mistakes or failures. Already some NRAs are following this path of “learning by doing”. When trying to avoid any mistakes, some of a NRA’s digital excellence might quickly move to organisations where mistakes are whole-heartedly accepted as they know that one learns quickly from mistakes. Consequently, a sustainable role model “study and learn” likely necessarily involves NRAs embracing some learning from errors and accompanying expectation management with the management and stakeholders. (Kulmala et al. 2020)

The key actions for deployment contain the following: (Kulmala et al. 2020)

- Optimised minimum risk manoeuvres and providing infrastructure for them
- Digital twins for road transport system including ODD and ISAD information
- Legal framework for driverless maintenance vehicles

All of the three actions are recommended to commence urgently at least for some parts of them. MRMs are currently worked upon in standardisation with little or no NRA participation while MRMs can in fact have major impact on the planning and building of the physical road infrastructure with potentially huge investment consequences. Providing input and maintaining digital twins may turn out to be resource demanding, but the key aspects of the action are the specifications and requirements for ODDs and ISADs. These call for close dialogue between road operators and the automated vehicle industry stakeholders to clarify the requirements and expectations from both sides and to agree on a consensus solution. It is anticipated that close dialogue with vehicle industry stakeholders will continue to be a rather bumpy road – and might need accompanying expectation management within NRA-related stakeholders and top management. This is less a personal issue and more an issue of point of control in historically rather different silos. Finally, the driverless maintenance vehicles are already being rolled out in the form of safety trailers and mowing robots, and a sound legal framework is a necessity for the road operators.

Most of the actions were labelled into the “study and learn” category. This implies the importance of research, pilots and large-scale demonstrations and pilot deployments in the short and medium term. In addition to national activities, the NRAs should actively participate in related Horizon Europe and Connecting Europe Facility actions for learning, networking and information sharing purposes. It is essential that CEDR should facilitate sharing of information and best practices, and openly discussing unanticipated challenges and early forms of failure.

NRAs need to consider whether they should participate in the international fora which are setting regulations for automated driving systems (ADS), specifically UNECE WP.29. Otherwise they run the risk that automated vehicles will operate to the detriment of the operational goals of the NRAs.

Almost all of the actions need to be carried out with a number of different stakeholders. The stakeholders include, among others, OEMs, ADS providers, HD map providers, fleet operators and managers, road authorities and operators, cities, traffic management operators, research and innovation organisations, road planning, building and maintenance contractors, road and vehicle equipment providers, telecommunications industry, mobile network operators, police, rescue operators, transport safety agencies, ministries, the EC, and standardisation bodies. In stakeholder cooperation, CEDR has a major role in carrying out stakeholder discussion on a strategic executive level with related organisations representing the other stakeholders while NRAs carry out the cooperation and collaboration on the project and national, and tactical and operational levels.

With rather ambitious policy goals and challenging financial contexts, we cannot choose between digitalisation, resilience, and greening Europe. All of these need to be accomplished. Some elements of digitalisation involve ecosystems and platform thinking with evolution path dependencies. Shutting down or minimising digitalisation forefront activities might quickly deprive NRAs from some of its current cooperation opportunities with different stakeholders.

4.1.2 Open questions

The key open question is what the requirements of highly automated vehicles towards physical and digital road infrastructure or in general towards the road operators in 10, 20 or 30 years from now will be. The current knowledge is based on the prototypes and test vehicles in use in 2020, and this knowledge has primarily been the basis for all analyses in MANTRA. This is an important question as the physical infrastructures deployed today are expected to have a lifetime of 30-50 years, and the digital infrastructures a lifetime of 8-15 years.

Another open question deals with the use of highly automated vehicles on open roads. When have a say about what kind of automated vehicles with what kind of properties (incl. following headway settings, minimum risk manoeuvres, etc.) vehicles and in what conditions will highly automated driving be permitted? Will the road operators have a say in the matter?

An important open question concerns the mobility impacts of highly automated vehicles. Will automated vehicles be taken in use mainly as private vehicles or as shared vehicles? This will determine whether road use by vehicles be considerably increased, remain the same, or even be reduced. And this impact will naturally have major consequences to road authority and operator investments, maintenance and operations.

4.2 DIRIZON

4.2.1 Overall conclusions and recommendations for the NRAs

The main outcome of the DIRIZON project, which integrates all results and recommendations from the other work streams within DIRIZON (WP2-WP6), is the roadmap developed in the final WP7. This roadmap starts from today's complex and heterogeneous landscape, where there are a lot of stakeholders who work mostly separately, and systems are far from being interoperable. The end goal therefore is an EU-wide interoperable system and the roadmap shows a sequence of steps that NRAs need to undertake in order to achieve that. Three fields of action were defined that are relevant over the entire evolution of the Roadmap: Data, Physical & Digital Infrastructure and Legal & Institutional Framework.

The roadmap as depicted in Figure 14 acts as a guide for a step-by-step transition especially targeted at NRAs that currently do not have an overview over their role in the area of Digitalisation and Automated Driving. All recommended actions are of great importance for NRAs, however, there are some **key recommendations** and conclusions which need to be highlighted in this report and which focus on internal and organisational steps.

Data

- Make data available (in machine-readable format and agreed standards)
- Build-up competences regarding data analysis

Physical & Digital Infrastructure

- Digitise relevant infrastructure elements
- Take part in the planning process of pilots and testing sites
- Categorise the road network and the required functional infrastructure in different categories

Legal / Institutional Framework

- Enforce communication and collaboration on all levels
- Agree on roles and responsibilities

In regard to the field of data, one of the main actions in the field of data is making data available to other stakeholders. The collected data has to be in a format that is machine-readable and in agreed standards, as one of the findings was that this is often not the case yet and hinders the process of digitalisation immensely.

Also, it is important to strengthen competencies regarding data analysis as NRAs need to prepare for huge volumes of data which will be more and more demanding over time, so they should start now. Here, it is crucial to either employ experts in this field or prepare the existing staff for these new tasks. Whatever role NRAs want to play in the process towards Connected Automated Driving, building up knowledge on data analysis within NRAs will be necessary. Since DIRIZON has found that many NRAs see themselves as infrastructure data providers, the ability to digitise and share data accordingly will otherwise be a challenge without the proper preparation of employees.

In the area of infrastructure, it is important to highlight that relevant infrastructure elements have to be digitised. This must happen in accordance with existing standards in order to make

this infrastructure-related data available to other stakeholders, e.g. HD map providers for integration into HD maps. The goal is to share data that has been collected and digitised in machine-readable format and to make it accessible under non-discriminatory conditions.

Moreover, NRAs should actively take part in pilots and testing sites as they will play a crucial part during the transition period and will need to focus on infrastructure support services dedicated for CAD in order to facilitate traffic flow. In order to be prepared for the scenario of both conventional and automated cars driving on the roads, NRAs will have to take part in the planning process of different testing sites. An early exchange of know-how with other actors will improve cross-border testing and ensure comparability and replicability of results.

Also, the necessary digital infrastructure will be dependent on what road type is concerned and what services want to be provided on the different roads. Therefore, the road network needs to be categorised which will happen on a more overarching level, however, NRAs will then need to prepare the required functional infrastructure for different categories.

Within the legal and institutional framework, two highly necessary recommendations need to be mentioned. As the roadmap reflects an NRA driven view on the transition towards full digitalisation, one of the first steps is an agreement on the obligatory and optional roles that NRAs intend to play in this process. Roles and responsibilities of the NRAs and stakeholders are partly unclear as e.g. there are uncertainties about who is responsible for data collection and, in consequence, the ownership of certain data. The lack of clarity on roles leaves all stakeholders confused to what they should or should not do at the short-term level, which makes this action a prerequisite for all others.

Another main finding was a great lack of collaboration especially between different stakeholders. Collaboration is the key to achieve connected automated driving and, as road operators/owners, NRAs are well positioned to ensure a constant dialogue and to bring stakeholders together. Trust needs to be strengthened by improving transparency and open communication between actors.

The following recommendations are listed according to the work packages that they were derived from. They comprise **specific actions** compared to the more general key recommendations above:

The NRA's & Other Stakeholders Perspective:

- Collaboration between NRAs and other relevant actors is essential for building 'trust' between the actors, particularly in relation to data (format, sharing, exchanging etc.). In this regard, a trusted Third party that evaluates data and quality in a neutral environment could be of benefit.
- All actors (NRAs, Governments, third parties, road operators and other stakeholders) must take collective responsibility in eliminating the barriers and mitigating the risks associated with Digitalisation and Automated Driving.
- Active participation of NRAs in the testing of various technologies and services is a significant prerequisite for the implementation of C-ITS and even more so for automated driving.
- Disparity in levels of Digitalisation & Automated Driving across countries is evident. For a harmonised, interoperable approach, all NRAs should develop action plans and have a strategy in place.
- Legislative frameworks should be put in place to deal with regulatory, standards and legal issues.

Deriving Data Requirements:

- Learn from outcomes of the Proof-of-Concept of the Data Task Force and other pilots and determine additional standards for data exchange, agree on standards for access, and explore where the quality checks need to take place and by which actors.

- Use pilots to refine data needed, data quality standards, implementations, and profiles.
- Engage with OEMs to achieve Operational Design Domain extension of connected and cooperative automated vehicles. Consider the use cases in a pan-European context.

Identifying Platforms Options:

- Approve the provided Future Mobility Data Exchange Concept based on the IDS concept.
- Evaluate the requirements and the feasibility of the IDS concept.
- Learn from national IDS pilots. Initiate i.e., an "IDS-ified" version of the Data Task Force's Proof of Concept.
- Further "institutionalize" the governance structure from e.g., C-Roads.
- Ensure pilots are "IDS-ified", for replicability and sovereignty.

Developing Business Models:

- Include sub-national authorities in the governance structure.
- Ensure commercial implementations in public-private collaborations (e.g., cities) are "IDS-ified".
- Expand legitimacy of governance structure to include advancing "European Values", e.g., data sovereignty.
- Extend governance structure to include automotive and small tech.
- Actively profile and monitor regional and national infrastructures and actively broker upscaling / replication of DS-ified pilots and (commercial) best-practices.

4.2.2 Open questions

One of the key questions that was accompanying the DIRIZON project throughout all work packages was what exact role NRAs intend to play in the field of connected automated driving. From conducting interviews and analysing the answers from a web questionnaire, it became more and more clear that there is no common understanding of their role or a clear strategy.

With a defined strategy and action plan, many of the unanswered questions/or uncertainties could be addressed in a structured manner. NRAs could then plan their allocation of resources, gaps as well as risks and mitigation strategies could be identified etc. This is why the definition of a strategy is recommended in the final work package, however, answering this question is the basis for many of the following steps on the way towards an EU interoperable system and would have made the roadmap less general and more specific to the NRAs vision.

Another question is to what extent NRAs would want to incorporate the DIRIZON recommendations into their strategy. Would they see IDS as a concept they want to explore and built "IDS-ified" pilot projects together with service providers and OEMs to establish a hybrid ecosystem?

4.3 STAPLE

4.3.1 Overall conclusions and recommendations for the NRAs

During the project, a greater investigation of test sites was undertaken to better understand how CAVs can impact on road administration operations, and test sites to reflect this. Despite the various findings, it should be recognised many actors involved in CAM have shared objectives, including:

- Reduction of number of killed or seriously injured, mainly because of the personal tragedy, but they also cost society money directly (insurance pay-outs, investigations) and indirectly (loss of potential taxes, disruption at the time of accidents),
- Improve traffic flow and efficiency to provide greater journey time reliability and smoother traffic, whilst also producing fewer emissions.
- Increase mobility options through shared mobility, repurposing road, or parking space for cycling / walking / new micro-mobility options,
- More efficient road maintenance, resulting in less disruption to road users and a reduction in costs incurred due to delays or diversions, higher customer satisfaction and improved road quality.

From the work undertaken, the findings were collected and grouped into the following categories: (Lamb et al. 2020)

4.3.1.1 Communications

Test site operators are generally reluctant to give detailed information about their site operations, other than the services they offer. This is partly due to client confidentiality, but also related to privacy. Certain test sites (e.g. AlpLab) do have data sharing agreements with NRAs, based on long-standing working relationships and contractual arrangements. The automotive industry and OEMs are reluctant to share data but will work on industry groups. In the USA, safety data is shared more widely, as it is used as a marketing tool. (Lamb et al. 2020)

4.3.1.2 Testing

Whilst there are a lot of simulation activities to assess the benefits / effects of CAVs in mixed traffic, there are few physical tests. Physical tests include individual vehicles driving autonomously or as platoon trials. Mixed traffic trials on sites / roads, could demonstrate clearer benefits of having CVs and at what penetration they would make a difference to areas such as congestion and efficiency. (Lamb et al. 2020)

Testing or demonstration of most activities relevant to NRA objectives are covered at various test sites. Closed test tracks offer an excellent opportunity for undertaking high speed and/or dangerous tasks that could not be undertaken on public roads. Some of the on-road test sites can provide excellent capabilities for testing data and implications of connectivity in a real environment. (Lamb et al. 2020)

4.3.1.3 Applications

The development of automated vehicles has not advanced to the extent envisaged at the start of the project and appear to be >15 years away (for level 5). This means that traditional physical infrastructure needs to be in place for some time and that there will be mixed fleet for some years to come, albeit with increasing levels of connectivity. Acceleration of connected vehicle capabilities would benefit from addition of digital infrastructure such as 5G, radio signs, I2V etc. (Lamb et al. 2020)

Connected Vehicles are becoming more common and offer shorter term benefits, e.g. lane assist, traffic jam assist, adaptive speed control, GLOSA, parking assist and valet parking. All offer benefits to safety, efficiency and customer service and the deployment could accelerate higher SAE levels. (Lamb et al. 2020)

Connected and autonomous plant offers significant benefits to safety, welfare, and efficiency in certain situations. (Lamb et al. 2020)

- Machine assist can increase construction accuracy, avoid obstacles, and increase productivity.
- Remote operation can remove workers from live carriageways or construction areas or hazardous locations. Truly remote location (i.e. controlling a machine from many miles away) could significantly increase productivity by having greater utilisation of

plant with less waiting time by being able to move from plant to plant as required. It would also improve welfare facilities and potentially encourage entrants to the labour force.

- Fully autonomous operation in certain locations would increase productivity by being able to operate continuously. It could also undertake monotonous, unskilled jobs, freeing plant operators to undertake complex tasks.

4.3.1.4 Data

NRAs offering data for others to test new products / processes / applications (e.g. ConVEx, Midlands Future Mobility) can be an excellent way to help develop capabilities that will benefit the NRA. However, the auto industry is unwilling to share data (except through specific projects like ConVEx). More sharing of data between both parties could lead to significant advances. NRAs do not necessarily value the data they hold to the same extent. (Lamb et al. 2020)

4.3.1.5 Process

For some projects, there is a step-by-step process potentially ranging from simulation, track trials, public road trials and finally deployment, e.g., Colas impact protection vehicle and recent UK cone laying trials. Other projects are not always undertaken in such a coordinated way. Innovative contractors (e.g., Colas, WJ) have invested in robotization and are willing to invest more but need a degree of certainty that NRAs will approve and adopt the technology and/or support their innovation efforts. There are likely to be non-transport robot developers / manufacturers / programmers who could address NRAs / NRA supply chain needs if they were engaged through innovation competitions or direct dialogue. (Lamb et al. 2020)

4.3.2 Open questions

In the areas investigated, there are a variety of simulation, visualisation, test tracks and test beds that address NRA needs across Europe. One area that is possibly lacking is road trials that traverse international boundaries and work on this should be undertaken to ensure interoperability of systems across Europe. Depending on specific NRAs needs there is a variety of testing scenarios available, NRAs can become mutual partners and participate in consortia together with the OEMs and other relevant data and service providers to be able to obtain and exchange data and best practices. Since the test site performance and safety information resulted from specific tests and trials undertaken by each site is typically confidential it is proposed that NRAs join such initiatives or join ventures and become a mutual partner. (Lamb et al. 2020)

Road owners and operators, auto manufacturers and OEMs have share objectives around safety, security, traffic efficiency and customer service. By communicating more openly and working together they could undertake trials that address these needs and potentially accelerate the deployment of connected and autonomous vehicles for various applications and use cases. (Lamb et al. 2020)

As the penetration rate of connected vehicles (in the short to medium term) increases, there will be requirements for increased V2I and I2V communication, which in turn will need increased interaction between NRAs, auto manufacturers and OEMs. (Lamb et al. 2020)

The C-ROADS and CCAM platforms are relevant to many of the recommendations, including this one as a means of taking forward a cross sector approach to the deployment of CAVs and as such could be useful in the development of joint research projects. (Lamb et al. 2020)

There are also shared risks from CAM. There is high potential for contradicting these outcomes by rebound effects. The ease of use and limited cost of CAV services could make them very popular, and demand for traditional transport modes will dramatically decrease, prompting severe cuts in public transport and the reduced use of non-motorized modes. How such increases in road travel will affect traffic congestion remains highly uncertain and is dependent

on the degree in which automated vehicles will be capable of “coordinating” themselves for a better use of the roads. Therefore, road trips may slow down, and more time is spent in cars. This increases the opportunity cost of time of car travel. (Lamb et al. 2020)

NRAs need to be aware of these issues and consider the wider and unintentional consequences of the trials they support or promote. With coordination of trials and wide communication between NRAs, positive outcomes could be secured. (Lamb et al. 2020)

4.4 Overall applicability of projects and common aspects

One strong result from this final conference was a confirmation of the excellent framing of this call and thread by the DoRN and its authors. It was prominently mentioned that the CEDR CAD WG DoRN has provided a fruitful framework and excellent preparatory work for guiding the strategic questions (see Figure 1).

The three projects had looked onto the guiding research questions from different angles – as well had taken up various degrees of guiding hints from members of the PEB group. Therefore the “overall applicability of projects and common aspects” might need to be evaluated by different teams within each NRA. This might be termed transferability of results and absorptive capacity.

One challenge for the months and years to come will be (for each NRA) to come up with a tailor-made prioritisation of impacts to be fed into management layers. Some representatives from NRAs have signalled that their management would probably prefer to narrow down the priority areas and the according management narratives to overall three; for some representatives this will be preferably done in different departments while keeping cross-links in mind.

Transferability and absorptive capacity: Within each NRA and even within each team it is most probably a good idea to kind of mirror the three guiding questions in the DoRN before picking priority items from single documents (out of context). The guiding question could well be: Where would we see the biggest deployment challenge for our organisation in the short term? The results of the discussions in the strategic break-out session (see chapter 3.2) provided the following:

- Deployment challenges for organisation → Who does what? Roles?
- Know-how exchange?
- Dependence on parallel developments?
- where to find the required competences?
- We have to cooperate on a global basis

MANTRA Deliverable 5.2 (Kulmala et al. 2020) provided a framework how these management narratives could be effectively grouped into three areas

- Actions with no regret
- Study and learn
- Key actions for deployment

These recommendations were prioritized by MANTRA together with validation and feedback from PEB-group and expert guests as well as during a web survey and some external expert reviewers. The way of grouping was considered by the NRAs as very helpful for actual deployment.

The “actions with no regret” are recommended to be carried out even with no highly automated vehicles as they will be beneficial to service providers, fleet operators and connected vehicles in addition to the NRAs own processes and operations. It needs to be pointed out that “no regret” should not be mistaken for “involving no risk”. Many digitalisation initiatives involve significant risk both in terms of competing technologies and increasingly ambiguous technology readiness levels. Depending on the strategic position of some NRAs, a focus on only this first

set of actions might involve additional risks of losing or not attracting highly qualified staff with digital proficiency. Therefore, the risk of not facing some of the tricky challenges might come through the back door of missed opportunities or high external dependency in not attracting and keeping digital competences.

Typically, any value added in providing information to partners in a varied ecosystem of stakeholders internally and externally depends on understanding the specific context of those who make decisions on the basis of digital information. Traffic management might involve entirely new roles such as predictive maintenance, contribution to greening Europe, maintaining economic strength in a world with jammed logistic hubs, coping with increasingly severe weather conditions, demographic changes in driver population, counter balancing for a further increase in high intensity mental workload during drivers' resting times due to online gaming and digitally enhanced resting intervals, and travellers avoiding air travel or train travel due to COVID-19 follow-up scenarios. Thereby digitalisation in traffic management is certainly not a trivial issue.

Studying and learning within several departments in a specific NRA would profit from in depth studying and providing ODD and ISAD specifications for some key priority areas on the road network and decision algorithms within a specific NRA for early forms of assisted vehicles as an internal preparation exercise on digitalization. The exercise should also aim at mitigating issues with e. g. minimum risk manoeuvres and support future proactive alignment with vehicle manufacturers and service providers.

Furthermore, it is important to develop a kind of mental model and organisational vision on what a specific NRA wants to grow into in a time of digitalisation and ecologically challenging political goals – even with a slow uptake of automated functions in vehicles. In other words, the individual actions should never be picked solely on the basis of individual projects or organisational silos but also for their contribution to a dynamically evolving vision and mission concerning digitalisation in NRAs.

The actions of study and learn provide additional information related to the deployment of highly automated vehicles, their function and evolution so that when the roll-out of highly automated vehicles is sufficient to warrant physical and digital infrastructure investments and changes in operational practices, the NRAs have the knowledge needed to make the related decisions and implementations. Some of the actions could commence and benefit immediately even human-operated vehicles, such as improving information quality or harmonised management and marking of incident and road works sites. The contents of such actions would likely be a bit different if the additional needs of highly automated vehicles are considered. Hence, these carry the “regret” element. However, at least some of the regret element can be mitigated by digitally enhanced learning and change detection mechanisms for instance via simulation capabilities in a Digital Twin environment. One tends to learn more if one is committed to doing something – even regrets or forms of mistakes or failures. Already some NRAs are following this path of “learning by doing”. When trying to avoid any mistakes, some of a NRA’s digital excellence might quickly move to organisations where mistakes are whole-heartedly accepted as they know that one learns quickly from mistakes. Consequently, a sustainable role model “study and learn” likely necessarily involves NRAs embracing some learning from errors and accompanying expectation management with the management and stakeholders.

Key actions for deployment contain the following:

- Optimised minimum risk manoeuvres and providing infrastructure for them
- Digital twins for road transport system including ODD and ISAD information
- Legal framework for driverless maintenance vehicles

All of the three actions are recommended to commence urgently at least for some parts of them. Minimum risk manoeuvres (MRMs) are currently worked upon in standardisation with little or no NRA participation while MRMs can in fact have major impact on the planning and building of the physical road infrastructure with potentially huge investment consequences.

Providing input and maintaining digital twins may turn out to be resource demanding, but the key aspects of the action are the specifications and requirements for ODDs and ISADs. These call for close dialogue between road operators and the automated vehicle industry stakeholders to clarify the requirements and expectations from both sides and to agree on a consensus solution. It is anticipated that close dialogue with vehicle industry stakeholders will continue to be a rather bumpy road – and might need accompanying expectation management within NRA-related stakeholders and top management. This is less a personal issue and more an issue of point of control in historically rather different silos. Finally, the driverless maintenance vehicles are already being rolled out in the form of safety trailers and mowing robots, and a sound legal framework is a necessity for the road operators.

Most of the actions were labelled into the “study and learn” category. This implies the importance of research, pilots and large-scale demonstrations and pilot deployments in the short and medium term. In addition to national activities, the NRAs should actively participate in related Horizon Europe and Connecting Europe Facility actions for learning, networking and information sharing purposes. It is essential that CEDR should facilitate sharing of information and best practices, and openly discussing unanticipated challenges and early forms of failure.

In addition to participation (only) in Horizon Europe, NRAs becoming a partner in the CCAM Partnership (co-programmed partnership in Horizon Europe) would constitute a valuable opportunity to stronger voice the needs of the road infrastructure in a cross-sector collaboration effort to form multi-annual Strategic Research and Innovation Agenda (STRIA) and to strive for appropriate representation in the governing bodies of the CCAM Partnership. Even more, NRA representatives - backed by CEDR - should make use of their vital interest in infrastructure related matters to aim for coordinating the research and innovation needs in the cluster on integrating the vehicle in the transport system.

All in all, with rather ambitious policy goals and challenging financial contexts, we cannot choose between digitalisation, resilience, and greening Europe. All of these need to be accomplished. Some elements of digitalisation involve ecosystems and platform thinking with evolution path dependencies. Shutting down or minimising digitalisation forefront activities might quickly deprive NRAs from some of its current cooperation opportunities with different stakeholders.

Concerning the immediate uptake from DIRIZON there has been raised some broader need for harmonising wording and concepts with ongoing work in the CEDR CAD WG and other projects. Also, DIRIZONs roadmap identified various actions around the digital infrastructure and the link to what road type is concerned and what services want to be provided on the different roads. Therefore, the road network needs to be categorised which will happen on a more overarching level and NRAs will then need to prepare the required functional infrastructure for different categories. Within the legal and institutional framework, two highly necessary recommendations need to be mentioned. As the Roadmap reflects an NRA driven view on the transition towards full digitalisation, one of the first steps is an agreement on the obligatory and optional roles that NRAs intend to play in this process. Roles and responsibilities of the NRAs and Stakeholders are partly unclear as e.g., there are uncertainties about who is responsible for data collection and, in consequence, the ownership of certain data. The lack of clarity on roles leaves all stakeholders confused to what they should or should not do at the short-term level.

Two hands-on candidate lessons were provided from STAPLE. Proactively encourage and even request valid presentation formats for all pilot tests where CEDR members are participating is necessary. A need for further pilots, tests and international cooperation has become obvious. The current presentation format is still too focused on descriptors and project marketing. They are difficult to compare and often not very relevant from a NRA perspective. A second hands-on candidate for immediate actions is to pro-actively share key questions and areas of interest from NRA perspectives in order to potentially guide test-site and pilot test narratives.

A fruitful and informative discussion on recent dynamically evolving perceptions with members in the CEDR CAD WG is seen as a candidate for further implementation activities on What hands-on actions can you think of to enforce collaboration and build up trust with different stakeholders? Input from several break-out session participants was bring the OEMs on board. Explicitly: Joint calls with ACEA also as optional next steps within upcoming CEDR CAD WG calls and tenders.

Acknowledging the iterative and spiral-like generation of knowledge the entire call 2017 and the final conference can be seen as a success and encouragement to take-up and follow through newly emerging questions and managerial implementation questions.

5 Summary

The aim of the Automation programme was to investigate what transformational change automation will create for National Road Authorities. NRAs wanted to understand how to embrace the new technology to improve road safety, traffic efficiency, the environment, customer satisfaction, maintenance and construction processes. In addition to what transformational change automation will create for NRA's the goal was to specifically answer, what new opportunities automation could produce and what core business changes are required to unlock these opportunities?

The three projects MANTRA, DIRIZON and STAPLE responded to the following questions:

- How will automation change the core business of NRA's?
- What new options do NRAs have from digitalisation and automation?
- Practical learnings for NRAs from test sites

All projects started in September 2018 and finalised in the autumn of 2020. Results were presented at a final web-conference on 6th November 2020 followed by interactive discussions on recommendations for implementation and identification of open questions.

One key open question is what the requirements of highly automated vehicles towards physical and digital road infrastructure or in general towards the road operators in 10, 20 or 30 years from now will be. The current knowledge is based on prototypes and test vehicles in use in 2020, and this knowledge has primarily been the basis for analyses and projections. This is an important challenge as the physical infrastructures deployed today are expected to have a lifetime of 30-50 years, and the digital infrastructures a lifetime of 8-15 years.

Another open topic is the question what exact role NRAs intend to play in the field of Connected Automated Driving and if this role would be the same for all CEDR members. So far project results show that at this point in time there is no common understanding of the role or a clear strategy. It is however not entirely clear whether this can be sufficiently addressed within Europe or would need kind of NRAs' full participation in a variety of globally pioneering activities where part of the yet emerging future is kind of made.

The topic is fast evolving and CEDR placed the call early on to start the work. However, even during the time since the launch of the call a lot of new issues and opportunities arose. To name just a few, the link of ODD and ISAD levels in a common framework, the development and use of digital twins to support cooperative, connected and automated driving or the definition of safe and effective minimum risk manoeuvres – these are just a few topics that were not even on the radar at the beginning of the call and are more than relevant for NRAs now. Therefore, these topics were discussed during the conference and all of them pose new research questions and unveiled a need for further pilots, tests and international cooperation.

The projects provided answers on the expected changes to NRAs core business and what can be done to use the developments to support their policy goals. Knowledge generation in this field can be seen as taking some form of a spiral. This means new questions and topics surfaced during the work of the projects and to stay in the driver's seat further research and international cooperation needs to be done to realize the full potential of cooperative, connected and automated driving for NRAs. CEDR as well as the C-ROADS and CCAM platforms are relevant to many of the recommendations across the three projects. This includes taking forward a cross sector approach to the deployment of cooperative, connected and automated mobility and as such develop further joint research projects.

Acknowledging the iterative and spiral-like generation of knowledge the entire call 2017 and the final conference can be seen as a success and encouragement to take-up and follow through newly emerging questions and managerial implementation questions.

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Appendices

Appendix 1: Final Conference 06.11.2020, Program

Morning Session: Presentation of Project Results (Plenary)		
9:00	9:30	Opening and Introduction
9:30	10:10	Project MANTRA Presentation and Q&A
10:10	10:50	Project DIRIZON Presentation and Q&A
10:50	11:10	Coffee break
11:10	11:50	Project STAPLE Presentation and Q&A
11:50	12:00	Closing Words and explanations for afternoon break-out sessions
12:00	13:00	Lunch break
Afternoon Session: Interactive Break-out Sessions & Final Plenary		
13:00	13:45	Strategic Break-out session: Impact of Automation on Infrastructure – Spotlight Digital Infrastructure
13:45	14:30	Technical Break-out session: Automation Hot Topics – ODD & ISAD, Digital Twins, Minimum Risk Manoeuvre <i>Break-out session 45min each, then group switch</i>
14:30	15:00	Closing Plenary Overview of Break-out session Results Resume and final remarks of key PEB members

Appendix 2: Live Poll Results



Table of contents

Morning Session

- MANTRA
- DIRIZON: Select all of the following suggestions which you consider to have practical potential:
- The STAPLE project developed some recommendations for future test sites. Which one of these recommendations do you think will be easiest to implement?

BO-Session | Infrastructure 1

- Warm up questions
- How helpful would you rate this hierarchy for discussing the lessons learnt within your organization?
- Selection of recommendations from ongoing roadmapping
- Survey
- What hands on actions can you think of to enforce collaboration and build up trust with different stakeholders?

BO-Session | Hot Topics 1

- If there is a common ODD-ISAD framework, what should the requirements be based on?
- Where should the framework focus?
- Who should be the champion of the ODD-ISAD framework development?
- Survey
- Today, stopping on lane has been proposed as MRM even on motorways. What is your view about this?
- Who should determine the MRM allowed on a specific road section?
- Who should cover the costs of providing the necessary infrastructure for MRMs of highly automated vehicles?

MORNING SESSION

Multiple-choice poll



MANTRA (1/2)

0 2 6

When should the road operators start to invest in the infrastructure required by highly automated vehicles?

Now



2025



2030



2035



2040



slido

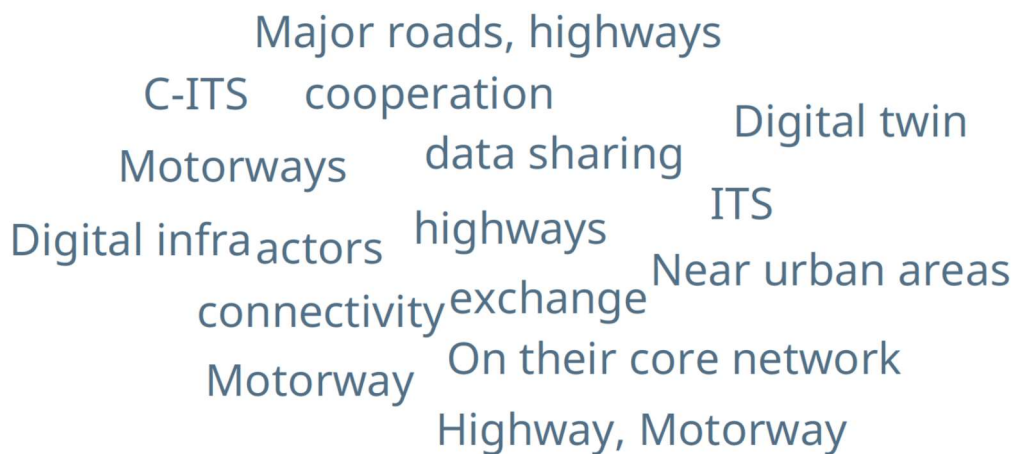
Wordcloud poll



MANTRA (2/2)

0 2 2

Where should the road operators start to invest in the infrastructure required by highly automated vehicles?



slido

Multiple-choice poll (Multiple answers)



DIRIZON: Select all of the following suggestions which you consider to have practical potential:

0 3 1

a distributed and interoperable infrastructure for data sharing and



a decentral governance model that links national and subnational road authorities, automotive and digital service industry



to establish a situation in which data can be shared



to manage traffic flow and safety and services provided,



whilst maintaining data sovereignty and European competitiveness



slido

Multiple-choice poll



The STAPLE project developed some recommendations for future test sites. Which one of these recommendations do you think will be easiest to implement?

0 2 6

Improve communication between test site operators, auto industry and NRAs



Encourage the auto industry to share data for mutual benefit



Interactions between Operational Design Domains (start and end triggers and active operation), and minimum risk manoeuvres: other than stopping



slido

BREAK-OUT SESSION INFRASTRUCTURE

Wordcloud poll



Warm up questions (1/3)

0 1 6

Where would you see the biggest deployment challenge for your organisation in the short term?

Public Key Infrastructure
european harmonization
knowledgeable staff
initial reliable data
Digital infra provision
Who does what on which basis?
Where to Find the required Competence?

slido

Multiple-choice poll (Multiple answers)



Warm up questions (2/3)

0 2 4

Where would you see the biggest challenge towards full digitalization of the road network operation from the NRAs' perspective?
(1/2)

Financial barriers



Lack of clarity on roles and responsibilities



Legal / regulatory issues



Insufficient collaboration between actors



Data issues (privacy, cybersecurity, sharing etc.)



slido

Multiple-choice poll (Multiple answers)



Warm up questions (2/3)

0 2 4

Where would you see the biggest challenge towards full digitalization of the road network operation from the NRAs' perspective?

(2/2)

Insufficient interoperability



Technical issues



Public acceptability



Other (please also comment in the Q&A)



slido

Multiple-choice poll



Warm up questions (3/3)

0 2 5

Will NRAs in Europe (your organization) be able to take an active role in digitalization and automation?

Certainly yes



Hopefully yes



I see this as rather challenging



Certainly not a role in a driver seat or active person



slido

Multiple-choice poll



How helpful would you rate this hierarchy for discussing the lessons learnt within your organization?

0 1 9

Very high



High



Quite useful



Difficult to use



Probably not effective



slido

Multiple-choice poll (Multiple answers)



Selection of recommendations from ongoing roadmapping
(1/2)

0 2 4

Make data available



Build-up competences regarding data analysis



Agree on roles and responsibilities



Enforce communication and collaboration on all levels



Digitise relevant infrastructure elements



slido

Multiple-choice poll (Multiple answers)



Selection of recommendations from ongoing roadmapping

0 2 4

(2/2)

Categorise the road network and the required functional infrastructure in different categories



Actively take part in the planning process of pilots and testing sites



slido

Multiple-choice poll



Survey (1/2)

What role should NRAs play regarding data?

0 2 2

Data collection/provision



Data collection/provision & Data processing



Neither



slido

Multiple-choice poll



Survey (2/2)

0 2 3

In what timeframe do you think it possible to provide infrastructure data in machine-readable format and agreed standards?

Short-term



Mid-term



Long-term



Already existing



Not realistic



slido

Open text poll



0 1 6

What hands on actions can you think of to enforce collaboration and build up trust with different stakeholders?

- Trials
- Information exchange
- Perhaps learn from the US example of data sharing between oem and research
- Data-usage-policy
- Projects and Pilots Common specification of use cases
- Involve them (ACEA) in calls of CEDR
- Trials
- participation in pilots
- good examples, such as DTF
- Pilot tests
- It is not possible to enforce collaboration. You can only encourage
- Do common test projects
- Do things together, step by step. Begin with small steps
- "IDS-ify" the pilots -- that would include 'regional' governance as well - without foreclosing international collaborations!
- Less dispersed initiatives
- Just do it on small scale even with some mistakes
- Define service level agreements

slido

BREAK-OUT SESSION HOT TOPICS

Multiple-choice poll



If there is a common ODD-ISAD framework, what should the requirements be based on?

018

Vehicle and AD system developers' views

0 %

Road operator/infrastructure manager views

17 %

Driver/traveller needs

0 %

Combined industry and road operator views

33 %

Combined view of all three

50 %

slido

Multiple-choice poll



Where should the framework focus?

020

Physical road infrastructure

0 %

Digital road infrastructure

0 %

Communication infrastructure

0 %

Physical and digital infrastructure

20 %

Digital and communication infrastructure

20 %

No specific focus, all of the above

60 %

slido

Multiple-choice poll



Who should be the champion of the ODD-ISAD framework development?

0 2 0

(1/2)

CEDR and its members



CEDR, ASECAP, POLIS and their members



ACEA, CLEPA and their members



CEDR, ASECAP, POLIS, ACEA, CLEPA and their members



Standardisation organisations



slido

Multiple-choice poll



Who should be the champion of the ODD-ISAD framework development?

0 2 0

(2/2)

European Commission



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Multiple-choice poll (Multiple answers)



Survey (1/4)

0 1 7

Which real-time data is available for a digital twin from NRAs that is considered reliable enough to support decision making automatically?

(1/2)

Weather data



Incidents



Road work zones



Traffic flow



Traffic signs



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Multiple-choice poll (Multiple answers)



Survey (1/4)

0 1 7

Which real-time data is available for a digital twin from NRAs that is considered reliable enough to support decision making automatically?

(2/2)

Road design (through e.g. BIM)



Road condition / service levels



Rules and regulations including traffic management plans



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Open text poll



Survey (2/4)

005

Any other real-time data available for a digital twin from NRAs that is considered reliable enough to support decision making automatically? Please add

- Traffic light signal phase and timing (after a few years of testing)
- Legal certainty
- Variable message signs (speed advices etc.)
- Road markings
- Non of the above is ready for this

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Multiple-choice poll



Survey (3/4)

017

Which use cases do you consider most valuable to be supported by a digital twin?
(1/2)

Braking patterns of (connected) vehicles to draw conclusions as to incidents such lost cargo, rock fall (data from vehicles)

0 %

Emergency lane/corridor information and requirements in case of incidents (data from NRAs)

18 %

Routing suggestions based on traffic and weather monitoring systems (data from NRAs and/or vehicles)

12 %

Road work zone traffic and lane width information (data from NRAs)

18 %

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Multiple-choice poll



Survey (3/4)

0 1 7

Which use cases do you consider most valuable to be supported by a digital twin?
(2/2)

Road condition surveillance through vehicle sensors (data from vehicles)



Cooperative traffic management based on real-time simulation utilizing current traffic flow and incident situation (data from NRAs and vehicles)



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Open text poll



Survey (4/4)

0 0 5

Or in other words what would be the most catchy selling point to sell digital twins within your organisation?

- better asset management and support for maintenance
- It will improve our asset management maturity level
- legal requirement
- ?
- Use cases have to be developpt

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Multiple-choice poll



Today, stopping on lane has been proposed as MRM even on motorways. What is your view about this?

0 2 0

Fully acceptable

0 %

Acceptable if speed level is at most 50 km/h

10 %

Not ok, MRM should be stopping on a "safe harbour" (wide shoulder etc.)

70 %

Not ok, MRM should be slowing down and putting on hazard flashers

0 %

Not ok, some other MRM than above is needed

20 %

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Multiple-choice poll



Who should determine the MRM allowed on a specific road section?

0 2 1

The OEM of the vehicle in question

5 %

The road operator responsible for the road section

38 %

The type approval authority accepting the vehicle for use

29 %

The OEMs and road operator together

29 %

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Multiple-choice poll



Who should cover the costs of providing the necessary infrastructure for MRMs of highly automated vehicles?

0 2 0

The infrastructure owner (road operator in case of physical infrastructure)



The infrastructure operator (if not the owner)



The drivers/owners of automated vehicles using the road e.g. via specific road tolls



All drivers/owners of vehicles using the road



All owners of highly automated vehicles e.g. via a specific vehicle tax



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CEDR Contractor Report 2021-01

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des Directeurs des Routes**

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Directors of Roads**

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