DIRIZON

Report on the step by step transition towards a full digitalisation of the road network

Deliverable 7.1

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Deliverable 7.1 – Report on the step by step transition towards a full digitalisation of the road network

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Executive summary

The aim of this last Work Package of DIRIZON - *Step by step transition towards a full digitalisation of the road network* - is to develop a Roadmap to support NRAs in preparing their own strategies in regards to Connected Automated Driving (CAD) within which the key activities required to achieve this goal are presented. In order to get an overall picture of required actions and measures, WP7, and ultimately the Roadmap, consolidates the outcomes of the other work streams within DIRIZON (WP2-WP6). In order to represent the path from a complex heterogeneous landscape today to an EU-interoperable system, the visualised roadmap summarises the main steps and actions required. Although all steps are quite closely linked, the actions are categorised into three specific fields of action: Data, Physical and Digital Infrastructure as well as Legal and Institutional Framework.

It has to be highlighted, that the recommendations in the Roadmap are mainly following the "agree-first" model, where strategic coordination is essential. Therefore, it was decided, to divide the measures into two levels: Strategic Level and Operational Level. Equally, while the intention was to consider short (1-3 years), medium (4-7 years) and long term (8-10+ years) actions, it became evident from the findings in WP2 that identifying long term actions was not feasible as it would depend on the success, or otherwise, of implementing the short- and medium-term actions and the inherent uncertainties that exist. As such, it was decided to omit long-term actions from the Roadmap.

Summarising all recommendations in the field of data, we can conclude that on short-term, agreements on data needs, which includes standards and data quality criteria, are needed before NRAs can start collecting data. As it will be challenging to commit on European-wide specifications based on agreed standards, cooperation is the key. This applies also when it comes to the field of data sharing & security, where the basis are agreements on data requirements and clear conditions including data liability, data access and usage. Summarised, NRAs are obliged to provide data under non-discriminatory conditions to ensure smooth and cross-border data sharing. In this context, the consideration of the International Data Spaces (IDS) concept for the exchange of mobility data is recommended as well. Therefore, in order to incorporate IDS, pilots and research in this direction are definitely in the NRAs' interest. Another aspect is the development of competences in the field of data handling and understanding which is necessary within the next 1-3 years. It is extremely important that NRAs prepare themselves for further developments. This also includes constant identification and monitoring of new technologies and best practices from other countries. The intensive involvement of multiple stakeholders and exchange between actors abroad is particularly required when it comes to cross-border services. In addition, interoperability might be seen as essential key if cross-border services should become more and more standard.

Besides interoperability, connectivity and reliability become more and more critical – especially when it comes to Physical and Digital Infrastructure, which can be regarded as the *glue for collecting, combining, sharing and transmitting of data necessary for automated vehicles* [ITF Working Group, 2020]. In this context, agreements on relevant physical elements on the hand and their digitalisation on the other hand is essential. After that, since there are different operating environments, NRAs will play an important role together with other stakeholders like MNOs to determine what categories of the road network are useful. This is directly linked with the needed agreements on requirements which services should be provided.

Once the basic physical and digital infrastructure is established, NRAs should play a crucial role during the transition period. In order to be prepared for the scenario of both conventional and automated cars driving (i.e. mixed fleets) on the roads, NRAs will have to take part in the planning process of different testing sites. As already mentioned in the beginning, strengthening collaboration can be highlighted as one of the main recommendations. It can be seen as the key in almost all areas as no stakeholder group alone can tackle the current problems. This aspect is also evident with the need for a precise definition and allocation of roles and responsibilities, not only with regard to the NRAs itself, but also to multiple stakeholders.

Summarised, the given recommendations of WP7 are not only the overview of steps NRAs need to undertake to reach full digitalisation of the road network, and ultimately fully automated driving on the network, but also an important basis for further work in this field. Since the recommendations are leading to the overarching goal of full digitalisation of the road network, it is proposed to work on a specific joint vision in the future to develop even more detailed actions for NRAs. In this context, especially the establishment of long-term measures and actions to generate a clear path in coming decades should be pushed forward.

Project information

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Abbreviations

Abbreviation	Full Title
ACEA	**A**ssociation des **C**onstructeurs **E**uropéens d'**A**utomobiles/European Automobile Manufacturers' Association
AD	**A**utomated **D**riving
CAD	**C**onnected and **A**utomated **D**riving
CAM	**C**ooperative **A**wareness **M**essage
CAV	**C**onnected and Cooperative **A**utomated **V**ehicle
CCAM	**C**onnected and **C**ooperative **A**utomated **M**obility
(C-)ITS	**(C**ooperative) **I**ntelligent **T**ransport **S**ystems
CEN/TC	**E**uropean **C**ommittee for **S**tandardization/ **T**echnical **C**ommittee
C-Roads	**C**ooperative **R**oads
DoS	**D**enial of **S**ervice
HD	**H**igh-**D**efinition
GDPR	**G**eneral **D**ata **P**rotection **R**egulation
INFRAMIX	Preparing road infrastructure for mixed vehicle traffic flows
ISAD	**I**nfrastructure **S**upport for **A**utomated **D**riving
ITS	**I**ntelligent **T**ransportation **S**ystem
MaaS	**M**obility **a**s **a** **S**ervice
MEC	**M**ulti-access **E**dge **C**omputing
METR	**M**anagement for **E**lectronic **T**raffic **R**egulations
MNO	**M**obile **N**etwork **O**perator
NRA	**N**ational **R**oad **A**uthority
ODD	**O**perational **D**esign **D**omain
OEMs	**O**riginal **E**quipment **M**anufacturer**s**
PKI	**P**ublic **K**ey **I**nfrastructures
RO	**R**oad **O**perator
SAE	**S**ociety of **A**utomotive **E**ngineers
TERAP	**T**rusted **E**lectronic **R**egulation **A**ccess **P**oint
V2I	**V**ehicle **to** **I**nfrastructure
WG	**W**orking **G**roup
WP	**W**ork **P**ackage

Definitions

Term	Definition
ACTIVE SAFETY SYSTEM	Vehicle systems that sense and monitor conditions inside and outside the vehicle for the purpose of identifying perceived present and potential dangers to the vehicle, occupants, and/or other road users, and automatically intervene to help avoid or mitigate potential collisions via various methods, including alerts to the driver, vehicle system adjustments, and/or active control of the vehicle subsystems (brakes, throttle, suspension, etc.) (SAE J3016 June 2018)
ACTOR	An entity (human or otherwise) that interacts with the system for the purpose of completing an event.
ACTOR (PRIMARY)	An actor that is necessary for the deployment of a use case. It has a goal with respect to the system - one that can be satisfied by its operation. It not only has a primary interest in the use case but can may also be the initiator of the Use Case.
ACTOR (SECONDARY)	A third-party actor from which the system needs assistance to achieve the primary actor's goal.
AUTOMATED DRIVING	A traffic system in which vehicles are capable of sensing its environment and operating and manoeuvring in traffic to achieve a goal, with little or no human input. It is supported by connectivity consisting of Vehicle-to-Infrastructure (V2I) communication, Vehicle-to-vehicle (V2V) communication, Vehicle to Everything (V2X) communication, Infrastructure to everything communication (I2X).
AUTOMATED DRIVING SYSTEM	The hardware and software that are collectively capable of performing the entire dynamic driving task on a sustained basis, regardless of whether it is limited to a specific operational design domain (ODD); this term is used specifically to describe a level 3, 4, or 5 driving automation system (SAE J3016 June 2018)
DEVICES	The components of an Information Technology (IT) network that permit the communications needed required for data applications and services (such as servers, routers, detection systems etc.).
DIGITAL INFRASTRUCTURE	A digital infrastructure includes and facilitates V2I, V2X and V2V communication
DIGITALISATION	The implementation of digital technologies, which when combined with Information and Communication Technology (ICT) tools, assist in making transport modes more interoperable and smarter
DIGITISATION	The process of converting physical information into a digital format.
DRIVING AUTOMATION SYSTEM	The hardware and software that are collectively capable of performing part or all of the dynamic driving task on a sustained basis; this term is used generically to describe any system capable of level 1-5 driving automation (SAE J3016 June 2018)

Term	Definition
OPERATIONAL DESIGN DOMAIN (ODD)	A description of the specific operating conditions in which the Automated Driving system is designed to properly operate. It includes but is not limited to roadway types, speed range, environmental conditions (weather, day/ night time, etc.), prevailing traffic law and regulations, and other domain constraints (SAE J3016 June 2018).
PHYSICAL INFRASTRUCTURE	All infrastructure on the road including, but not limited to, grass verges, roadway widths, cross sections, safety barriers, signage, lines, power requirements ducting and C-ITS based devices.
PUBLIC KEY INFRASTRUCTURE (PKI)	A set of dedicated policies, procedures and technology that are needed to deal with digital certificates in a public key cryptography scheme. This includes Certificate Authorities (CA) communication for initial enrolment of ITS stations, certificate requests and re-keying and certificate renewal (ENISA, 2019 & C-Roads, 2018c)
SYSTEM	It comprises a set of sequences of actions and variants that are performed within it and lead to value of an actor. It can be a complex combination of various components that interact each other to satisfy individual objectives.
SYSTEM SECURITY	It consists of all functions required for a secured message generation, i.e. signature generation, key and certificate handling, as well as authentication (verification) of received messages (C-Roads, 2018c).
USE CASE / CORE TOPIC	A function of the system, the desired behaviour (of the system and actors), specification of system boundaries and definition of one or more usage scenarios. It combines all possible scenarios that can occur when an actor tries to achieve a certain technical objective (business goal) with the help of the system under consideration.

1 Introduction

1.1 WP7 - Step by step transition towards a full digitalisation of the road network in the DIRIZON overall project context

The major goal of DIRIZON is to support the European National Road Authorities (NRAs) in their digital transition and in their interaction with other stakeholders regarding Cooperative Automated Driving. To this end, DIRIZON is assisting the aforementioned road authorities/Road Operators in identifying how these developments will affect their operations and their interaction with others. In this respect, DIRIZON determines the implications of Digitalisation and Automated Driving on specific core topics and their consequences on data needs and requirements for data-exchange.

This deliverable is part of WP7 (*Step by step transition towards a full digitalisation of the road network*). The objectives, according to the proposal, of this WP are to

- Identify the sequence of steps the NRAs need to undertake to achieve digitalisation. This includes internal and organisational processes as well as stakeholder interaction needed.
- Define short-, medium and long-term actions
- Consolidate input from other WPs, develop conclusions and provide a Roadmap as a guide for NRAs to prepare their own strategies

WP7 consolidates the findings of the other work streams within DIRIZON, namely work packages 2 to 6. The proposed Roadmap for a step-by-step transition towards full digitalisation of the road network is developed based on the output from these work packages, focusing particularly on the Use Cases. The results of WP2 *(NRAs and Digitalisation)*, where the use cases were initially identified and defined, as well as the findings of WP3 (*Implications for use cases, Identification of Stakeholders and Data Needs and Requirements*) and WP4 (*Report on stakeholder responsibilities in the areas of data exchange, digital platform, and actions needed for making identified use cases reality)* through an in-depth-analysis with NRAs and external stakeholders, form the basis for the sequences and actions within the Roadmap. Also, the eliciting stakeholder views on security and privacy issues in WP4 have been considered. To obtain a complete picture, *data-exchange concepts for NRAs* (WP 5) and *business models options for data-exchange in context of CAD* (WP 6) needed to be taken into consideration to ensure a proper sequence not only in technical terms, but as well in taking processes (organisational, governance, etc.).

The outcome of WP7, as described in this report, will give a better understanding of the necessary short- and medium-term milestones NRAs must take to reach the end goal of an EU-interoperable system for CAD. Short-term measures comprise activities over the next 1-3 years, medium-term measures refer to the time frame 4-7 years. As it is very difficult from today's perspective to provide recommendations for long-term measures, it was decided not to include long-term measures in the Roadmap (see 4.3). This decision is supported by the WP2 finding which underlies growing uncertainty, the bigger the time frame gets. Therefore, this was one of the main arguments that led to omitting long-term actions in the Roadmap. It is very difficult to predict what will and needs to happen in the next 10 years.

1.2 Structure of this report

This report summarises the work done within WP7, starting with an analysis of the previous WPs as basis for described sequences towards full digitalisation of the road network, in addition, the overall objectives of CAD and why the Roadmap with concrete steps for NRAs can be seen as an important basis for the work of NRAs regarding automation in the next years. This document summarises the results of the other WPs and recommendations for NRAs are derived in the form of a Roadmap. This output will draw conclusions as basis for further work within projects in the field of digitalisation and automation.

This report is structured as following:

- **Chapter 2: Methodology and Sources**, describes the overall methodological approach and the steps taken to collect recommendations for the Roadmap towards full digitalisation of the road network.

- **Chapter 3: Summary of key findings of all other WPs of DIRIZON,** summarises the outcomes of WPs 2 to 6 of DIRIZON as basis for recommendations. The summaries are focused on the parts of the deliverables that were actively integrated in the Roadmap.

- **Chapter 4: Roadmap for NRAs for a step-by-step transition towards full digitalisation of the road network** provides, as a starting point, an overview of the Roadmap structure. Based on the visualisation of the Roadmap in 4.2, the main part of this Deliverable is Section 4.3 which gives an insight in the recommended actions at a short- and mid-term level for NRAs in cooperation with other stakeholders. The chapter concludes with an overview on risks & challenges on the way towards full digitalisation of the road network NRAs have to overcome.

- **Chapter 5: Summary and main takeaways**, identifies the major key recommendations towards full digitalisation of the road network at the short- and mid-term level from the analysis. Therefore, some particularly important actions are highlighted in this chapter.

2 Methodology and Sources

2.1 Sources and methods used

WP7 is based on the following sources and methods:

- Outcomes of WP2 (literature review, interview findings and definition of the use cases) which are in principle summarised in Deliverable D2.1. (Tucker et al., 2019).
- Outcomes of WP3 (list of data and data categories for the selected use cases), which can be found in Deliverable D3.1. (Malone et al., 2020), as well as the updated WP3 use cases.
- Outcomes of WP4 (literature review with focus on position papers (concentrating on relevance for the DIRIZON use cases), Data collected from the web-based questionnaire
- Outcomes of WP5 (literature review with focus on data exchange options, research on innovative projects and initiatives)
- Outcomes of WP6 (literature review, development of business model options for an NRA driven data-exchange platform)

2.2 Overview of DIRIZON Use Cases as basis for Roadmap

The project approached the broad topic of digitalisation by identifying three use cases (which are referred as core topics in the following), which were based on the previous work done in DIRIZON and finally selected together in a workshop with the CEDR/CAD working group in Oslo on November 6-7, 2018:

- **Provision of High-Definition (HD) 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 (CCAV) ability to understand its precise positioning, plan beyond sensor vision, possess contextual awareness of the environment and local knowledge of the road rules.

- **Distribution of Digital Traffic Regulations:**
  Distribution of digital traffic regulation becomes more and more relevant for CAM (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.

- **Infrastructure Support for Cooperative Automated Driving (CAD):**
  Infrastructure support for Connected and Cooperative Automated Driving (ISAD) is digitised information, on top of the HD map and the digitised traffic regulations, to support CAD (connected and Automated Driving) functioning.

The three use cases are conceptually linked, as illustrated in Figure 1 below.

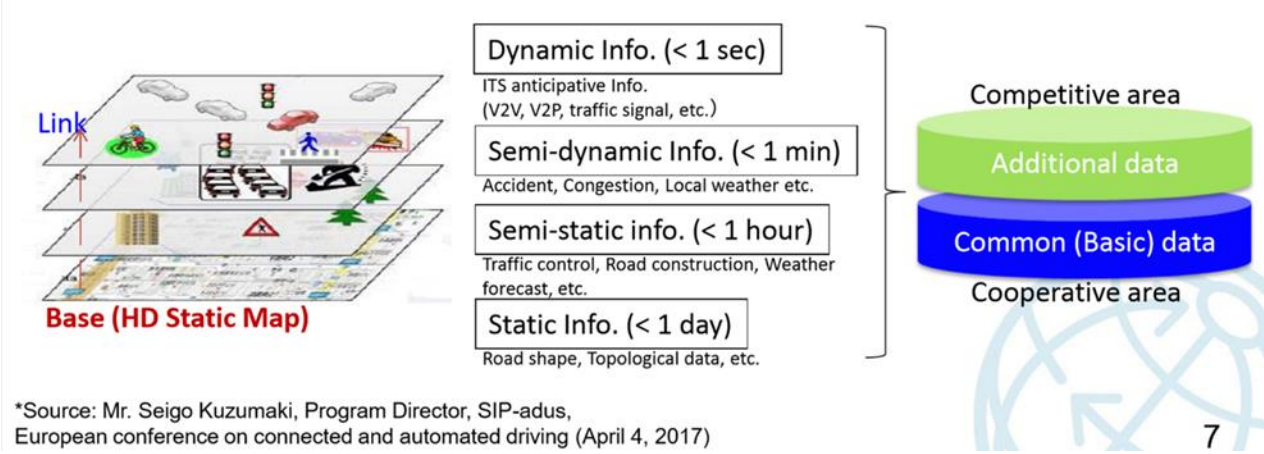

Figure 1: Visualisation of the layers and data types for a High-Definition (HD) map. Source: presentation of Jun Shibata at the SIS 37, 12th ITS European Congress Strasbourg, June 21, 2017 [Shibata, 2017]

The DIRIZON project sees the core topics as building on top of each other. The base layer is the static data in the HD map. The Distribution of Electronic Traffic Regulations adds regulations to the static data in digital form. Infrastructure support for Connected and Cooperative Automated Driving (ISAD) is digitised information, on top of the HD map and the digitised traffic regulations, to support CAD functioning. Thus, this use case covers vehicles in a mixed environment, supporting Cooperative, Connected and Automated Vehicles (CCAVs) by extending their Operational Design Domain (ODD) and improving safety, traffic flow and environmental impacts. Figure 1 illustrates the layers and data types for a High-Definition (HD) map. Figure 1 shows layers that differ according to how static or dynamic the data is. Conceptually, the HD map integrates layers of different types of data, which can come from different use cases. Furthermore, the core topics will evolve over time, for example, information provision will be to human drivers in the short term, evolving to providing information to more and more vehicles with higher levels of automation. The focus of DIRIZON is on digitised information for the Cooperative and Connected Automated Vehicles (CCAVs), not on presenting to the human driver. Of course, on-going research on human-machine interaction in the automated vehicle is of critical importance but not addressed specifically within DIRIZON.

3 Summary of key findings of all other WPs of DIRIZON

Since the other WPs of DIRIZON are an important basis for the given recommendations for NRAs towards full digitalisation and automation of the road network, the essential outcomes are summarised in the following chapters. It should be emphasised that the summaries are intentionally kept short. A complete list of the results can be found in the deliverables of the WPs.

For clarification, only WP 2 to 6 are being included in this chapter since WP1 and WP8 are project management and dissemination and did not add content for building the Roadmap. The outcomes are also especially focused on the parts of the deliverables that were actively integrated in the Roadmap in order to explain how they were fed into the final result of the project DIRIZON.

3.1.1 Outcomes of WP2 – NRAs and Digitalisation

The goal in WP2 was to identify the current Level of Digitalisation and Automated Driving of NRAs and also to explore their future 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.

The literature review summarises the most notable past and ongoing platforms and projects implemented by European countries in this area, while the analysis of the interviews gives insights in what responsibilities NRAs are likely to take on during the process. These findings were especially important for building the Roadmap since they represent how NRAs currently view their role and what they think needs to happen in the future. Many steps that are now depicted in the Roadmap were directly taken from this WP. Moreover, WP2 explored the barriers in achieving digitalisation and full automated driving that are seen at the moment which are explored in Chapter 4.4 (risks & challenges). Current barriers were also taken into account formulating the actions in the Roadmap as they show what needs to be overcome and, in consequence, what needs to be done.

It became obvious that the results ask for more clarity on the role of NRAs towards Digitalisation and especially Automated Driving. Some countries identified that they have a Digitalisation Action Plan and most do have an overall ITS strategy, however, for Automated Driving, Action Plans are typically not in place. A main finding was also the growing uncertainty, the bigger the time frame gets. This was one of the main arguments that led to omitting long-term actions in the Roadmap. It is very difficult to predict what will and needs to happen in the next 10 years.

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. It is acknowledged that the NRAs role is in infrastructure data provision with data being made available to private service providers, who use it for their own business. In other words, the NRAs provide the infrastructure and subsequently private industries infrastructure can be installed on it. NRAs also see their responsibility in 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 (see Roadmap on agreement on categorisation of 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. Therefore, it should be considered that they play a leading role in advising Governments of legal, governance and communication issues.

Since it was made clear that 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. where collaboration occurs with other countries and Third parties in addition to assessing technologies.

Additionally, WP2 recommends steps that NRAs will need to take within their internal organisation in order to facilitate the transition towards CAD. Interviewees felt that NRAs will change how things are organised internally with more office-based work/staff. More people will be needed on the technological side and the role of traffic experts and management will be increased.

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) will be required.

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 aid the relevant actors 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.

WP2 identified the main risks and challenges to achieving full Digitalisation of the road network and Automated Driving and categorised them into:

- Financial barriers: amount of investment required is unclear both for initial investment and operation costs
- Lack of clarity on roles and responsibilities
- Legal / regulatory issues: need for legislative framework
- Insufficient collaboration between actors
- Data issues (privacy, cybersecurity, sharing etc.): Harmonisation of data in a standard format is required and there are questions around how to deal with large volumes of data
- Insufficient interoperability both at national and EU level: Formalising and standardising data requirements, formats and exchange/sharing mechanisms critical
- Technical issues: technology needs to be validated and tested in a real environment
- Public acceptability: without acceptance of public, implementation could be difficult

In order to minimise these risks and address barriers, it is acknowledged that NRAs should participate in research projects and platforms. Moreover, NRAs are not responsible for eliminating all barriers and risks. Governments for example have a key role to play in developing the legal frameworks, ethics standards, insurance regulations etc.

Digitalisation and Automated Driving will invariably change how NRAs operate, and notwithstanding the associated barriers and risks, it is expected that their implementation will significantly improve how NRAs operate and manage their networks thus providing NRAs with

the tools to impact traffic safety positively. Equally, their implementation could see a reduction in NRAs costs by eliminating the need to collect data and construct hard infrastructure (i.e. gantries etc.).

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

Within WP3, 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. The evolution of the Use Cases were major results that played a big part in creating the Roadmap because of the added time frame and planned development of the Use Cases.

In the Roadmap, steps regarding prerequisites for the adoption of HD Maps have been integrated in the short-term section as (at least static) HD Maps are the base for the other Use Cases. Digital Traffic Regulations (METR) can be found more in the medium-term. ISAD builds on top of the first two Use Cases, however, actions can be seen throughout the whole process to prepare for the implementation of the third and final Use Case (see chapter 2.2).

Use Case 1: HD Maps

For Use Case 1 HD Maps, one of the main milestones defined in WP3 is the establishment of NAPs or processes for data provision. Profiles, formats, structures and procedures are needed to handle data streams. Basically, 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. This leads to an important step for NRAs to start digitising their physical infrastructure now. 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 (METR)

The second Use Case Distribution of traffic regulations (METR) 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.

Use Case 3: ISAD

The third and final Use Case ISAD Infrastructure Support for Automated Driving (ISAD) for CAD is digitised information lies on top of the other two Use Cases. Therefore, the use of a 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.

3.1.3 Outcomes of WP4 - Report on 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, 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. A specific focus was given 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.

As already mentioned, one of the core issues of WP4 is the definition and clarification of roles and responsibilities in the area of automated driving. First of all, it can be emphasised on a higher level that the need for collaboration of the various stakeholders was considered critical by all stakeholders independent of the core topic. It can be seen as a requirement for all processes and, therefore, this might be the biggest challenge. Collaboration, which also includes an exchange at different levels of policy-making, will be important in order to achieve the vision of fully Automated Driving in the EU. A proposed multi-stakeholder environment can only be successful, if cooperation is effective, profitable and transparent.

The Roadmap addresses the need for actions to clarify roles and foster cooperation on several levels. Exchange and communication between actors should be promoted at both strategic and operational levels.

The fact that cooperation is essential is especially reflected in the area of data and data types. The results of WP4 show that different data types which are relevant to implement 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 absolutely needed. Therefore it is recommended 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). When it comes to the automation of the process and Automated Driving, the availability of data in a machine-readable format is the very basis to make this reality. With regards to data quality, besides the definition of quality criteria for data, feedback loops might be of high relevance.

Beyond the distribution of roles, it must be clarified whether and which information is exchanged directly between the stakeholders or whether an exchange platform is always absolutely necessary. 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 and their part within the process is pretty unclear. The results show clearly that the NAP is a task of a national organisation/authority, like ministries or similar public organisations. Equally, this is a task for those institutions that have already been providing the NAP like the National Data Warehouse for Traffic Information in the Netherlands. Moreover, the option of international organisations or communication system providers were added as options.

These 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 on the examination of potential benefits as well as risks and challenges in regards 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. At the same time some benefits were expected, which includes better traffic management and improved road capacity.

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

The focus of WP5 was on the development of data exchange options for Use Case 3 “Infrastructure Support for Automated Driving” as the most complex use case, which also covers the others to show the technical options, considering the evolvement over the time. Therefore, some research on innovative projects and initiatives related to the topic of data exchange was carried out in WP5. In the end recommendations and conclusions for a future strategy were derived.

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.

In the deliverable there was given an overview of data requirements with regard to data exchange options as a starting point. This list especially covers technical requirements like latency, refreshment rate and availability. This outcome was 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.

In this context we would like to highlight some essential contribution about International Data Spaces (IDS) first, because there are also included some actions in respect to the introduction of the IDS concept for the exchange of mobility data between the mentioned backends in the Roadmap. The IDS Association is an alliance of multiple organisations with the aim of establishing a decentralised platform concept for secure and trusted data sharing maintaining data sovereignty. The IDS concept seems to be very innovative and promising. It offers new possibilities to trustful access even sensitive mobility data sources (e.g. fleet data) in order to use them e.g. for traffic condition monitoring, traffic prediction models, future AI applications. The IDS concept revolves around so called ‘connectors’ that allow to make even existing data sharing systems interoperable with others, and therefore allow for building forward on local, regional or national deployments, without foreclosing the opportunity of an interconnected and interoperable European data landscape (for mobility). A German research project is investigating such possibilities by applying the IDS concept on the German NAP, following successful and operational implementations of the concept, e.g. in manufacturing. Operation of the so-called Mobility Data Space is planned for 2022 and will provide the first comprehensive findings on the application of the IDS concept in the mobility sector. The sectoral Data Spaces are explicit part of the European Commission’s Digital Strategy and includes mobility as a sector.

It is important to notice that on the one hand this decentralised approach in principle deviates from the somewhat central system design approach NRAs took in designing systems, e.g. NAPs – and on the other hand how decentralised CEDR and other European governing organisations actually already function.

The results of WP4 has shown that the role of National Access Points (NAP) in the field of automated driving is still not unanimously accepted respectively not absolutely clear. 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) (European Parliament, 2010). In addition, in the beginning of 2020 the EC adopted the European Strategy for data (COM (2020) 66 final), which provides in particular for the establishment of EU-wide common, interoperable data spaces in strategic sectors including a Common European mobility data space (MDS) (European Commission, 2020). In general we also recommended the involvement of NAPs in the Roadmap and assume that the role of the NAP will be strengthened in the future. A further obstacle to the use of the European NAPs for internationally operating companies such as vehicle manufacturers and navigation service providers is the still large number of platforms in Europe. Around 30 NAPs, some of which are implemented in significantly different ways, have to be served in this way in order to be able to offer services internationally (https://eip.its-platform.eu/activities/monitoring-and-harmonisation-national-access-points). Apart from a few exceptions, they do not offer any possibilities for direct data exchange. Further harmonisation, or rather the networking of the European NAPs with Mobility Data Space concepts, would be welcomed from many sides.

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 can be said that cooperation with various stakeholders in this area - as is so often the case - 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 needed cooperation. Based on this, 5G – the next (fifth) generation of cellular radio technology - was discussed. It is assumed that 5G enables low latency and high-performance applications, as they are expected to emerge from C-ITS services and will have increasingly challenging requirements in the scope of Infrastructure Support for Automated Driving (ISAD). Latency issues were also mentioned in WP4 as a potential challenge and should be considered in the Roadmap as well. It is remarkable that Mobile Edge Computing (MEC) application servers will necessarily have to be operated in the future which could strengthen the role of Mobile Network Operators (MNOs) in the future.

The report of WP5 also mentioned a discussion paper of the European Automobile Manufacturers' Association (ACEA), where dialogue with the road authorities, road operators and cities regarding physical and digital infrastructure requirements, harmonised traffics rules and regulations, specifics for urban mobility and the role of road authorities was emphasised.

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.

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

In WP6 business model options for an NRA driven data-exchange platform in the context of future CAD deployment in Europe were provided. 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 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. 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*)

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. CEDR can help achieving this, as it has a long standing organisation. Yet it would be necessary to adopt a mission statement along the lines of the CAD-fleet-as-a-Service scenario. It is important to understand that such objective has overarching implications, and goes well beyond harmonisation. This means that such a governance body, from the perspective of

the NRAs would deal with infrastructure, regulation, traffic and safety and digitisation from an integral and strategic perspective. Therefore it must have support from the highest levels of the NRAs.

2. Ensure pilots are "IDS-*ified*", for replicability and sovereignty. Currently the pilots and implementations are, given its novelty, not compliant with IDS. And, assuming IDS can be made applicable to deployments such as Use Case 3, new pilots should be implemented following this paradigm, to ensure replicability and engrained data sovereignty. This will help to gradually build the landscape.

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. In order to leverage that interest and relevance for the data-exchange, the sub-national authorities should be included in the governance structure. This can help them to participate in the same "wave". Furthermore, as there seems not to be a unifying coordination at sub-national level, this may also represent a benefit for automotive and collaborate also at the aggregated national level beyond standardisation.

4. Ensure commercial implementations in public-private collaborations (e.g. cities) are "IDS-*ified*". For the same arguments as 2. It is important that also local deployments become aligned in this principle. It should be investigated to what extent this can be posed as a requirement, even in existing situations and licenses.

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. As the CAD-fleet-as-a-service scenario is by no means a public-only endeavour, participation from automotive industry and digital parties in the governing body is necessary. The exact level of involvement is however yet to be determined.

7. Actively profile and monitor regional and national infrastructures and actively broker upscaling / replication of IDS-ified pilots and (commercial) best-practices. In order to spur the transition, and because the advised scope of governance is very large, it is advised to set up a monitoring facility to observe the progress in becoming "CAD-fleet-ready". Furthermore, such monitoring facility and organisation, should also aid in pro-actively identifying brokering opportunities. E.g. services developed in one area, to be applied elsewhere. This is known to increase the learning effect and speed up the transition.

4 Roadmap for NRAs for a step-by-step transition towards full digitalisation of the road network

The goal of WP7 is to recommend the most important actions for NRAs to take in order to achieve full digitalisation of the road network and put together a structure that considers an ideal but also realistic timeframe. Since these actions are aimed as a plan for NRAs to decide on their next steps, it was decided to include them into a visualised Roadmap.

In this chapter, firstly, the structure of the Roadmap is explained. Secondly, the recommended steps the NRAs need to undertake towards full digitalisation are presented. The Roadmap can also be seen as a checklist for NRAs. The aim was to identify measures which can be classified especially in short-term and mid-term actions. As it is very difficult from today's perspective to provide recommendations for long-term measures, it was decided not to include long-term measures in the Roadmap.

4.1 Roadmap Structure

The main outcome of WP7 is a visualised Roadmap (see Figure 2 and Figure 3Figure 3) that summarises the main steps and actions, NRAs must take in the process of transitioning towards full digitalisation of the road network. This chapter explains the structure and shall serve as a guide for the reader in how to approach the Roadmap.

First of all, three fields of action were defined that are relevant over the entire evolution of the Roadmap:

1. Data
2. Physical and Digital Infrastructure
3. Legal and Institutional Framework

All measures can be assigned to one of these three categories. The three fields are quite interconnected and many steps go alongside each other. One example might be that the digitalisation of physical infrastructure leads to the collection of data. However, the categorisation shall help NRAs understand how to approach Connected Automated Driving.

The fields of action are defined based on the DIRIZON outcomes and recommendations of WP 2 - 6 as well as first results from the International Transport Forum Working Group on Preparing Transport Infrastructure for Automated Vehicle Integration [ITF, 2020].

1. **Data**:

This refers to the sets of information that are used to support automated driving such as mapping information, live information about the road environment, and any future functionality that becomes possible on the back of wider connectivity.

2. **Infrastructure**:

Physical Infrastructure: Includes the elements that present the roadway to the Automated Driving System.

Digital Infrastructure: Includes the systems and networks that provide for connecting the roadway system to communications, and data.

3. **Legal & Institutional Framework:**

The term institutional framework refers to a set of formal organisational structures, rules and informal norms for service provision. Actions regarding roles and responsibilities fall under this category [IEES, 2006].

For all three fields of action, the measures have also been divided into the following levels:

- Strategic Level *(rows 1 and 2)*
- Operational Level *(rows 3 and 4)*

Strategic Level

The actions within the first two rows Figure (Figure 2, 1*/2)* in the Roadmap are on a strategic level where NRAs and other stakeholders usually form agreements and strategies. The main pathway of the Roadmap is based on an "agree-first" approach. Generally, this means that stakeholders need to reach agreements first before a homogeneous implementation can happen. However, as this can prove rather difficult and cause delays in some areas, the IDS concept has been investigated by WP5 and 6. Therefore, although IDS is still in its early phases, actions exploring and moving this concept further have also been included in the Roadmap.

The first row (*1*) symbolises that a lot needs to happen on an overall level, where, in the best case, all European NRAs come together and agree on certain aspects within the process. Agreements on data needs and standards and the definition of the NRAs role are included on this level.

After the NRAs have defined their role and goals on their own, they will have to cooperate with other stakeholders and tackle certain aspects that are dependent on other actors. A vision and long-term strategy for CAD, for example, has to be developed with all stakeholders in order to achieve results.

Operational Level

Below the strategic level, the operational level (Figure 3, 2/2) considers actions that are focused on the implementation side. The first row within the operational level *(3)* includes actions that have to be taken by NRAs individually. The internal and organisational steps are especially important for an NRA to look at since these are the steps that are mostly their own responsibility like e.g. training their staff to acquire data analysis skills or employing experts in the field of Automated Driving.

The last row *(4)* then represents the operational actions that have to be taken in cooperation with other stakeholders as projects and testing sites, for example, will include OEMs in order to ensure seamless communication of the infrastructure with the vehicle.

Generally, the Roadmap can be read from top to bottom, so starting with the strategic and moving to the operational level. However, the reader has to keep in mind that there are also interconnections between the levels, as results of tests and projects will influence definitions of standards and strategies as well.

At the end of the Roadmap there is one row (*5*) which does not directly represent actions but rather identifies the primary stakeholders to cooperate with in respect to the three fields of actions. As already mentioned, as there are a lot of cross-cutting issues, interaction with other stakeholders is required.

4.2 Visualisation of the Roadmap

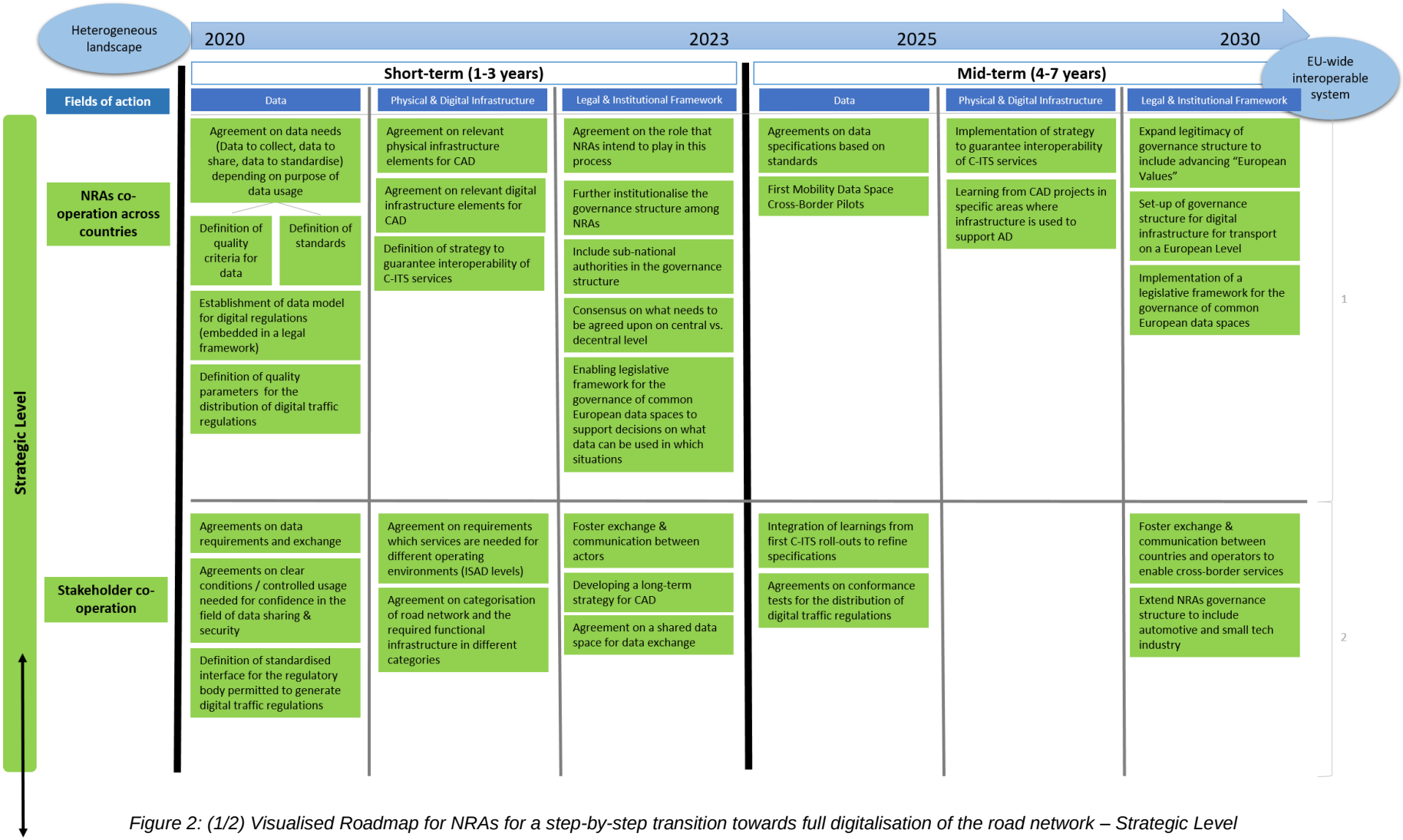

Figure 2: (1/2) Visualised Roadmap for NRAs for a step-by-step transition towards full digitalisation of the road network – Strategic Level

Heterogeneous landscape → EU-wide interoperable system

2020 — 2023 — 2025 — 2030

Operational Level

Fields of action	Short-term (1-3 years)			Mid-term (4-7 years)			
	Data	Physical & Digital Infrastructure	Legal & Institutional Framework	Data	Physical & Digital Infrastructure	Legal & Institutional Framework	
Internal & organisational steps of NRAs	Collection of static and dynamic data for integration into HD Maps Making Data available in agreed standards Developing competencies regarding data analysis	Digitisation of physical infrastructure elements for integration into HD Maps Start of implementation of C-ITS services	Trainings of staff to acquire skills in order to deal with data Employing experts or upskilling existing staff within area of digitalisation and automated driving (e.g. software developers) Identification of countries or/and industry agents that could provide insights and analysis of best practices	Implementation of standards Upgrade of existing data in accordance to data specifications Implementation of standardised interface for the regulatory body permitted to generate digital traffic regulations	Focus on infrastructure support services dedicated for CAD to facilitate traffic flow during transition period Introduction of appropriate C-ITS services on road network on a large scale	Adaption of organisational structure to fulfil technical requirements of CAD Set-up of governance structure for digital infrastructure for transport within the single member states Set up a monitoring facility to actively monitor regional and national infrastructures	3
Steps in interaction with stakeholders	Participation in pilots to refine data requirements Consideration of learnings from first (national) IDS pilots and initiation of further IDS Pilots	Making infrastructure-related data available to other stakeholders Preparing digital interfaces for engaging with digitalised systems in vehicles and Third parties Taking part in planning process of different testing sites to ensure comparability and replicability of results Establishment of communication infrastructure to ensure desired quality of service levels for different operating environments	Foster exchange & communication between actors Identification and monitoring of new technologies (e.g. MEC) and new combinations (MEC + 5G) Participation in research projects, testing, platforms,... for assessing technologies and collaborating with Third parties	Set-up of specifications to be used by all actors detailing the usage of standards Provision of data under non-discriminatory conditions to ensure smooth and cross-border data sharing Introduction of conformance tests for the distribution of digital traffic regulations		Foster exchange & communication between countries and operators to enable cross-border services Implementation of a shared data space for scalable data exchange Ensure commercial implementations in public-private collaborations (e.g. cities) are "IDS-ified".	4
Primary stakeholders to cooperate with	Data analysts (C-)ITS service providers MNOs OEMs	HD Map Providers (C-)ITS service providers Communication Network Providers/MNOs OEMs	National Governments EU Commission UNECE	OEMs Data aggregator	(C-)ITS service providers MNOs OEMs	National Governments EU Commission UNECE	5

Figure 3: (2/2) Visualised Roadmap for NRAs for a step-by-step transition towards full digitalisation of the road network – Operational Level and Primary Stakeholders

4.3 Description of the Roadmap

The starting point of our way towards full digitalisation of the road network is a complex heterogeneous landscape today. In the end we are striving for an EU-interoperable system. There are many goals and further actions for NRAs and other stakeholders along the way divided in short- and mid-term measures.

The focus of this Roadmap is to create a kind of checklist for NRAs to ensure digitalisation of the road network to achieve basic functionality of autonomous technology. The question of how and for which exact purpose Automated Driving can best be used has been the subject of other studies and continues to be explored.

Originally, it was planned to formulate a specific end-vision, to which the Roadmap leads, like a utopian scenario of the CAD fleet as a service or similar. Since this goal was discussed several times and no agreement for a final end-vision was achieved, the consortium decided to focus on a more overarching goal, a roadmap towards full digitalisation of the road network which can support NRAs to prepare their own strategies. As this aspect could not be completely solved, we recommend that an end-vision should be established in more detail in future projects. The need to create a joint vision in future should be highlighted in future work streams on this topic.

As already mentioned it has to be emphasised that automated driving is based on many objectives. For this reason this chapter also includes a short overview of the basic goals of CAD.

Overview of the goals of Cooperated and Automated Driving (CAD)

Automated vehicles could make roads safer, the primary goal of NRAs, as well as reduce congestion and could have a positive impact on the environment. An OECD report [OECD/ITF, 2015] based on car usage in Lisbon suggested that a city-wide driverless taxi service combined with high capacity public transport could reduce the number of cars on the roads by anything up to 90%. As well as leading to a reduction in the total number of cars, automated vehicles are expected to drive more efficiently and are also increasingly likely to be fitted with electric motors (due to their ability to dock and recharge themselves in between pick-ups), all of which should combine to lessen the amount of harmful emissions released into the environment [OECD/ITF, 2015].

In addition, providing more equitable access to mobility can be seen as an expected impact of automated mobility. But the pace of development has been slower than expected and therefore some level of infrastructure adaption might be needed in the next years if automated driving will become more and more reality.

NRAs and their role in CAD

Recently, the International Transport Forum at the OECD established a working group to deal with the topic "Preparing Transport Infrastructure for Autonomous Mobility". The Working Group seeks to reach agreement between different infrastructure providers on an international level, and with industry, about what the focus areas are for investing in infrastructure to support the introduction of autonomous travel. This working group was created since there is just little global consensus about how infrastructure providers can invest in making their networks ready for a new type of traffic.

In developing and describing necessary actions for NRAs, we initially followed a simple pathway with fundamental questions that need to be answered:

- Why? (What problem are we trying to solve?)
- Who? (Is cooperation with other stakeholders needed? who needs to be involved?)

- What is needed on infrastructure, data and legal/institutional level? (Details on infrastructure elements, data needs and quality, legislative framework and governance, etc.)

➔ **Actions & Measures (How to make this happen?)**

The detailed description of **actions & measures** towards full digitalisation of the road network will be described in the sections 4.3.1-4.3.3. As an early strategic action, research and definition of a guideline for what has minimally to be agreed upon on central (global, European) and what can be deferred to the decentral levels (national, regional), with respect to data, physical and digital infrastructure and organisation is needed.

4.3.1 Actions (short- and mid-term) in the field of data

The following section deals with the short- and mid-term measures in the area of data. Data can be seen as the binding element, to make use of physical and digital infrastructures in new ways [ITF, 2020]. But to be able to use this potential at full scale, an appropriate and well-functioning data infrastructure has to be established and guaranteed.

According to the agree-first principle, the first steps are always including agreements and definitions at a strategic level. Only after these first steps, further actions especially on the operational level can be taken.

Data needs

The results of WP4 of DIRIZON show a general broad acceptance of the data for CAD that the DIRIZON questionnaire suggested. These outcomes lead to the conclusion that an agreement on **data needs (Data to collect, data to share, data to standardise) depending on purpose of data usage** can be reached within the next 1-3 years.

First of all, it must be determined which data are required for full digitalisation of the road network. Based on the defined core topics we divided the different data types into the following general parts: Static (road) parameters and semi-static information as well as semi-dynamic and dynamic data. Static data includes especially road related data, e.g. road classification, maximum speed limits, HD lane model, permanent access restrictions as well as location of parking spaces. In contrast, information about the availability of parking spaces or charging points for electric vehicles belongs to the semi-static data category. Looking at the results of WP4, one can particularly see the importance of semi-dynamic and dynamic data when it comes to CAD. This category includes for instance information about road/lane/bridge closures as well as information related to events and conditions (e.g. road works, accidents, slippery road).

Although the data needs and requirements will be defined in the next 1-3 years and are already collected to a large extent, adjustments and updates are needed at the mid- and long-term level as well. In respect to the required data to reach full digitalisation of the road network, the involvement of relevant stakeholders like OEMs, MNOs or C-ITS service providers, is essential. Therefore, in order to get a broader picture and understanding of the data that is needed, **participation of NRAs in pilots to refine data requirements** is seen as essential.

Standards and Specifications

The agreement on data needs includes also the **definition of quality criteria for data** and **definition of standards**. Without a global consensus about what standards will apply, it becomes risky for any one infrastructure provider to invest heavily in upgrading their roads [ITF, 2020]. Unified standards are essential to reduce costs and improve the robustness of products and services. Therefore, it should be examined and clarified which quality criteria and standards have to be considered if full digitalisation of the road network is desired. In this respect, national road authorities across Europe should first clarify these questions before other stakeholders are involved at a strategic level. Summarised agreements on data needs could be seen as a basis for further decisions on data usage and implementation in regards to data exchange.

The definition of standards has already started and is an essential measure on a short-term level. Based on this decision within the next years, **agreements on data specifications based on the agreed standards** can be seen as a further step at a mid-term level. These data specifications refer to the underlying standards, but add the required profiling and additional specifications needed to actually turn them into specifications that allow implementation of interoperable services – in this context cooperation with ITS service providers is recommended. This can be seen as challenging, D5.1 concluded that European-wide specifications particularly for digital traffic regulations are difficult to create and continue to be hard to maintain [Lüpges et al., 2020].

For that reason, OEMs and infrastructure operators/NRAs have meanwhile reacted with first concrete, real-world deployments and by launching the required cooperation groups. In the C-Roads project, there is a step-by-step approach to develop specification profiles as standards can often be interpreted in multiple ways. Hence, the profiles serve as a more concrete and harmonised interpretation in order to make an application or service work across Europe. Approved and tested profiles are then published as C-Roads C-ITS Releases [Lüpges et al., 2020].

The objective of C-Roads is to advance the implementation of C-ITS on the TEN-T high-level road network, while working on the harmonisation of "Day 1 C-ITS services", encompassing messages about traffic jams, hazardous locations, road-works and slow or stationary vehicles, as well as weather information and speed advice to harmonise traffic, in the EU and supporting it through testing and validation. These developments in the field of C-ITS clearly show that the **integration of learnings from first C-ITS roll-outs to refine specifications** based on data analysis is one main recommendation for NRAs in cooperation with other stakeholders in the future.

After specifications based on standards have been refined, it is expected that in the next 4-7 years an **upgrade of existing data in accordance to data specifications** will be necessary. This step shows how interconnected the strategic and operational level are and how this is not a one-way street. It is clear that there must be certain agreements in place before the implementation stage, however, through testing and pilots, we gain a better understanding what is actually needed. This knowledge is then fed into agreements and standards on the strategic level. Therefore, we can see a loop where the strategic and operational level are connected and rely on each other.

Furthermore, there is a need for NRAs to cooperate with all other stakeholders at mid-term level with regard to data specifications and their implementation. This means that the involvement of all stakeholders is crucial if one thinks of the **set-up of specifications to be used by all actors detailing the usage of standards.**

Digital traffic regulations

An important step towards CAD is the **establishment of a data model for digital regulations**. A data model needs to be defined and must also be embedded in a legal framework. D4.1 summarises that the provision of a standardised framework is one of the most important tasks within the core topic METR that has been fully approved by all stakeholder groups [Radics et al., 2020]. This emphasises the need for even more efforts in the related standardisation groups (as CEN/TC 278 WG17). It has to be clear who is authorised to distribute digital traffic regulations and how this is done.

This action goes hand in hand with the evolution of Use Case 2 METR in WP3. D3.1 states that an interface **for the regulatory body permitted to generate digital traffic regulations must be defined and implemented**. By consequence, these steps were also included in the Roadmap.

Another action on the strategic level is the **definition of quality parameters for the distribution of digital traffic regulations**. Data on traffic regulations needs to be distributed in a consistent format, it must be complete etc. Therefore, certain quality parameters need to be defined and put in place.

In the medium-term, these quality parameters are used for conformance testing. Together with other stakeholders, **agreements on conformance tests for the distribution of digital traffic regulations** have to be put into place. Conformance testing (CT) is a test procedure that determines whether an implementation conforms to the specifications of a standard. It has to be ensured that all the essential information reaches the vehicle in the agreed format and is detailed enough to guarantee safety. On the operational level, the **introduction of conformance tests** is the follow-up action to the strategic planning.

Data sharing and exchange

As the essential and basic agreements regarding data needs including standards and specifications as well as digital regulations are already discussed in detail, the following section deals, in particular, with needed agreements in the field of data sharing. The next step is thus to clarify under what conditions data is collected and who is responsible for it. Ultimately, one of the most important questions is how data is used and shared among different stakeholders.

When it comes to data exchange, the involvement of necessary stakeholders is already at a strategic level and not only mandatory during the implementation stages. **Agreements on data requirements and exchange (concepts, interfaces and content)** can be evaluated as a needed measure on a short-term level. This is also accompanied by the following point regarding data sharing. As already mentioned above, **agreements on clear conditions / controlled usage needed for confidence in the field of data sharing & security** are needed across the borders of the NRAs in Europe. This includes decisions on data rights, data access, data usage, data liability, etc.

Moving towards implementation measures, clear agreements at the strategic level are needed. At the same time, it must be emphasised that there is always a correlation between the strategic level and the operational level. Once agreements on data needs and quality criteria for data as well as definitions of standards and data specifications have been established at a strategic level, steps of NRAs at an operational level have to be taken. At this operational level, recommendations for implementation steps are made und are directed at NRAs internally as well as NRAs in cooperation with other stakeholders.

In the field of data, we have identified the following main internal and organisational steps which have to be done within the structures of NRAs. Once a clear picture of the desired data types, data requirements and standards exists, a further step leads to data collection and data provision to other stakeholders.

Data collection and provision

One of the steps NRAs can take on their own at the short-term level is to start **collecting static and dynamic data for the integration into HD Maps**. In order to describe this task a little bit in detail and to break down to the essentials, we have to look at the use cases which were selected and presented in DIRIZON Deliverable D2.1. [Tucker et al., 2019]. As already mentioned in chapter 2.2, the use cases are building on top of each other, all within a High-Definition (HD) map. The base layer is the static data in the HD map. The distribution of digital traffic regulations adds traffic regulations in digital and machine-readable form.
Consequently, the task of NRAs in this context focus on collecting required data which is needed in a next step for integration into HD Maps which are often implemented from digital map providers.

In the field of data, it must be kept in mind that - as the results of WP4 show – regarding the availability of the data in machine-readable format as well as access conditions for data and information, huge differences between the different countries exist as well. In principle, it can be stated that making the relevant data available in machine-readable form must be one of the next steps towards full digitalisation of the road network. Therefore, besides agreeing on data needs and standards, one of the initial and most important steps is **making data available in agreed standards.** This step is essential because without the availability of this data in defined standards HD Maps cannot be developed and further infrastructure support for Cooperative Automated Driving is not possible. In cooperation with other stakeholders, NRAs are obliged to **provide data under non-discriminatory conditions to ensure smooth and cross-border data sharing.** This action is important to ensure interoperability of systems, as different systems have to be able to “understand” the data that is being sent.

Nevertheless, in order to be able to collect and provide data to others, NRAs also need to have the competencies to analyse these huge volumes of data themselves. **The development of competencies regarding data analysis** can be seen as a necessary prerequisite in the context of full digitalisation of the road network. Only if the NRAs prepare themselves for further developments and generate needed knowledge in the field of data handling and understanding, automated driving can be successfully implemented in the next years. It is the task of the NRAs to be prepared in time and engage appropriate data analysts. In addition to the involvement of data analysts, data aggregators will play an important role, especially at mid-term level when it comes to the provision of data.

IDS pilots

As already discussed above, the participation in pilots can generate extensive knowledge. One of the main challenges is to find a solution to consider the different national organisational structures. A transnational solution will not be easy to develop in this respect, but seems possible with the help of the IDS concept despite national system’s heterogeneity. DIRIZON Deliverable D5.1 has identified and evaluated corresponding options [Lüpges et al., 2020]. In this context NRAs should consider the **learnings from first (national) IDS pilots and initiate further IDS Pilots with appropriate content (PoC extension, CAD)** to properly identify the use cases in which IDS adds value and where it cannot. As the implementation of IDS concept would not rely on agreements in every aspect and would allow for national and local differences, the DIRIZON consortium sees this as a valuable solution that needs to be explored. The system shows a lot of flexibility and could prove to be a key to deal with certain problems during the process towards CAD.
However, as the concept of IDS is only its early stages in the mobility domain, the Roadmap is largely based on an already established “agree-first” model where strategic coordination is essential. In order to incorporate IDS, nonetheless, pilots and research in this direction are definitely in the NRAs’ interest.

Medium-term, the learnings from national pilots are due to be considered during the development of **first Mobility Data Space Cross-Border pilots**. These pilots should define the framework conditions for the Mobility Data Space. The German Mobility Data Space project has the aim to establish an open data space which, in addition to secure exchange, enables the development of real-time traffic data and sensitive mobility data, as well as networking existing data platforms. In this way, comprehensive mobility data could be made available on a (inter-)national level in the future with MDS.

4.3.2 Actions (short- and mid-term) in the field of Physical and Digital Infrastructure

While in lower vehicle automation levels, systems are expected to cope with existing road infrastructure, at higher level, autonomous mobility increases the complexity of the infrastructure required for a safe and efficient traffic flow. Therefore, connectivity, interoperability and reliability become more and more critical.

Physical and digital road infrastructure has to be upgraded, adapted and harmonised to make it suitable for automated driving [ACEA, 2019]. While the requirements for physical infrastructure is easily visualised, as we are confronted with it on a daily basis and see the roads, traffic signs and junctions, the requirements for digital infrastructure is harder to understand and less easy to visualise. It can be seen as the glue for collecting, combining, sharing and transmitting of data necessary for automated vehicles, transport management and other services [ITF Working group].

As we are moving towards SAE levels 4-5, the adaptation of physical infrastructure and its link with the digital infrastructure is becoming a key factor for the deployment of connected and automated vehicles [CARTRE, 2018].

The majority of what can be seen in the Roadmap are actions based on an agree-first approach. This means that there has to be cooperation on strategic level in order to agree on standards, necessary data and required actions first, before implementing these.

<u>Physical Infrastructure</u>

Short-term, in regards to **physical infrastructure**, NRAs from different countries have to **agree on relevant elements for CAD**. Physical infrastructure includes all elements that present the roadway to the Automated Driving System, e.g. roads, lanes and localisation landmarks. It needs to be agreed on what is relevant for first roll-outs and generally what is necessary for the deployment of Connected Automated Driving on a larger scale. When digitised, relevant physical infrastructure elements are an important part of the base layer in HD Maps. This layer contains static data like road shape, topological data and localisation landmarks and serves as the foundation on which semi-static, semi-dynamic and dynamic data is built on (see Figure 1).

After agreeing what the **relevant physical infrastructure elements** are, their **digitisation** is the following action each NRA has to achieve for their road network at the operational level. This must happen in accordance to existing standards in order to **make this infrastructure-related data available to other stakeholders**, e.g. HD Map Providers. D4.1 concluded that making sure that the relevant data can be provided in machine-readable format must be one of the first measures. 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.

D2.1 concludes that the NRAs see their role in infrastructure data provision with data being made available to private service providers, who use it for their own business. In other words, the NRAs provide the infrastructure and subsequently private industries can use infrastructure onto which to incorporate their products/services. In consequence, the data on digitised physical infrastructure can be made available to HD Map Providers or other stakeholders in order to be integrated into HD Maps [Tucker et al., 2019].

Digital Infrastructure

Another big part of the transition towards a full digitalisation of the road network is its digital infrastructure. Digital infrastructure includes the systems and networks that provide for connecting the roadway system to communications, and data. Digital infrastructure is therefore changing constantly with new technologies, nevertheless, **relevant digital infrastructure elements for CAD need to be agreed on**. This will be different for different road types, as for example motorways and urban streets are very different operating environments. For each road type, it needs to be defined what the digital infrastructure has to offer in order for NRAs to make CAD possible.

Since there will be different operating environments, there has to be an **agreement on the categorisation of the road network and the required functional infrastructure in different categories**. NRAs will need to determine, together with other stakeholders, what is feasible on the European road network. They have to decide what categories there will be and how the functional infrastructure will look like. NRAs will have to cooperate, for example with MNOs, and figure out where it makes sense to invest in digital infrastructure etc.

The categorisation of the road network also corresponds with services that must be provided in the different operating environments. Therefore, there must be **agreements on requirements which services are needed for different operating environments**. Different roads call for different services, so infrastructure must be equipped for services that shall be provided on different roads with different ISAD levels, Figure 4.

	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
Digital infrastructure	A	Cooperative driving	Based on the real-time information on vehicles movements, he infrastructure is able to guide AVs (groups of vehicles or single vehicles) in order to optimize the overall traffic flow	X	X	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	
	C	Dynamic digital information	All dynamic and static infrastructure information is available in digital form and can be provided to AVs	X	X		
Conventional infrastructure	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			
	E	Conventional infrastructure / no AV support	Conventional infrastructure without digital information. AVs need to recognise road geometry and road signs				

Figure 4: Levels of the Infrastructure Support for Automated Driving (ISAD Levels) [Carreras et al., 2018].

As there is a need for a certain level of **communication infrastructure in order to ensure a desired quality of services**, the infrastructure has to be defined for different operating environments. First, NRAs need to assess their road network and what desired quality of services should be provided on the road segments. Then, in cooperation with MNOs and communication infrastructure providers, they need to define what kind of infrastructure is feasible to invest in and how this can be achieved.

Ensuring interoperability

While agreements on the relevant elements of both physical and digital infrastructure are made on a strategic level, NRAs also should **define a strategy to guarantee interoperability of C-ITS services**.

The EU ITS Platform highlights the importance of ensuring "consistency and continuity within the network but also between networks, without many local particularities that would require special treatment, for things like road markings, signs, road surface quality, traffic management strategies and maintenance processes" [Courbon et al., 2016]. D4.1 concludes in its findings, that on balance, interoperability might be seen as the key if cross-border services should become more and more standard. In this context, it is important to emphasise that the general willingness to transfer knowledge and to cooperate between different stakeholder groups as well as countries is necessary in any case.

In simple words, interoperability means that different systems can interact with each other, they are able to communicate and share data with each other. The aim is that all different stakeholders can offer their services at the same time. However, this can only happen if they install systems that can "talk to" and "understand" each other. Therefore, there is a great need for cooperation and defined standards to make this possible.

In a paper of CE Delft and TNO, standardisation of technologies and procedures is considered a main way to help ensure high levels of interoperability and (cross-border) service continuity [CE Delft, TNO, 2020]. This also includes a set-up of specifications to be used by all actors detailing the usage of standards. Here a perfect example can be seen of how interconnected the different fields of action are, as everything plays together.

Since NRAs are seen as the harmonising element in the mix of all actors, it is in their interest to formulate a strategy to achieve interoperability. In the medium-term, the follow-up step is to then **implement the defined strategy to guarantee interoperability of C-ITS services**.

At the operational level, an important step in this direction is the **preparation of digital interfaces for engaging with digitalised systems in vehicles and Third parties**. In D2.1 the findings state that, 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 [Tucker et al., 2019].

Implementation of C-ITS services

Short-term, one of the crucial steps at the operational level is the **start of the implementation of C-ITS services**. The roads selected should provide a mix of all road types. It has to be mentioned that the outcomes of first implementations always feed into the strategic level, since there are important learnings that can be taken into account when defining strategies, relevant infrastructure elements and certain requirements.

In the next three years, it is expected to only achieve first roll-outs of C-ITS services, however, in the medium-term, **appropriate C-ITS services will be introduced on a larger scale**. Not only front-runners should be involved anymore, it will go beyond installing testing-sites and really move implementation to a larger scale. This leads to the internal operational step for NRAs to **focus on infrastructure support services dedicated for CAD to facilitate traffic flow during transition period**. The transition period is bound to be very challenging for NRAs since they need to facilitate both automated cars with different automation levels and conventional cars. Large-scale testing and validation of automated driving systems on open roads across the EU is vital to furthering their development and deployment [ACEA, 2019]. Therefore it is essential that NRAs are **taking part in the planning process of different testing sites.** In this context an early exchange of know-how with other actors will improve cross-border testing and **ensure comparability and replicability of results.**

Medium-term, **observations and learnings from CAD projects on specific areas like harbors, hubs etc**. will especially help to gain insights how **infrastructure can be used to support Automated Driving**. These learnings from projects with unique infrastructure will help better understand what infrastructure elements are needed and how results can be translated to the whole road network. Even though agreements on the essential elements of physical and digital infrastructure should be achieved already at the short-term level, this shows that the process must be dynamic and allow for learnings to be integrated later on. Therefore, while needing to set up agreements and definitions in the beginning in order to be able to move further, the road towards CAD also needs to be flexible.

D2.1 finds that NRAs will need to introduce appropriate C-ITS services on their road network to aid the relevant actors such as road users and OEMs to have a smooth transition from limited automated vehicles to fully automated vehicles operating on the network. If the automated vehicles are connected in the future, NRAs may be able to reduce the number of physical infrastructure elements it has to install such as gantries and road signs. Equally, NRAs will need to focus on infrastructure support services dedicated for CAD so as to facilitate the traffic flows during the transition period where both conventional and automated vehicles will exist on their road network [Tucker et al., 2019].

4.3.3 Actions (short- and mid-term) in the field of Legal & Institutional Framework

In order to enable the deployment of CAD on Europe's roads in the next years, it is essential to set up the right institutional and legal framework at the international, EU and national level. Legal and institutional infrastructure means a framework that allows the use of digitalised/automated technology which ultimately ensures that it can operate safely and effectively. This also includes all activities in respect to governance. The required framework has to be reviewed, adapted and harmonised in the future. For this purpose, e.g. ACEA recommended a list of legal frameworks which has to be considered. This list includes, inter alia, technical regulations, traffic rules and road infrastructure regulations, frameworks in regards to cybersecurity and liability as well [ACEA, 2019].

<u>Clarification of roles & responsibilities</u>

As the Roadmap reflects an NRA driven view on the transition towards full digitalisation, one of the first steps on a strategic level is an **agreement on the obligatory and optional roles that NRAs intend to play in this process.** Previous work has found that the roles and responsibilities of the NRAs and Stakeholders are partly unclear. For example, there are the uncertainties about who is responsible for data collection and, in consequence, the ownership of certain data. In D2.1, this was described as a major barrier seen by the interviewees as the lack of clarity on roles leaves all stakeholders confused to what they should or should not do at the short-term level [Tucker et al., 2019].

While NRAs should define their role on their own in the beginning and set goals of what they see themselves contributing in the area of Automated Driving, they should also keep in mind that the roles of various stakeholders involved often overlapping. The results of D4.1 showed that the allocation of roles of various stakeholders is still under debate which means that there must be some exchange and integration of other actors. As road operators/owners, NRAs are well positioned to ensure a constant dialogue and to bring stakeholders together.

In order to achieve a clear definition of the roles and responsibilities of the stakeholders, mutual trust is essential. Trust between main stakeholders can be strengthened by improving transparency and open communication [CE Delft, TNO, 2020]. The C-ITS security policy serves as a good example where the involvement of all relevant stakeholders has been successful. Securing the communication channels used is important to ensure a trustworthy and interoperable system. In order to steer the development of a common security and certificate policy multiple actors work together. Currently the C-ITS security governance system is running and first certificates are already distributed [C-ITS Platform, 2017].

Therefore, an open dialogue on mutual expectations as well as pilots should be organised. These steps fall under the overarching action of **fostering exchange and communication between the actors** at both strategic and operational level. In the future, the development of contractual arrangements with concrete agreements on roles and responsibilities might be helpful. Moreover, collaboration between **countries and operators** will gain importance in respect to enable **cross-border services**.

This required **exchange and cooperation between multiple actors** must be continued and intensified on an operational level in any case. On a mid-term level the **intensive involvement of operators and stakeholders abroad to implement transnational services** has to be added.

Governance Structure

The first recommendation in D6.1 proposes to **further institutionalise the governance structure among NRAs**. This can be achieved, by, for example, adopting a mission statement along the lines of the CAD-fleet-as-a-Service scenario, NRAs would agree on certain goals and a common vision which would help clarify their responsibilities. Institutionalising the governance structure basically means that processes and decision making regarding Automated Driving and Digitalisation need to be incorporated into the structured and formalised systems of NRAs.
This can be achieved by establishing a new or using an already existing governance body that really focuses on the role of NRAs in the European data landscape, and including the different issues concerning CAD. These issues would include for example, infrastructure, regulation, traffic and safety and digitisation and be looked at from an integral and strategic perspective. This body must have support from the highest levels of NRAs

Another recommendation at the short-term level is to **include sub-national authorities in the governance structure**. In order to leverage interest and relevance for data-exchange, sub-national authorities should be included in the governance structure. This has mutual benefits as national authorities would generally be more capable of organising and accumulating the perspectives of cities, municipalities and provinces by integrating them more in the process.

The exploration of the market driven scenario in WP6 revealed that automotive and tech companies are generally interested in servicing and collaborating in the urban domain. Therefore, at the medium-term level, it is recommended to **extend NRAs' governance structure to include the automotive and small tech industry**. It has been mentioned many times that cooperation is necessary for the achievement of CAD, therefore it only makes sense to integrate OEMs and digital parties in the process.

Another important step is the **set-up of a governance structure for digital infrastructure for transport on a European Level** which is also planned mid-term. It is essential to have a legal and institutional framework for the European digital infrastructure in order to implement C-ITS services throughout Europe. This set-up of a governance structure on the highest level of the EU will then go alongside the **implementation of a governance structure for digital infrastructure for transport within the single member states.**

Mid-term at the strategic level, the **legitimacy of NRAs governance structure should be expanded to include advancing "European Values**", e.g. data sovereignty. As the scope of a competitive European data landscape includes the mobility domain, which definitely includes the NRAs, and as the scope of data goes beyond safety, traffic regulation and infrastructure, the mandate for NRAs should include the data landscape. In this context the involvement of national ministries in support of the governing structure mentioned above is necessary.

Governance of IDS

Although the IDS concept is in its early stages, it raises the issue as to what **needs to be agreed upon at a centralised (agree-first principle) vs. decentralised (IDS approach) level**. To answer this question, a transnational consensus should be found among NRAs before taking the next steps.

As already explained in 4.3., the IDS concept is worth exploring and new pilots should be implemented following this paradigm for replicability and engrained data sovereignty. Mid-term, an action in this direction is to **ensure that commercial implementations in public-private collaborations (e.g. cities) are "IDS-ified"**. It is important that also local deployments become aligned in this principle, because these deployments play a part in the mobility data landscape and therefore have also to become interoperable, as well as they are currently part of the commercial arena in which OEMs and other services providers are hugely interested.

Common European data spaces

After vast discussion in the field of data collection and exchange (see chapter 4.3.1), the appropriate framework should be created as well. In the next 1-3 years, NRAs should join forces to **enable a legislative framework for the governance of common European data spaces to support decisions on what data can be used in which situations.** In this context, governments should support the basic principles to foster common European data spaces, e.g. with policy measures. This especially refers to the problems and risks regarding data ownership and security. It needs to be clarified which stakeholder is allowed to use different data for what purpose. Governance issues on collaboration for data sharing have to be resolved in a legislative framework.

As soon as a legislative framework for the governance of common European data spaces exist**,** there has to be **agreements on a shared data space for data exchange** with the involvement of other stakeholders. This could lead to the establishment of the role of National Access Points (NAPs). But in general, WP4 results show that there is still disagreement about the role of the NAP and their part within the process is pretty unclear. The outcome was that the NAP is a task of a national organisation/authority, like ministries or similar public organisations.

As the framework should already be defined in the next 1-3 years, NRAs will be responsible for the **implementation of the legislative framework for the governance of common European data spaces** in the mid-term. Regarding the expected time period, the same applies to the operational level. It can be assumed that the **implementation of a shared data space for scalable data exchange** is part of the mid-term strategy of the NRAs. Therefore, the involvement of the European commission could be helpful, since WP5 emphasises, 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).

Build-up of know-how

There are various ways policy makers and regulators can prepare for CAD. Some important preparatory steps include, such as for example, funding research and skilling staff in automated driving issues. In the field of data (see 4.3.1) it was already highlighted, that the development of competencies regarding data analysis can be seen as a necessary prerequisite in business area of NRAs. As part of the institutional framework towards full digitalisation, NRAs have to include **training/upskilling of staff to acquire skills in order to deal with data** in their internal and organisational steps. This should be done in parallel with **employing appropriate experts within the area of digitalisation and automated driving (e.g. software developers).**

Besides training of staff and recruiting experts, a regular market analysis in the field of CAD could provide insights in the field of CAD which in turn are crucial to strengthen the role of NRAs and to broaden their horizon. As a basis for the build-up of know-how, the **identification and monitoring of new technologies (e.g**. **Multi-access Edge Computing**, **short MEC) and new combinations (MEC + 5G)** should be fostered as internal and organisational steps of NRAs. MEC enables cloud computing capabilities and an IT service environment at the edge of the mobile network and, more in general at the edge of any network. The basic idea behind MEC is that by running applications and performing related processing tasks closer to the cellular customer, network congestion and latency is reduced and applications perform better.

Therefore, the **identification of countries or/and industry agents that could provide insights and the analysis of best practices** is essential. As basis for a successful transition towards full digitalisation, best practices from across a range of nations/industry on how to deal with fundamental issue in regards to CAD should be analysed by NRAs. In order to achieve positive results and benefit in the long term, the **set-up of a monitoring facility to actively monitor regional and national infrastructures** should be on the agenda of NRAs in the next 4-7 years.

If NRAs want to be in closer exchange with other stakeholders, **participation in research projects, testing, platforms** must be pushed forward. This will help **assessing technologies and collaborating with third parties**.

The build-up of know-how through research activities, more exchange between countries as well as training of staff and monitoring of trends/new technologies is the prerequisite when it comes to the implementation of the measures planned at strategic level. As the agreements should be ready in 1-3 years, the effective implementations will follow as next steps at the mid-term level. In consequence, the **adaption of an organisational structure to fulfil technical requirements of CAD** can be seen as an important internal step of NRAs.

4.4 Risks & Challenges on the way towards full digitalisation of the road network

In this chapter, the focus is on the risks and challenges NRAs potentially have to deal with. It mostly summarises the findings from WP2 and WP4 as they have dealt with identifying risks by doing interviews and a web-based questionnaire. It was first attempted to categorise the risks according to the three fields of action, however, as most challenges are overarching and come up in all categories, they are ordered in a similar way to D2.1 [Tucker et al., 2019].

Insufficient collaboration between actors

As already mentioned above, cooperation between different stakeholder groups is a key element in the successful implementation of Automated Driving. Cooperation is also necessary with regard to risks and challenges since lots of issues regarding privacy, security and responsibilities have to be solved. It becomes clear that no stakeholder group alone can tackle these problems, but that there needs to be a constant dialogue. There is a significant need for all actors to work together and discuss which kind of Digitalisation and Connectivity and Automated Driving strategy is required on the road network.

D2.1 summarises that this is not only a coordination issue, but all actors need to understand each other's needs and requirements. In some cases, NRAs do not know what data exists and what is needed, while OEMs are unwilling to reveal their future plans to other OEMs or NRAs. The relevant actors should be aware of the vehicles' ODD in order to develop the appropriate technology. In some cases, interviewees further noted that the data needs are unclear as vehicle manufacturers are not talking to the NRAs. Generally, it was observed that the relevant actors do not trust each other's information, hence reliability of data was identified as a barrier. Equally, this raises concerns about the quality of data that is collected and/or required which can also lead to problems regarding interoperability.

At present, there appears to be limited interaction between actors, and automated vehicle manufacturers are not always relaying their requirements to the NRAs. It was observed to a certain extent that OEMs are willing to work with each other however the technologies that are developed by OEMs are considered intellectual property and as such not shared openly. One organisation noted that while their government has already invested a significant amount of money in connected and autonomous vehicles, they argue that if collaboration with OEMs and other mobility providers does not exist, NRAs will never come to a solution in terms of Automated Driving even if the investment is infinite.

Financial barriers

When considering investment barriers, there are a number of issues to be addressed. One is the Level of financial support that is actually available for implementing the technologies (i.e. the initial investment costs). Secondly there are still questions over who is required to make the investment and thirdly, there is a question over where the investment needs to be made.

Furthermore, NRAs need to know what exactly they are investing in and how that investment can benefit their operations in advance of making it. The initial investment appears unclear at the moment. However, as operations will change significantly with the implementation of ITS services, it is also not clear what the ongoing investment will have to be.

There are still various issues to be resolved in relation to the communication technologies available. Vehicles should be connected, and they should also have a full coverage, low latency, high-speed reliable internet connection. This requires investments from the telecom sector. Therefore, it again comes down to cooperation between different actors.

Roles and responsibilities

The precise definition and allocation of roles and responsibilities to NRAs and relevant actors is still unclear. So, for example, in terms of data, there are still uncertainties as to who is responsible for collecting the data, and subsequently who owns the data and, for the most part, what data needs to be shared. This leads to the problem that NRAs want to make their staff ready for change and are aware that a skilled workforce is essential, however, at present it is unclear what skills are required.

Public Acceptance

Achieving public and social acceptability is considered a main barrier as ultimately public perception of the services that can arise out of a fully digitalised network will impact the users/customers journeys. At present, the majority of people do not necessarily trust automated vehicles, however, public trust in automated vehicles is essential to achieve full Automation on the road network.

Moreover, it is important to ensure that Automated Driving benefits society as a whole, and not just certain sections of society, such as for example, those who can afford to purchase automated vehicles.

Legal / regulatory issues

There are legal and regulatory questions that need to be resolved, such as for example who is liable in the case of misinformation, what changes are required in the traffic code? This as well includes organisational and governance issues on collaboration for data sharing.

Legal responsibility or liability issues are also identified as an area of uncertainty. For example, in the event of an accident involving an automated vehicle then the question arises as to where the responsibility lies – is it the responsibility of the driver, the manufacturer or possibly even the data provider.

These issues lead to the strong need for a legislative framework which was also included in the Roadmap.

Insufficient interoperability (both at national and EU level)

A lack of interoperability is strongly connected to a lack of cooperation, data issues as well as a missing institutional framework. Formalising and standardising data requirements, formats and exchange/sharing mechanisms, both at EU and National Level, is critical to realise the full benefits of Automated Driving.

Linked to a lack of European interoperability, the lack of a common traffic management strategy is also considered a barrier. In one case it was noted that the development of one single traffic management strategy is critical in this topic, otherwise different strategies could lead to chaotic traffic flows and/ or unsafe situations on the road network.

Technical issues

Generally, there are still challenges to overcome in terms of technology and reliability, particularly when it comes to creating fully automated vehicles that can carry out complete door-to-door journeys in all driving scenarios. Even when the technology is deemed ready, there may still be potential legal hurdles as well as questions over insurance liability, cyber-security and public acceptance [HumanDrive, 2019].

D2.1 summarises that technology needs to be validated and tested in a real environment. Moreover, there are various opinions on the extent of technical barriers, which can largely be explained by the various Levels of current Digitalisation within each organisation (and country). As different organisations and countries are at different stages of implementation and testing of technologies, interoperability becomes an issue.

Answers from the D4.1 questionnaire also mention that older technology might not be able to cope with large HD Map data, for example. This is especially challenging since there will be all kinds of vehicles on the road network during the transition phase.

Data issues

In regards to data, one of the conclusions of D2.1 notes that harmonisation of data in a standard format is required, but the question is how to deal with large volumes of data. Moreover, resolution of issues related to cybersecurity is a concern, particularly in relation to data protection and data privacy which requires resolution of legal, regulatory, ethics and social acceptability issues.

Answers from the questionnaire in D4.1 also see privacy and security of data as main challenges. Data must be anonymous and the users must have the choice of not opting in. In relation to HD Maps, HD Map Providers have the task to ensure privacy of the user in line with relevant standards. The backend system should not get the position information of a user. The need for data standards has to be highlighted and the compliance with standards has to be ensured.

It is important to add that latency issues are also to be focused on in the field of data. This goes hand in hand with the problem of huge volumes of data, as some safety critical features may suffer if too much data is being sent. In regards to traffic data, the problem of “Limited accuracy as not all vehicles/nodes have the same level of localisation accuracy” has to be considered as well.

When it comes to the distribution of digital traffic regulations, D4.1 summarises that major challenges in respect to METR are concerning GDPR aspects and IP protection. A general “information security control” will be even more in the focus when we talk about cross-border aspects. Experts see a risk of sharing too much data, so the challenge is to inly share what is necessary.

There is the challenge of securing that the data provided to autonomous vehicle is not manipulated, as well as privacy issues (especially related to probe data). This is also mentioned in regards to ISAD where concerns about hacking are raised. Sharing among non-EU countries may also raise legal restrictions.

5 Summary and main Takeaways

The following section provides a summary of the key findings of D7.1. This chapter includes an overview of the main recommendations for NRAs towards full digitalisation of the road network. The takeaways are primarily based on the three identified fields of action (Data, Physical and Digital Infrastructure, Legal and Institutional Framework).

Summarising all the given recommendations within the Roadmap, we can conclude the following on an overall level:

- The actions and measures should lead to an EU interoperable system for CAD. The Roadmap can also be seen as a checklist for NRAs including steps the NRAs need to undertake to achieve full digitalisation of the road network and ensure basic functionality of autonomous technology.
- In the future, it is recommended that a specific end-vision compared to the more overarching goal of “full digitalisation of road network” should be established with the involvement of all stakeholders. Based on created joint vision, more detailed actions could evolve in the future.
- Therefore, the need for ecosystem collaborations on the different levels can be highlighted.
- Due to the difficulty of developments at the long-term level, the focus was on actions at short and mid-term level.
- Measures were divided into strategic and operational level.
- Early decisions need to be made on what has to be agreed on a central (global) level and what can be postponed to a decentral (national) level.

The following can be concluded on the field of data:

- Agreement on data needs depending on purpose of data usage on short-term level is required so that NRAs can start collecting static and dynamic data for the integration into HD Maps at the short-term level.
- Equally, NRAs in Europe should elaborate consensus about required quality criteria for data and definition of standards.
- Agreements on data specifications on agreed standards will follow at the mid-term level although it is challenging to commit on European-wide specifications. Thereby learnings from first C-ITS roll-outs in Europe can help to refine specifications.
- As already mentioned in previous WPs of DIRIZON, digital traffic regulations (METR) have to be considered in the context of CAD. Starting with the establishment of a data model and the definition and implementation of an interface for the regulatory body for METR. In parallel, definitions of quality parameters for the distribution of digital traffic regulations are needed, also with regard to conformance tests.
- In addition to the collection of required data as basis for CAD, all WPs of DIRIZON have shown that the provision of data in machine-readable format and agreed standards is essential.
- Besides Agreements on data requirements and exchange, agreements on clear conditions / controlled usage needed for confidence in the field of data sharing & security are needed across the borders of the NRAs in Europe. Summarised, NRAs are obliged to provide data under non-discriminatory conditions to ensure smooth and cross-border data sharing. Considerations of learnings from first MDS pilots may be an important basis in this context.

- Overall, however, partly all recommended actions can only work, if competences regarding data analysis are built up. It is becoming increasingly important that NRAs prepare themselves for further developments and generate needed knowledge in the field of data handling and understanding.

The following can be concluded on the field of Physical and Digital Infrastructure

- One of the first steps has to be the agreement on relevant physical infrastructure elements and their following digitisation as static infrastructure makes up a big part of the base layer of HD Maps. The goal is to share data that has been collected and digitised in machine-readable format and to make it available to other stakeholder under non-discriminatory conditions.
- 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, a categorisation of the road network as well as the required functional infrastructure in each category have to be agreed on.
- Since all systems need to able to communicate with each other, another important action is to define and implement a strategy to guarantee interoperability of C-ITS services. There is a great need for cooperation and defined standards to make this possible.
- Short-term, it is essential to start the implementation of C-ITS services, through first local roll-outs and installing testing sites. After that, appropriate C-ITS services will be introduced on a larger scale.
- NRAs 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.

The following can be concluded on the field of Legal and Institutional Framework:

- One of the first steps has to be the agreement on the role that NRAs intend to play in the process towards full digitalisation. Short-term, it is essential to eliminate lack of clarity on roles. Therefore, exchange and communication between multiple stakeholder groups must be fostered. In this case, NRAs are well positioned to ensure a constant dialogue and to bring stakeholders together.
- Short-term, it is recommended to further institutionalise the governance structure among NRAs. As already described at a higher level, the establishment of a common vision is essential.
- Besides the increased involvement of automotive and small tech industry, sub-national authorities should play an essential role. With the participation of sub-national authorities, the perspectives of cities, municipalities and provinces can be increasingly covered.
- As it is essential to have a legal and institutional framework for the European digital infrastructure, a corresponding implementation of the governance structure in the single member states is recommended at mid-term.

- The same applies to the establishment of a legislative framework of common European data spaces. This leads to enhanced involvement of governments, which has to support basic principles regarding shared data spaces for data exchange, e.g. with policy measures. In this context, clarity on the implementation of the NAP should be ensured.
- To generate common frameworks and agreements, the exchange and cooperation between multiple actors must be continued and strengthened. In addition, the intensive involvement of operators and other stakeholders abroad is needed to implement cross-border services.
- Another preparatory step for full digitalisation of the road network is in the field of know-how development. On the one hand, NRAs have to include training of staff to acquire skills in order to deal with data and on the other hand they have to broaden their horizon by identifying and monitoring new technologies. It is recommended to look beyond borders and other branches of industry by analysing best practices and collecting crucial insights on how to deal with fundamental issued in regards to CAD.
- In addition, participation in research projects, testing, platforms must be pushed forward.

Summarising on expected risks and challenges the following can be stated:

- Collaboration is the key in almost all areas, no stakeholder group alone can tackle the current problems. There needs to be a constant dialogue.
- There are a number of issues regarding investment since the questions of how much the initial investment costs are, who is required to make the investment and where the investment needs to be made are all unclear.
- The precise definition and allocation of roles and responsibilities to NRAs and relevant actors is still not clarified. NRAs want to make their staff ready, but do not currently know what will fall under their responsibility and what other stakeholders will be responsible for.
- Achieving public and social acceptability is considered a main barrier as ultimately public perception of the services that can arise out of a fully digitalised network will impact the users/customers journeys.
- There are lots of legal and regulatory questions that need to be resolved that call for a clear legislative framework. This as well includes organisational and governance issues on collaboration for data sharing.
- A lack of interoperability is strongly connected to a lack of cooperation, data issues as well as a missing institutional framework. Formalising and standardising data requirements, formats and exchange/sharing mechanisms, both at EU and National Level, are essential to overcome current insufficient interoperability issues.
- There are various opinions on the extent of technical barriers, which can largely be explained by the various levels of current digitalisation within each organisation (and country). As different organisations and countries are at different stages of implementation and testing of technologies, interoperability becomes an issue. Older technology might not be able to cope with new technologies, e.g. large HD Map data. This is especially challenging since there will be all kinds of vehicles on the road network during the transition phase
- In the field of data, harmonisation in a standardised format as well as preparing systems for dealing with large volumes of data are important. There is the challenge of securing that the data provided to an autonomous vehicle is not manipulated, as well as privacy issues (especially related to probe data).

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