DIRIZON

NRAs and Digitalisation

Deliverable D2.1

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Deliverable D2.1 – NRAs and Digitalisation

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Author(s) this deliverable:

Mark Tucker, Emmanouil Kakouris, ROD-IS, Ireland

Max Schreuder, Kerry Malone, TNO, Netherlands

Katharina Helfert, AustriaTech, Austria

Christian Lüpges, Albrecht Consult, Germany

Christian Kleine, HERE, Germany

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Executive summary

The Digitalisation of road networks and the rapid developments in Automated Driving will affect the core activities that National Road Authorities (NRAs) carry out, offer new business opportunities and provide NRAs with new and more efficient ways to achieve goals for road safety, traffic efficiency, the environment and customer service. To assist the NRAs in moving towards the Digitalisation of their road networks and Automated Driving, the DIRIZON project's goal is to support NRAs in identifying how these developments will affect their operations and their interaction with other actors.

However, a detailed investigation on the current status of European NRAs within this area is lacking. Hence, the ultimate objective of this deliverable is to identify, not only their current Level of Digitalisation and Automated Driving but also to explore their future plans. To this end, a three-stage methodology, presented in this deliverable, is proposed, namely undertaking a literature review, conducting interviews with representatives from relevant actors 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. The literature review provides an overview of the projects, the location of the pilot tests and services covered and standards/regulations.

The interviews were conducted with representatives from NRA's, Ministries' and Road Operators both from CEDR funding countries and Non-CEDR funding countries. The goal of the interviews is to obtain general information regarding issues such as the current & future status of Digitalisation & Automation, their policies, and their views on benefits and barriers. In addition to analysing the output from the interview questions, the background of the organisations interviewed in respect of Digitalisation and Automated Driving is presented.

The output of both these stages is subsequently used, in conjunction with input from the CEDR CAD WG, to select three Use Cases specific to the areas of Digitalisation and Automated Driving.

The key findings from both the literature review and interviews are identified and described and conclusions drawn based on these findings.

It is noted that the current Levels of Digitalisation and Automated Driving varies between countries, and different countries are at different stages of deployment and implementation. This is reflected in organisations participation in previous, ongoing and planned research projects and platforms. However, while there are numerous C-ITS pilot projects ongoing and planned the same cannot be said in respect of Automation/Automated Driving. Participation in projects and platforms is seen as critical, not only for validating the technologies and services developed but also to develop collaborations with Third parties and provide confidence to the public (i.e. the user) that these technologies and services can have a positive impact on traffic flow and safety.

In terms of the future outlook, Digitalisation is more defined through relevant action plans, which are generally not in place in respect of Automated Driving.

The main barriers or risks to achieving full Digitalisation of the road network and Automated Driving, are for the most part identified as being similar and include; financial barriers; a lack of clarity on roles and responsibilities; legal/regulatory issues; insufficient collaboration between actors; data issues (privacy, cybersecurity, sharing etc.); insufficient interoperability, both at national and European Level; technical issues and public acceptability. Specific aspects of these barriers and risks include;

Financial: While the need for investment is clear, the amount of investment required is still unclear both for the initial investment and operation costs.

Roles and Responsibilities: These are largely unclear at present though the organisations interviewed do have a view on where they see their primary role.

Legal/Regulatory issues: Legislation and/or legislative frameworks are required to address items such as liability, data privacy, data ownership and data sharing, to name a few.

Insufficient Collaboration between actors: Without collaboration, inconsistent information could be provided to users, which can lead to unsafe traffic conditions.

Data Issues: Harmonisation of the data in a standard format and putting in place legislative frameworks is required for all aspects of data. Equally how to deal with large volumes of data will need to be addressed.

Insufficient interoperability: Formalising and standardising data requirements, formats and exchange/sharing mechanisms, a both an EU and National Level, is critical to realise the full benefits of Automated Driving

Technical Issues: The technology needs to be validated and tested in a real environment.

Public Acceptability: Without public acceptability of the technology and services developed, implementation will be difficult.

Typically, it is acknowledged that the risks can be minimised, and barriers addressed through participation in research projects, and platforms. It is also noted that the NRA’s are not necessarily responsible for eliminating all barriers and risks – Government has a key role to play in this regard in developing the legal frameworks, ethics standards, insurance regulations etc.

Digitalisation and Automated Driving will invariably change how NRA’s operate, and notwithstanding the associated barriers and risks, it is expected that their implementation will significantly improve how NRA’s operate and manage their networks thus providing NRA’s with the tools to impact traffic safety positively. Equally, their implementation could see a reduction in NRA’s costs by eliminating the need to collect data and construct hard infrastructure (i.e. gantries etc.).

Project information

Project title	advanced options for authorities in light of Automation and **DI**gitalisation ho**RIZON** 2040.		
Acronym - Logo			
CEDR **Topics addressed**	CEDR Call 2017: Automation: ☐ A. How will Automation change the core business of NRA's? ☒ B. What new options do NRAs have from Digitalisation and Automation? ☐ C. Practical learnings for NRAs from test sites.		
Project Coordinator	Max Schreuder TNO	**Email**	Max.schreuder@tno.nl
Address	The Hague - New Babylon Netherlands	**Tel.**	+31 (0) 88 866 32 79
Partners	TNO	**Country**	NL
	Roughan & O'Donovan Innovative Solutions (ROD-IS)		IRL
	Albrecht Consult		DE
	AustriaTech		AT
	HERE (Associated Partner)		DE
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Abbreviations

Abbreviation	Full Title
AADT	Annual Average Daily Traffic
ADS	Automated Driving System
AUTOPILOT	Automated Driving Progressed by Internet Of Things
CAD	Connected and Automated Driving
CAM	Continuous Awareness Message
CAV	Connected Autonomous Vehicles
CCAM	Connected and Cooperative Automated Mobility
CCTV	Closed-Circuit Television
C-ITS	Cooperative Intelligent Transport Systems
CEN/TC	European Committee for Standardization/ Technical Committee
C-Roads	Cooperative Roads
DAB	Digital Audio Broadcasting
DENM	Dedicated Environmental Notification Message
DMB	Digital Multimedia Broadcasting
DDT	Dynamic Driving Task
Drive C2X	DRIVing implementation and Evaluation of C2X communication technology in EuropeAutomated Driving
DSRC	Dedicated Short Range Communications message set dictionary
ECo-AT	European Corridor – Austrian Testbed for Cooperative Systems
eIDAS	electronic IDentification, Authentication and trust Services
ENISA	European Union Agency for Network and Information Security
euroFOT	European Field Operational Test
GIS	Geographic Information System
HD	High-Definition
ICT	Information and Communications Technology
INFRAMIX	Preparing road infrastructure for mixed vehicle traffic flows
IoT	Internet Of Things
IT	Information Technology

Abbreviation	Full Title
ITS	Intelligent Transportation System
LCS	Lane Control Sign
LIDAR	Light Detection and Ranging
InterCor	Interoperable Corridors
MaaS	Mobility As a Service
METR	Management for Electronic Traffic Regulations
NIS	Network and Information Security regulation
NCAP	The European New Car Assessment Programme
NRA	National Road Authority
ODD	Operational Design Domain
OEDR	Object and Event Detection and Response
OEMs	Original Equipment Manufacturer
PKI	Public Key Infrastructures
PDRM	Probe Data Reporting Management
PRT	Personal Rapid Transit
SAE	Society of Automation Engineers
SRTI	Safety Related Traffic Information
RDS-TMC	Radio Data System Traffic Message Channel
TeleFOT	Field Operational Tests of Aftermarket and Nomadic Devices in Vehicles
TEN-T	Trans-European Transport Network
TPEG	Transport Protocol Experts Group
VMS	Variable Message Signs
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
WG	Working Group
WP	Work Package

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 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 DDT 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 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 DDT on a sustained basis; this term is used generically to describe any system capable of Level 1-5 driving Automation (SAE J3016 June 2018)
DYNAMIC DRIVING	All of the real-time operational and tactical functions required to operate a vehicle in on-road traffic, excluding the strategic functions

Term	Definition
TASK	such as trip scheduling and selection of destinations and waypoints (SAE J3016 June 2018)
EVERYTHING	Vehicles, infrastructure and users (i.e. the public).
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 and roadside equipment.
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	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	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	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

The CEDR Transnational Research Programme was launched by the Conference of European Directors of Roads (CEDR). CEDR is the Road Directors' platform for cooperation and promotion of improvements to the road system and its infrastructure, as an integral part of a sustainable transport system in Europe. Its members represent their respective National Road Authorities (NRAs) or equivalents and provide support and advice on decisions concerning the road transport system that are taken at national or international Level.

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

1.1 The Research Need

Digitalised data facilitates new activities on road networks and changes the way these activities are carried out. Behind these activities, data plays a key role and enables the Connectivity needed to improve efficiencies in managing, maintaining and operating the road network. Equally Digitalisation, along with Connectivity, are the crucial prerequisites to enable Automated Driving.

NRAs are already working on Digitalisation and Connectivity as enablers for improved services of the future, especially when it comes to the topic of Automated Driving. This will affect the core activities that NRAs carry out, offer new (business) opportunities and provide new and more efficient ways to enhance road safety, traffic efficiency, the environment and customer services. Equally, Digitalisation and the opportunity to extend data exchange mechanics via, for example, cloud services, will be the basis for the forthcoming development of connected and Automated Driving on European roads.

These developments will ultimately, change the way NRAs will interact with their existing actors but also will lead to new opportunities with new ones. The roles and responsibilities of both NRAs and other relevant actors will change from the transition to full Digitalisation of road infrastructure. Equally, when considering Automated Driving, cooperation between the relevant actors will change and the roles and responsibilities will need to be defined considering the challenges ahead. However, what exactly are these challenges? What changes are on the horizon and how can the road authorities deal with these changes? Where do they need to invest? Where do they need to start new types of cooperation? These are all questions that are only partly answered by the existing literature and will be investigated in detail within this project. It is envisaged that there will be a growth of C-ITS services in the future and this will encourage industries such as, for example, the automotive industries and the communication service providers, to further investment in these areas.

In the past, various platforms and research projects were introduced in the realm of Digitalisation and the topic of Connectivity throughout Europe. To overcome fragmentation, when it comes to the deployment of C-ITS services, in 2016 the C-Roads Platform was launched. The aim of C-Roads is to harmonise the deployment of interoperable C-ITS services based on tested and proven communication technologies, which are ITS-G5 and 3G/4G cellular networks. The so-called Day-1-C-ITS services are laid down in several communications from the European Commission such as, for example, the results of the C-ITS Platform and the EU Strategy on the deployment of connected and cooperative automated mobility services. To reach that goal of interoperable C-ITS service deployment, several European pilot projects are piloting C-ITS services.

Even though C-ITS services are about to be deployed based on harmonised specifications it is important to note that they are only one element to making Automated Driving a reality. Major elements of the digital and physical infrastructure, including, among others, data access and data storage, HD maps and physical landmarks, are not harmonised. Implemented test systems for Automated Driving vary across different European countries and as a result, Europe is not homogeneous in these areas. Equally, heterogeneousness on automated tests can exist in the same country.

DIRIZON seeks to address these issues and questions. Through exploring the current and expected status of Digitalisation and Automated Driving in European countries the project aims to not only take a deeper look at the challenges faced but also to assess the NRA's roles and responsibilities which will be assessed in the context of the analysed Use Cases within the project.

1.2 The DIRIZON research project

The overall objective of the DIRIZON research project is to provide a concept for a technical data-exchange platform, with corresponding business models for its exploitation, in light of the step-by-step Digitalisation of NRAs' road assets and current and future relationships with relevant actors.

This objective will be achieved through a set of Work Packages (WPs) as described in *Figure 1.1* below.

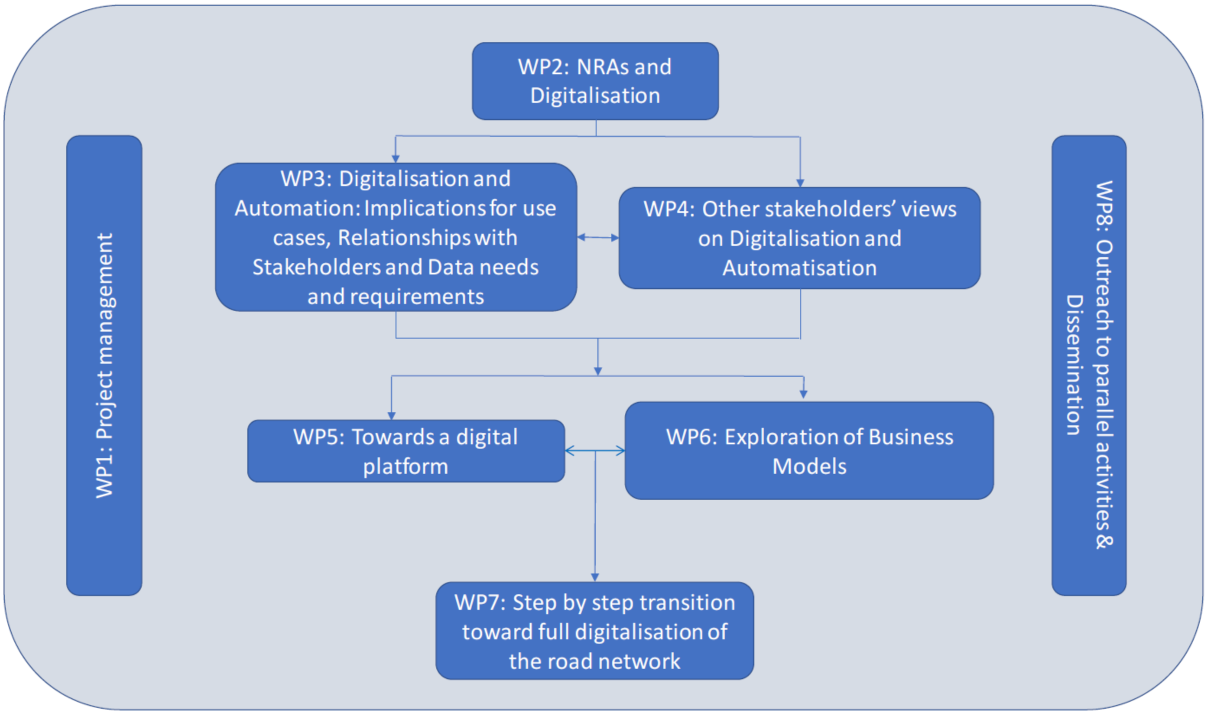

Figure 1.1 DIRIZON work package structure.

In total, eight WPs have been defined to meet the objectives of the project. As NRAs move towards Digitalisation of their infrastructure assets, operations and Automated Driving, it is essential to not only understand how Digitalisation and Automation will impact the management of their assets in the future, but also to understand current Levels of Digitalisation and what is needed to enable Automated Driving on the existing road networks such as, for example, the investment required, new collaborations and new types of services offered. This will enable a baseline from which a seamless transformational change to Digitalisation and Automated Driving can take place. As such, the focus of WP2 is to define Digitalisation and Automated Driving in the context of NRAs' current and future operations and assess which assets require Digitalisation and identify not only the roles and responsibilities, both technical and regulatory of NRAs, but also relevant actors. Finally, within WP2, three Use Cases particularly affected by Digitalisation and Automated Driving deployment, are proposed based on the output of the literature review, interviews and a multi-criteria selection process; the latter which received input from the CEDR CAD working group.

Using the Use Cases selected in WP2, WP3 will map the actors including the relationships and how this field can evolve, and determine the data issues, data requirements and new opportunities for each Use Case. In WP3, the data requirements, its quality, and potential sources will be analysed. WP4 aims to discuss actors‘ roles within the Use Cases with other actors than NRAs and identify the congruent and conflicting views in the present and future with respect to data exchange.

WP5 will focus on a growing technical cooperation between NRAs, service providers and OEMs. To define such a data-exchange platform (or integrated platforms) it is assumed that appropriate backends e.g. already existing systems platforms or clouds of different stakeholders have to be connected in order to maximise the benefit.

WP5 and WP6 will run in parallel. WP6 will derive requirements, strategic considerations and propose business model options for NRAs to exploit a data-exchange platform. Business model scenarios will be developed for each Use Case that promise additional benefit through cooperation. The analysis will determine which business model scenarios score high on compatibility and consistency, and draw conclusions, and provide input to WP7. WP1 and WP8 consist of the project management and engagement with parallel initiatives, respectively.

DIRIZON will provide a number of benefits for NRAs and relevant actors. It is building on knowledge and expertise within NRAs for bi-lateral and multi-lateral discussions with key actors on the topic of data-exchange and Automated Driving. It will determine, based on an in-depth analysis of data needs, the requirements and actors' interaction of the three selected Use Cases. The Third parties' view on Digitalisation and Automated Driving on the selected Use Cases will be clarified and a technical data-exchange platform concept for these different Use Cases (between NRAs and relevant actors) will be provided. The new business models that will emerge will be explored while a step-by-step implementation of Digitalisation by NRAs will be proposed.

2 Objectives of WP2: NRAs and Digitalisation

WP2 is undertaken to provide the DIRIZON consortium with an understanding of the current and expected Level of Digitalisation and Automated Driving across Europe. It allows gaps to be identified and recommendations to be made for the step-by-step transition toward full Digitalisation and Automation of the NRAs road networks. To this end, the following research objectives are met:

1. Definition of Digitalisation and Automated Driving within the scope of the DIRIZON research project.
2. Establishment of what NRA assets and operations are currently digitalised, and what Digitalisation is required to facilitate Automated Driving.
3. Identification of fundamental roles and responsibilities of NRAs and private actors regarding the Digitalisation of their assets.
4. Assessment of current policies and regulations in place and how these may be required to change.
5. Identification of key areas of operation of NRAs in respect of Automated Driving and Digitalisation which will subsequently form the basis for the selection of Use Cases for further assessment in WP3 and WP4.

The aforementioned research objectives were accomplished by conducting an extensive literature review within this topic in combination with appropriate interviews.

It should be noted that in regard to Item 2 above, the conclusions drawn are limited to those countries from which representatives are interviewed.

3 Methodology

The research objectives introduced in Section 2 were accomplished using the methodology illustrated in Figure 3.1.

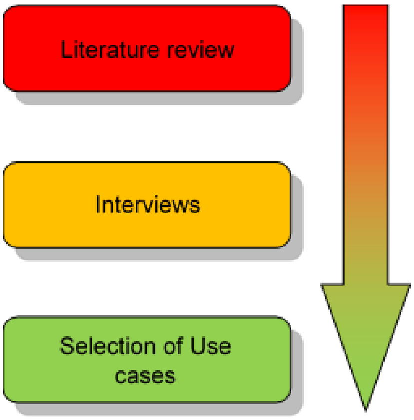

Figure 3.1 WP2 research methodology

The methodology is divided into three main stages, namely; A literature review, a series of interviews and the selection of the Use Cases.

In the first stage, a detailed literature review is carried out to identify the gaps, barriers and risks in order to achieve full Digitalisation and Automation of the NRAs' road network. Then, in the second stage a set of interviews is conducted with both representatives from organisations on the Programme Executive Board (PEB), including NRA's, and other CEDR non funding country organisations. Considering the outcomes of both the literature review and the interview results, three Use Cases are selected in stage three based on carefully selected criteria. Although, three stages are defined, it should be noted that there was an overlap between the stages. Equally, In selecting the Use Cases, input was received from the CEDR Connected Automated Driving Working Group (CAD WG).

3.1 Literature review

A detailed literature review is performed to investigate the current and expected Level of Digitalisation and Automation on NRAs' road networks and the needs, challenges, barriers and expectations regarding Automated Driving, using pre-existing literature reviews and publications from both prior CEDR projects and other European research projects and platforms relevant to this topic. In Section 4.3, Literature Review Key Findings, the most notable past research projects and platforms are introduced within the topics that build the basis for the upcoming challenges for the future. These include, such as for example, areas of interoperability and Connectivity, C-ITS, traffic management, travel and traffic information, data exchange mechanisms, infrastructure support services for CAD and Automated Driving services. Ongoing research projects and platforms are also presented to facilitate understanding of the current status within this area.

The past research projects presented include a brief description of the projects' objectives, details of the locations of the pilots' tests and the services covered. Furthermore, the identified impacts, barriers, risks and uncertainties are also presented and discussed. Existing policies, regulations and standards developed within these projects are also listed.

3.2 Interviews

3.2.1. Introduction

A key activity within the DIRIZON project is to conduct a series of interviews with PEB members and relevant actors. The interview questions, Appendix A, were developed, using the outcomes of the literature review and consortium partners expertise and knowledge. The aim of the interviews is to assess the roles, responsibilities and requirements of, predominantly NRA's and actors in relation to Digitalisation and Automated Driving on the road infrastructure.

To this end, the interviews are divided into two phases, Phase 1 and Phase 2. Phase 1 interviews focused mainly on organisations responsible for managing and operating national road networks, predominantly NRA's, with a view to obtaining general information regarding issues such as the current & future status of Digitalisation & Automation, their policies, and their views on benefits and barriers. In this set of interviews, representatives were interviewed using a list of general questions in order to prepare the groundwork for the further work within DIRIZON and to derive some general conclusions. These interviews are conducted within WP2.

After the proper definition of the Use Cases, Section 4.6, in order to align the information collected from the Phase 1 interviews, Phase 2 interviews will consider Use Case specific NRA & actor interviews focusing on specifics such as, data availability, sharing and privacy. These interviews are to be conducted as part of WP4.

3.2.2. Interview Questions

The interview questions were formulated considering the literature review findings as presented in Section 4.3 and input from the consortium partners. The interview process was considered a semi-structured process, allowing for interaction/discussion between the interviewers and the interviewees and was scheduled to last no more than 1.5 hours.

The interview questions were circulated to the interviewees in advance of the interview along with a short introduction to the DIRIZON research project, its research objectives, interview guidelines and relevant definitions (Digitalisation, Automated Driving etc.).

The initial questions focused on gathering general information about the background of the organisations and interviewees in respect of Digitalisation and Automated Driving. Subsequently, more specific questions related to the current Levels of Digitalisation and Automated Driving are posed, including questions related to issues such as for example, current barriers, risks, roles and responsibilities. Finally, questions are posed on similar issues relating to the future of Digitalisation and Automated Driving.

3.2.3. Interviewees

3.2.3.1. Introduction

In Phase 1, representatives from NRAs, research institutes, road operators and Ministries of Transport are interviewed as shown in Table 3.1. The interviewees predominantly represented those from the CEDR Automation call Funding Countries, however additional relevant actors from non-funding countries are also interviewed. The experience and background of the interviewees covers a wide range of areas such as connected mobility, road design and standardisation, traffic management and traffic information, C-ITS technology, connected vehicles and Automated Driving.

The interviews were conducted either using Skype, over the phone or face-to-face when possible. The majority of the interviews were conducted by Roughan & O' Donovan Innovative

Solutions (ROD-IS), WP2 leader, while AustriaTech (ATE) and Albrecht Consult (AC) also contributed to the process. One organisation prepared responses to the questions in text format.

Table 3.1 Organisations that participated in the interviews.

No.	Organisation		Country	Call Funding Country	Interviewer
1	Austrian motorway road operator (*ASFINAG*)	NRA	Austria (AT)	✓	ROD-IS
2	Finnish transport and communication agency (Traficom)	NRA	Finland (FI)	✓	ROD-IS
3	Federal Highway Research Institute (BASt)	NRA	Germany (DE)	✓	AC
4	Transport Infrastructure Ireland (TII)	NRA	Ireland (IE)	✓	ROD-IS
5	Directorate-General for Public Works and Water Management (Rijkswaterstaat)	NRA	Netherlands (NL)	✓	ROD-IS
6	Motorway Company in the Republic of Slovenia (DARS)	NRA	Slovenia (SI)	✓	Provided Text Response
7	Swedish Transport Administration (Trafikverket)	NRA	Sweden (SE)	✓	ROD-IS
8	Highways England (HE)	NRA	United Kingdom (UK)	✓	ROD-IS
9	The Ministry of Transport of the Czech Republic	Ministry	Czech Republic (CZ)	×	ATE
10	Autostrada del Brennero (AdB)	Road operator	Italy (IT)	×	ATE

3.2.3.2. Organisations Interviewed

An overview of the organisations that are interviewed is presented here and consists of 8 organisations responsible for managing and operating the road network (i.e. the NRA role), 1 road operator and 1 Ministry of Transport. Within this setting, three topics were covered for each organisation, namely, one, its involvement in road infrastructure, two, its areas of operation in respect of road infrastructure and three, its involvement in the area of Digitalisation, Connectivity and Automated Driving.

3.2.3.2.1. Austrian Motorway Road Operator (ASFINAG)

ASFINAG was founded in 1982 and is the Austrian motorway road operator. *ASFINAG* is responsible for building, maintaining, operating and managing the 2,200 kilometres motorways and express roads in Austria.

ASFINAG focuses on traffic management, traffic information, road safety and technological innovations where a sustainable and future-oriented approach is its main priority. *ASFINAG* is also responsible for items such as, for example, the ITS infrastructure on the motorways and express roads, collecting and providing traffic related data and roadworks installations.

ASFINAG monitors the tunnel and road infrastructure though nine traffic management centres, i.e. the national centre in Vienna-Inzersdorf and eight other centres in the federal provinces.

Its road network comprises more than 6,000 cameras from which large volumes of traffic data is collected. *ASFINAG* also has route control systems and network control systems. Route control systems control the traffic flows during accidents, traffic jams or exceptional weather conditions while network control systems deliver traffic information and warnings to the road users.

ASFINAG also utilises traffic sensors that record traffic data along its motorways and expressways. These sensors detect items such as traffic volume data, speed data, weather-related data (e.g. reduced visibility) and air pollution data.

3.2.3.2.2. Finnish Transport and Communication Agency (Traficom)

Traficom (Finnish Transports and Communications Agency) is a new Finish agency, commencing operations in January 2019. Traficom comprises parts of the Finnish Transport Safety Agency (Trafi), the Finnish Communications Regulatory Authority (FICORA) and certain functions of the Finnish Transport Agency. Traficom, consists of two separate organisations, (1) the Infrastructure Agency that holds the road infrastructure and its maintenance and (2) the Communication Agency that is responsible for the planning and evaluation of the entire traffic system.

Furthermore, the communication agency of Traficom is also working on research projects that study the impacts of Automation on road infrastructure and is studying how Automation and road infrastructure are affected by Digitalisation.

3.2.3.2.3. Federal Highway Research Institute (BASt)

BASt does research in this area and provides technical advice, including input on standardization. Some departments who are working with Euro NCAPs do further testing i.e. researching, advising, testing is what happens there. As far as infrastructure is concerned, BASt is of course involved to the extent that the Federal Government, ultimately the owner and also the financier of the federal highways, is interested in the relevant statements and findings. The main road network will be operated by the Autobahn GmbH which was founded in September 2018 and will start operations in 2021. It should also be added that some of the tasks that the Ministry performs as Road Authority are delegated to the BASt, such as participation in various CEDR working groups, including the working group on 'Connected and Automated Driving' and ultimately representing German interests in the CEDR Call '2017 Automation'.

BASt naturally has a wide range, which includes the hard infrastructure such as road construction, bridges and tunnels etc. The Traffic Engineering Department deals with the operational road maintenance services, classical telematics, appropriate research and the development of related standards or regulations. However, this department is not yet specifically responsible for road maintenance. This responsibility still lies with the states. In its field of activity, 'Vehicle Technology', BASt looks from the vehicle perspective at the shift towards Automated Driving and Connectivity between various players, such as vehicles and infrastructure.

3.2.3.2.4. Transport Infrastructure Ireland (TII)

Transport Infrastructure Ireland (TII) is a merger of the National Roads Authority and the Rail Procurement Agency (RPA). TII is responsible for delivering high quality transport infrastructure and services and also the main strategic road network of 5,500 kilometres of national roads, which comprises only 5% of the network but 45% of the traffic. In respect of road infrastructure, TII manages the network in order to deliver a safe, sustainable and efficient road network.

TII's current areas of operations can broadly be split up into Capital Management, i.e. the delivery of Capital projects, and Network Operations. TII operates the national network with its local authority partners. In respect of motorways, TII operates them through motorway maintenance and renewal contracts.

3.2.3.2.5. Directorate-General for Public Works and Water Management (Rijkswaterstaat)

The Directorate-General for Public Works and Water Management (Rijkswaterstaat) was founded in 1798 and it is part of the Dutch Ministry of Infrastructure and Water Management. Rijkswaterstaat is responsible for network planning, design, construction procurement, traffic and incident management. Rijkswaterstaat acts as an agency of the Dutch Ministry of Infrastructure and is integrally responsible for managing 3,046 kilometres of national roads.

3.2.3.2.6. Motorway Company in the Republic of Slovenia (DARS)

Motorway Company in the Republic of Slovenia (DARS) was established in 1993 and it is the national operator of all motorways in Slovenia. DARS main responsibilities are the operation of tolling systems, maintenance (infrastructure and buildings), road management investment and reconstruction. DARS is providing safe and comfortable mobility by measuring the traffic flows on its road network. In the area of Digitalisation and Automated Driving, DARS integrates roadside units and devices to the servers and into the Traffic Management Centres.

3.2.3.2.7. Swedish Transport Administration (Trafikverket)

The Swedish Transport Administration (Trafikverket) was founded in 2010 and it is a merger of the National Road Administration, the National Rail Administration, as well as parts of the National Maritime Administration, LFV (Civil Aviation Administration Sweden) and the Swedish Institute for Communications Analysis. Trafikverket's ultimate objective is to provide a robust and efficient transport system. It is responsible for building, construction and maintenance and traffic management of roads and railway systems in Sweden. Trafikverket is also in charge of road management, the national road network that consists of approximately 100,000 km of road and approximately10,000 bridges. It also assists the municipalities and others to join its plan and invest together in certain types of infrastructure where there is a lack of investment which is mostly in rural areas.

Its operations are divided into three categories, namely, ITS, road and rail operations. The ITS road operations include the placement and maintenance of electronic signs, variable speed limits, automatic speed surveillance and smart traffic signals. These are applied to provide information to the road users about issues such as possible accidents, delays and weather conditions, but they can also be utilised to control the traffic flows when needed to increase the traffic safety. Road operations assist the road users to check the traffic conditions in real-time and avoid delays for example due to road works. They are also rail operators that focus on improving the capacity of the railway system and facilitate mobility for goods through Europe.

3.2.3.2.8. Highways England (HE)

Highways England (HE) is the strategic road network operator in England, managing, maintaining and operation the same. HE has seven regional control centres and one national control centre that manage the road networks using ITS technology such as for example, variable message signs and variable speed limit indicators. It covers about 2% of the road network (major roads, motorways and trunk roads) which is a Third of all traffic and two-Thirds of all freight movements on the English road network. In the area of Digitalisation, HE has been transmitting traffic related information over the Internet since 2001.

3.2.3.2.9. The Ministry of Transport of the Czech Republic

The Ministry of Transport in the Czech Republic is a central authority of the state administration for transport related issues. It is responsible for the preparation of the state transport policy and, within its competence, for its implementation. The main tasks of the Ministry include legal, administrative and financial management of Road Transport, Railway Transport, Water Transport, Air Transport, Public and Combined Transportation, Intelligent Transport System, Connected, Cooperative and Automated mobility, Transport Research, Development and Innovation, Road Traffic Safety (BESIP), the State Fund of Transport Infrastructure and Crisis Management Issues. The Czech Ministry of Transport is also the competent ministry concerning the European Space Agency, EU Council on space, satellite navigation and space applications matters. Czech Ministry of Transport is the project coordinator of EU project “C-Roads Czech Republic”.

3.2.3.2.10. Autostrada del Brennero (AdB)

Autostrada del Brennero (AdB) was founded in 1959 and it is an Italian road operator that manages the highway from the Austrian border of Tyrol to the city of Modena Campo Galliano, along the Baltic Scandinavian-Mediterranean Adriatic corridor. This route is especially relevant as a tourist and freight corridor.

AdB’s main responsibilities include infrastructure services, motorway services such as truck parks; mobility services such as motorway stations, operation & safety centres; safety and comfort services such as road surfacing, crash barriers, fog systems and sustainable development such as charging stations for electric vehicles, noise protection walls.

AdB has also participated in various EU projects mainly in the areas of C-ITS and reducing emissions on its road network. Examples of EU projects that deal with infrastructure emissions are the “BrennerLEC” and “Zero Emission IP Life” while C-ITS related projects are “C-Roads Italy”, “ICT4CART” and “5G-Carmen”.

3.3 Selection of Use Cases

Following assessment of the broader areas of operation determined in Section 4.5, a list of possible Use Cases was proposed by the consortium at the CAD working group meeting in Oslo, on the 6th to 7th November 2018. Using a multi-criteria approach, various selection criteria were presented and discussed, and three Use Cases were selected.

In this third stage of the research methodology, the scope, boundaries, relevant actors and real-world examples are presented for the selected Use Cases in Section 5. However, a detailed description of the Use Cases e.g. their implications, relations with actors and data needs will be analysed in WP3.

4 Analysis

4.1. Introduction

Using the methodology outlined in Section 3 the current and expected levels of Digitalisation and Automated Driving, considering factors such as for example, barriers and risks on the NRAs' road networks, are identified. In the following sections the output from the Literature review and interviews are assessed and conclusions drawn on various issues related to Digitalisation and Automated Driving with respect to NRAs.

In the first instance, definitions of Digitalisation and Automated Driving are provided to establish the boundaries and objectives within this research project.

Subsequently, the findings of the literature review are presented where the most notable research projects, relevant to DIRIZON project, are discussed. Based on the results of past and ongoing research projects, the existing gaps are identified, providing information to formulate the interview questions. This is followed by an analysis of the interview responses to investigate the current and future trends and actions within this area but also to serve as a further validation of the literature review findings.

Finally, after the appropriate analysis of both the literature review and interview findings, three Use Cases are selected based on a multi-criteria selection process. These criteria are used to explore the NRAs' key areas of operations, and hence, the Use Cases are primarily selected according to them.

4.2 Definition of Digitalisation and Automated Driving

The first objective that needs to be met in WP2 is the definition of Digitalisation and Automated Driving within the scope of the DIRIZON project. Thus, the consortium has identified the definitions below.

It should be noted that an overview of all the definitions provided in this document can be found in the Definitions section. However, the definitions below are presented not only to facilitate the understanding of the rest of the text but also to serve as the basis for further exploring the realm of Digitalisation and Automated Driving from published projects.

Digitalisation is the implementation of digital technologies, which when combined with Information and Communication Technology (ICT) tools, assist in making transport modes more interoperable and smarter, including increased efficiency of NRA's operations in respect of their road network.

Automated Driving is 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, and Infrastructure to everything communication (I2X).

4.3 Literature Review Key Findings

In this section, the findings of the literature review are presented using existing literature reviews, publications from previous and ongoing research and deployment projects and existing platforms in the area of Digitalisation and Automated Driving.

The relevant actors and their roles and responsibilities are provided in the areas of Digitilisation and Automated Driving in Section 4.3.1. Subsequently, a set of representative research projects and platforms are presented for the same in Section 4.3.2 and Section 4.3.3 respectively. In this section, a summary of each research project is presented, highlighting the pilot studies, main outcomes, barriers, risks and existing gaps. Considering the outcomes from the literature review, a set of interview questions is prepared as presented in Appendix A.

4.3.1. Roles and Responsibilities of NRA's and actors

Eckhardt, J. et al. (2017) have published the roles and responsibilities of actors within the Mobility as a Service for Linking Europe (MAASiFiE) ecosystem and a European MaaS roadmap which outlines the step-by-step transition to Automation up until 2025. While the roles and responsibilities of the actors within the context of Mobility as a Service (MaaS)may not be the same as those for Automated Driving and Digitalisation, this could give a first overview of the potential roles and responsibilities for the public on the one hand and other actors on the other hand and how these could be defined for Automated Driving and Digitalisation. The former are summarised in Table 4.1 which identifies, for the purpose of this work, the actors that are primarily influenced by the forthcoming Digitalisation and Automation of the road network.

It is worth noting that roles may vary in different countries, thus one may need to adapt the table accordingly if interpreting it for a specific country context.

Table 4.1 Roles and responsibilities of NRAs and relevant actors for MAASiFiE

Actors	Roles and responsibilities
National road authorities	Organise the national road network (motorways); Provide data related to physical and digital infrastructure to other stakeholders.
Ministries for Transport	Act as a Legislator; Provide transport related policies and regulations; investment in transport infrastructure; public and research funding.
Governments	Responsible for the legislation processes e.g. for tests and pilots pertinent to Automated Driving.
Road operators[1]	Operate, monitor and maintain the road network.
Local authorities	Organise the local road network and region. Provide data to NRAs and relevant stakeholders.
Transport service providers (e.g. public transport, taxi etc.)	Provider of transport services, schedules, fares and other relevant data.
Logistics service providers	Management of flow of goods.
Mobile service providers (e.g. ICT providers, digital map providers)	Provide mobile technology and services to other relevant stakeholders e.g. e-ticketing to public transport customers, digital maps, and mobile apps
Users/Customers	Provide and consume data.
Funding agencies (National, international etc.)	Provide financial support. Investments to transport infrastructure, automated mobility etc.

Actors	Roles and responsibilities
Academia (e.g. Universities, research institutes)	Provide knowledge, innovative methods for evaluating traffic flows, data analysis etc.
OEMs (e.g. automotive industry)	Implement new technologies and create new business models through service.
Network service providers	Provide network coverage to the road infrastructure. when the Connectivity is provided though long-range communication e.g. 3G/4G cellular networks. In comparison, when a short-range communication coverage is used, e.g. ITS-G5, the road operators are fully responsible for it without the support of a Third party.
Cloud service providers	Provide storage and security protection of the produced data.
Trusted Third party	Ensures a trustful environment for all partners including the provision of security (in terms of secured CCAM services)

[1] In this case, while NRAs may be road operators, this excludes NRA's

4.3.2. Digitalisation

In this section, the findings from the literature review in the area of Digitalisation of road infrastructure area is presented. The section is further subdivided into platforms, national & international pilot/ projects and relevant standards to present an overview of the existing and expected Level within this area. The most notable projects and pilot tests are briefly described while others are only listed. Subsequently, the pilots and services tested are discussed to provide the consortium input for the selection of the Use Cases the impacts, benefits, barriers and risks are also presented when available.

4.3.2.1 Platforms

In this section the platforms that form the basis of C-ITS technology and those which are expected to lead towards full Digitalisation of the road infrastructure towards are introduced.

4.3.2.1.1 C-Roads (Harmonisation of C-ITS related deployments throughout Europe)

The C-Roads platform is a joint initiative of European Member States and road operators for testing and implementing C-ITS services to ensure harmonisation and interoperability in the deployment of C-ITS across Europe. The C-Roads Platform was launched in December 2016 and there are currently C-ITS deployment activities ongoing in 16 European Member States. There are currently 17 core members plus 6 associated members, including Australia and Israel. All of the countries funding DIRIZON are represented in the C-Roads Platform either as a core member or as an associated member.

The ultimate objective of this platform is to deploy enhanced interoperable cross-border C-ITS services for road customers. Equally, the C-Roads platform develops and publishes technical specifications pertinent to C-ITS technology service deployment such as for example for network coverage ITS-G5 (the C-ITS Infrastructure Functions and Specifications, 2018). Specifications pertinent to V2I (and vice versa, i.e. I2V) communication i.e. between roadside units and vehicles, have already been published in C-ITS Infrastructure Functions and Specifications (2018).

Within the C-Roads platform a number of pilot tests and implemented services are ongoing, as summarised below in Table 4.2 and Table 4.3 respectively (Kernstock, W., 2017b, C-Roads

Pilots, 2018). The Use Cases and services covered within the C-Roads platform assisted the consortium in the selection of Use Cases as presented in Section 5.

Table 4.2 C-Roads Pilot tests

Country	**Location**
Austria	The Austrian pilot site: A1 motorway from Vienna to Salzburg (part of *Rhine-Danube TEN-T corridor*); Area around Graz (part of *Baltic-Adriatic TEN-T corridor*)
Finland	The Finnish pilot site (part of *NordicWay* project); the Artic Challenge for Automated Driving.
Germany	Lower Saxony and Hessia pilot activities. They are located on the North Sea-Baltic and Orient-East med corridors (Lower Saxony) as well as on the Rhine-Alpine and Rhine-Danube corridors (Hessen)A2, A5, A39, A45 and A391 motorways.
Netherlands	Area 1 on Dutch motorway A2, A58, A16 and A15 (part of *Rhine-Alpine corridor).*
Norway	The Norwegian pilot site (part of *NordicWay* project).
Slovenia	The Slovenian pilot test. Tests on A1 highway on section from Ljubljana to Koper and the splitting motorways A3 (Divača-Sežana) and H4 (Razdrto-Vipava)
Sweden	The Swedish pilot site (part of *NordicWay* project).
United Kingdom	Blackwall tunnel to Dover (part of *North Sea – Mediterranean TEN-T corridor*).
Czech Republic	Tests on Rhine-Danube Core Network Corridor in the section Munich/Nürnberg – Praha, the Orient-East Med Core Network Corridor in the section Praha – Brno and the urban nodes Plzen, Brno and Ostrava.
Italy	Tests on motorways A22, A4, A28 and A57.
Portugal	The Portuguese pilot site on 460km national network and areas around Lisbon and Porto. It also includes cross-border sections in Valenca and Caia.
Spain	Madrid Calle 30 in Madrid, test site in the city of Vigo and metropolitan area, Mediterranean pilot (Catalonia and Andalusia), Cantabrian pilot tests.
France	South-West Area of Bordeaux, Main roads around the area of Brest, Rennes, Nantes and Le Mans, the French TEN-T Core network, Lyon TEN-T Urban Node.
Hungary	The Hungarian pilot site (M1 motorway between Austria and Budapest).
Belgium	The North Sea-Mediterranean corridor, the E19, the E34 and the east part of the E40-motorway, area around Antwerp and the motorways connecting Antwerp with the Netherlands.
Denmark	The Danish pilot site (part of NordicWay pilots)

Table 4.3 Services covered within C-Roads platform implemented or ongoing pilots.

Legend:

✓ = it has been tested, × = it has not been tested

DIRIZON interviewed organisations

AT = Austria, FI = Finland, DE = Germany, NL = Netherlands, NO = Norway, SI = Slovenia, SE = Sweden, UK = United Kingdom, CZ = Czech Republic, IT = Italy

Other European countries

PT = Portugal, ES = Spain, FR = France, HU = Hungary, BE = Belgium, DK = Denmark

		Country															
		AT	FI	DE	NL	NO	SI	SE	UK	CZ	IT	PT	ES	FR	HU	BE	DK
Service covered & Description	Slow or stationary vehicle. The vehicles can signal their presence to other vehicles to improve the traffic flows by choosing alternative routes.	✓	✓	✓	×	✓	✓	×	✓	✓	✓	✓	✓	×	×	✓	✓
	Road works warnings. The vehicles communicate with the road operators (I2V) about roadworks details.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Weather conditions. The drivers are informed about critical weather conditions ahead	✓	✓	×	×	✓	✓	×	×	✓	✓	✓	✓	✓	✓	✓	✓
	Emergency vehicle approaching. The emergency vehicle generated data to help other drivers on the infrastructure clear the road.	×	✓	×	×	×	×	✓	×	✓	×	✓	✓	×	×	×	×
	In-Vehicle signage. Vehicles receive relevant road signs though V2I communication.	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	×	✓	×	×

Legend:

✓ = it has been tested, × = it has not been tested

DIRIZON interviewed organisations

AT = Austria, FI = Finland, DE = Germany, NL = Netherlands, NO = Norway, SI = Slovenia, SE = Sweden, UK = United Kingdom, CZ = Czech Republic, IT = Italy

Other European countries

PT = Portugal, ES = Spain, FR = France, HU = Hungary, BE = Belgium, DK = Denmark

Service covered & Description	In-Vehicle speed limits. Roadside units transit data to drivers about speed limits.	✓	✓	×	×	✓	✓	×	✓	×	✓	✓	✓	×	✓	✓	×
	Signal violation/ intersection safety. Drivers receive instant warnings when they violate the red light and a warning is automatically generated to another vehicles.	✓	✓	×	×	✓	×	×	×	✓	×	✓	✓	×	×	×	×
	Green light optimal speed advisory. The roadside units broadcast traffic light information to vehicle to optimise their routes.	✓	✓	✓	✓	✓	×	✓	✓	×	×	✓	✓	✓	×	×	×
	Probe vehicle data. The vehicles share their position, speed, motion and driver actions e.g. steering and braking. Hence, the other vehicles can estimate the future infrastructure action to facilitate traffic flows and enhance safety.	✓	✓	✓	✓	✓	✓	×	×	✓	✓	✓	✓	✓	×	✓	✓
	Shockwave damping. The traffic flows are smoothed by damping traffic/ shock waves.	×	×	✓	×	×	×	×	×	×	×	✓	✓	×	×	✓	×

Legend:																	
✓ = it has been tested, × = it has not been tested																	
DIRIZON interviewed organisations AT = Austria, FI = Finland, DE = Germany, NL = Netherlands, NO = Norway, SI = Slovenia, SE = Sweden, UK = United Kingdom, CZ = Czech Republic, IT = Italy **Other European countries** PT = Portugal, ES = Spain, FR = France, HU = Hungary, BE = Belgium, DK = Denmark																	
	This is implemented by using real-time traffic data to vehicle.																
Communication technology used	ITS-G5	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	N/A	✓	N/A	N/A
	Cellular communication	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	×	N/A	×	N/A	N/A
	DAB	×	×	✓	×	×	×	×	×	×	×	×	×	N/A	×	N/A	N/A
	RDS	×	×	×	×	×	×	×	×	×	×	×	×	N/A	×	N/A	N/A
	Wi-fi/ Bluetooth	×	×	×	×	×	×	×	×	✓	×	×	×	N/A	×	N/A	N/A

4.3.2.1.2 *TM2.0 (Traffic Management 2.0)*

The TM2.0 platform was launched in 2014 under the ERTICO platform. Its main objective is to create an interactive interface that will facilitate data exchange/sharing between traffic management centres and the actors e.g. on-road vehicles. The proposed advanced interactive traffic management system uses a set of interfaces, principles and business models to develop next generation ITS transportation management and real-time traffic information to connected vehicles.

Potential benefits from the deployment of TM2.0 are for the traffic management centres to collect additional data from private sources to improve end-user services, such as for example, to avoid traffic jams and unnecessary emissions, enhancement of traffic safety, and for other service providers to receive real-time traffic information and optimise their individualised services on optimised travel route information.

The Task Force (TF) TM2.0 Platform agreed to conduct pilot tests in four regions in Europe, namely; Thessaloniki (Greece), Helmond-Eindhoven-Tilburg (the Netherlands); the extension of the “COMPASS4D” project, Salzburg (Austria) and Barcelona (Spain).

The C-ITS services that were tested are summarised below:

- The Netherlands: energy efficient intersection services, red light violation and road hazard warnings;
- Austria: in-vehicle speed advice, real-time travel routes advice, available parking lots and public transport information;
- Barcelona: dynamic exchange of data / information between TM and users enabled by ICT;
- Thessaloniki: better monitoring of the traffic status and providing proactive traffic management measures to the road users.

The TM2.0 identified barriers pertinent to traffic management that were further used for the development of interview questions and validation with the interview results in the DIRIZON project. These barriers, identified by the Task Force 2TM2.0 are as follows (Task Force 2 on Enablers and barriers TM2.0, 2015);

Technical Barriers

Lack of compatibility with legacy systems: The interoperability between traffic management centres and vehicles should be upgraded. The systems may also face restrictions and limitations from the rapid growth of technology and the adaption of new specifications.

Lack of Data in Standardised format: The transferred data between vehicles and traffic management centres does not follow certain data formats. The TM2.0 recommends to the research community to identify the existing data formats, such as for example DATEX II, and to develop harmonised data format specifications.

It is very often that actors do not share data from the same platforms which can lead to inconsistencies and unpredictable behaviour on the road infrastructure, leading to safety and liability issues. Hence, there is the need for an open access data platform where all the produced data will be filtered and shared to the public.

Organisational Barriers

Cybersecurity issues exist for V2I, V2V and V2X communication where there is a concern over the vulnerability of C-ITS systems to hacking. Standards related to data security and privacy are currently under development though there is the need for common data formats for intermodal traffic information and harmonisation of transport data exchange between NRAs and data providers and between transport service providers and road operators.

Business-related Barriers

There is no clear knowledge or appreciation of the investment cost required for an advanced interactive traffic management system either from the NRAs or the actors. The potential benefits from the deployment of a connected traffic management system with on-road vehicles are equally unknown. Furthermore, the actors operational and maintenance cost is also unclear.

Legal barriers

Liability: There are no legal and liability implications to data providers when erroneous data is provided. As such there is a need to introduce legal requirements for the sharing of data especially when the data is safety-relevant.

Users Privacy Concerns: There are a number of questions outstanding as to Who controls the data; Who has access to the data and Who is responsible for its (re)-distribution? These unknowns raise the question as to whether the consumers trust the services? There is some guidance in this area through EU national laws pertinent to the privacy of probe data such as Directive 95/46/EC ''Protection of personal data'' and Directive 2009/136/EU ''Personal data and the protection of privacy in the electronic communications sector''.

Conceptual Barriers:

Concerns also exist about the reliability of exchanged data and the public and political acceptability of this data.

4.3.2.1.3 ENISA (European Union Agency for Network and Information Security)

ENISA is a platform for cyber security in Europe that was established in 2014, created by Regulation (EC) No 460/2004 on information security. The aim of ENISA is to develop advice and recommendations on good practice in information security and assist the EU to implement the relevant legislation. In terms of C-ITS, ENISA has published documents related to "Cyber Security and Resilience of smart cars (ENISA, 2016), "Cyber Security and Resilience of Intelligent Public Transport". Good practices and recommendations (ENISA, 2015) and "Cyber security for Smart Cities An architecture model for public transport (ENISA, 2016).

In these documents, best practice and recommendations for C-ITS cyber security are presented. These include the promotion of public and private collaboration on cyber security at EU-Level and the promotion and facilitation of a harmonised EU approach for cyber security. They also suggest regular reviews of cyber security processes and practices, development of products that comply with cyber security requirements and the development of sharing platforms of trusted information.

Apart from these, two regulations were introduced by the European Council to deal with privacy and security aspects, namely; Directive 1995/46/EC, Regulation (EC) No 2016/679 - General Data Protection Regulation on the processing and movement of personal data and Directive 1999/93/EC, Regulation (EC) No 910/2014 - eIDAS (electronic IDentification, Authentication and trust Services) on a framework for electronic signatures. These regulations form the basis of EU cyber-security regulations. However, there is still work to be done in this regards as is identified from the DIRIZON interviews and it is currently identified as a significant barrier in the Digitalisation of road network.

4.3.2.1.4 TISA (Traveller Information Services Association)

TISA is a platform that was established in 2007. Its aim is to provide traffic and travel information services and products based on existing standards, i.e. RDS-TMC and TPEG technologies (TISA, 2018a). TISA also supports the maintenance and development of standards related to traffic and travel information with its main areas of interest in weather and environmental data, public transport and road traffic information.

The Traffic Message Channel (TMC) is used for real-time traffic and weather information. Data messages are directly delivered to vehicle users (vehicle sensors), to choose alternative travel routes and avoid traffic congestion and/or incidents. The TMC and TPEG service providers of DIRIZON's interviewed countries are summarised in Table 4.4 (TISA, 2018b, TISA, 2018c). TPEG provides road traffic messages, public transport and parking information. The transmission methods include DAB digital radio, Digital multimedia broadcasting (DMB) and Internet.

Table 4.4 TMC and TPEG service providers

Country	TMC service providers	TPEG service providers
Austria	ASFINAG (Austrian motorway operator), ORF (Austrian broadcasting corporation)	HERE, INRIX, TomTom Traffic
Finland	Mediamobile	HERE, Mediamobile, TomTom Traffic
Germany	Public broadcasters via ARD, HERE	ADR, HERE, INRIX, TomTom Traffic
Ireland	TrafficNav	HERE, INRIX, TomTom Traffic
Netherlands	ANWB, Be-mobile, VerkeersInformatieDienst (VID)	Be-Mobile, HERE, INRIX, TomTom Traffic
Norway	Norwegian broadcasting corporation (NPK), Mediamobile	HERE, Mediamobile, TomTom Traffic
Slovenia	TrafficNav	HERE
Sweden	Swedish Transportation Administration (STA), Mediamobile (NORDIC)	HERE, INRIX, TomTom Traffic, Mediamobile
United Kingdom	INRIX, Trafficmaster	HERE, INRIX, TomTom Traffic, Trafficmaster
Czech Republic	National traffic information centre of Czech Republic, Administration of Roads of Prague, CE-Traffic	HERE, INRIX, TomTom Traffic
Italy	RAI, Infoblu	HERE, INRIX, TomTom Traffic, Infoblu

4.3.2.2 National and International Pilots/ Projects

In this section major projects that took place in Europe are briefly introduced while a full list of projects within the Digitalisation area is represented in the end of this section.

4.3.2.2.1 C-ITS Corridor - ECo-AT (European Corridor Austrian Testbed for Cooperative Systems)

ECo-AT is the national Austrian pilot deployment project to create harmonised and standardised cooperative ITS applications jointly with partners in Germany and the Netherlands and is part of the C-ITS corridor (AT-DE-NL). The pilot has been deployed to harmonise and standardise cooperative ITS applications between the Netherlands, Germany and Austria. The project is led by ASFINAG and the consortium consists of Kapsch TrafficCom AG, Siemens AG Österreich, SWARCO AG, High Tech Marketing, Volvo Technology AB, ITS Vienna Region, FTW and BASt. The Austrian section of the corridor is prepared and developed within Eco-AT Phase I which commenced in November 2014 and lasted for one year. Phase 2 of the project, which is currently underway, is concerned with procurement of the C-ITS equipment though ASFINAG are the only participant in this phase.

The objective of the project was to bridge the gap between research and industry in the deployment of C-ITS technology. It was implemented prior to the development of the C-Roads platform where a set of Use Cases were tested (ECo-AT, 2018). These Use Cases include road work warnings, in-vehicle information, Decentralized Environmental Notification Message (DENM) aggregation, intersection safety and other DENM messages generated exchanged through C-ITS stations.

The roadwork Use Cases provide real-time information to the road users about their duration, exact location, Level of obstruction and lane closures. Furthermore, the vehicles received probe data (including speed information) and infrastructure to vehicle information (IVI; including traffic regulations, speed limits and emergency warnings). Related to traffic regulations, speed limits and emergency situations from both the infrastructure and other vehicles though V2V communication. Apart from these, cooperative traffic lights were studied as an effort to increase the traffic safety. ECo-AT was a primary step in the Digitalisation area where C-ITS services were tested in Europe. The studied pilot tests at ECo-AT were taken into consideration by the consortium for the selection of the Use Cases within the DIRIZON project.

4.3.2.2.2 SCOOP@F (Connecting Europe Facility TRANSPORT)

Similar to the ECo-AT pilot project deployed in Austria, The SCOOP@F pilot deployment project (Esposito, M.-C., 2016, Kernstock, W., 2017a) was Part 1 of a C-ITS pilot deployment project which ran from 2014-2016 on the national road network in France. Part 2, from 2016 to 2018, includes the validations of C-ITS services in open roads, the development of a hybrid communication solution (3G-4G/ITS-G5) and cross border tests with Spain, Portugal and Austria.

The Use Cases that have been tested were data collection and probe-vehicle data, roadworks and in-vehicle signage such as for example obstacles on roads, emergency breaking, weather conditions, emergency vehicle approaching and queues. The SCOOP@F project brings the OEMs into the pilot deployment phase of C-ITS where its first results showed that the relevant actors will be highly affected by it.

The SCOOP@F project also tried to summarise future legal, technical and organisational impacts from the C-ITS deployment (Esposito, M.-C., 2016). C-Roads France exploits and further extends the results from SCOOP@F project. The results from the SCOOP@F project identified that questions pertinent to current and future impacts and risks from C-ITS technologies should be included as part of the interviews.

4.3.2.2.3 InterCor (Interoperable Corridors)

The InterCor pilot deployment project was proposed to link the C-ITS corridor initiatives of the Netherlands and the French SCOOP@F project, and to further extend them in the C-ITS Initiatives for the United Kingdom and Belgium. InterCor is an ongoing three-year project started in September 2016 and is co-financed by the EU. Its aims are to facilitate V2I data communication through cellular, ITS-G5 or hybrid (cellular and ITS-G5) networks on road corridors in the Netherlands, Belgium, France and UK.

The scope of the InterCor project is to provide safer, more efficient mobility of people and goods. There are four InterCor TESTFEST (InterCor, 2018), namely, ITS-G5, Hybrid communications, PKI and C-ITS services. Validation of C-ITS specifications for ITS-G5 communication was made in the ITS-G5 TESTFEST while the validation of the C-ITS specifications for hybrid communication was studied in Hybrid communications TESTFEST.

PKI TESTFEST validated the public key infrastructures authentication of messages sent from different ITS stations (implemented) and the C-ITS services TESTFEST is going to examine the C-ITS specifications for logistics services and traffic management. The services that have already been tested are probe vehicle data, in-vehicle signage, green light optimal speed advisory, multimodal cargo transport optimisation, truck parking and tunnel logistics in the Netherlands area. In UK, the probe vehicle data, in-vehicle signage and green light optimal speed advisory have been covered to date (Kernstock, W., 2017a).

4.3.2.2.4 NordicWay

The NordicWay pilot deployment project (2015-2017) was the C-ITS deployment pilot in the Nordic countries of Norway, Sweden, Denmark and Finland (Bjerkan, K.Y., 2017). It was introduced to test and demonstrate the interoperability of cooperative safety-related traffic information to road users. NRAs and relevant actors (e.g. traffic management centres, vehicle manufacturers service providers, digital map service providers) shared massages related to roadworks, exceptional weather conditions, poor quality of road surface (e.g. slippery road warnings) and blocked road warnings (Scholliers J. et al. 2017).

The pilot tests studied within the NordicWay project included cooperative hazardous location warning, cooperative weather and slippery road warning, probe data services and cross-border traffic information. Both ITS-G5 and cellular communication were tested, demonstrating how traffic information messages were transmitted between vehicles and traffic management centres. In this, a cloud communication was utilised where the data text messages were transmitted over an Interchange Node by using the DATEX II standard for data exchange.

A detailed overview of the NordicWay pilots can be found in Bjerkan, K.Y., (2017) while the identified gaps and potential benefits from the deployment of C-ITS services are investigated in Meland, S. and Bjerkan, K.Y. (2017). In the second document, the identified barriers were explored though a survey and a workshop where the NordicWay partners discussed how NRAs and relevant actors can benefit from C-ITS technologies. They expect to use this information to inform future projects within this area and provide recommendations for future work and a detailed roadmap, which is currently lacking.

The barriers identified from the C-ITS deployment are summarised below;

Data-related Barriers:

Data sharing, standardisation and quality are identified as the main barriers for further improvement of C-ITS. NRAs and relevant actors are unwilling to share their data due to lack of trust and security/privacy issues. Equally, the availability, or lack of availability, of data is an issue. Some data exists in abundance while other data may be difficult to find or is not consistent, such as for example real-time details for accidents on motorways. Other issues are the quality of the produced data and the lack of compatible data despite the existing data formats. The survey conducted in NordicWay project about the importance of data issues is summarised in Table 4.5 below (Meland, S. and Bjerkan, K.Y., 2017)

Table 4.5 NordicWay survey of data-related issues.

	Critical [%]	Important [%]	Not important [%]	Not relevant [%]
Willingness to share data	59	36	5	0
Data availability	57	22	21	0
Data formats, compatibility issues.	47	32	21	0
Data quality	41	54	0	5
Standardisation	22	66	12	0
Data maintenance	11	48	36	5

Technical Barriers:

Technical interoperability (towards further deployment of C-ITS services), maturity and standardisation are the three technical barriers identified within NordicWay project. In fact, a need for a data sharing mechanism was recommended, where data will be shared via the cloud and open-source. Moreover, the C-ITS evolution in the long term needs to be considered both in terms of technological upgrades and adequate standardisation. Otherwise, data privacy and security (i.e. possibility of hacking) are also considered as critical technical barriers. The survey results from NordicWay project are shown in Table 4.6 below (Meland, S. and Bjerkan, K.Y., 2017):

Table 4.6 NordicWay survey of technology-related issues.

	Critical [%]	Important [%]	Not important [%]	Not relevant [%]
Interoperability	62	33	5	0
Privacy	41	49	10	0
Security	37	53	10	0
Standardisation	19	56	25	0
Maturity	10	60	30	0
Validation	10	85	5	0
Maintenance	5	65	25	5

Legal Barriers:

These consist of three main barriers namely, liability, privacy and access to data. For example, a set of new rules and regulations should be introduced by the Ministries for Transport as part of the forthcoming deployment of Automated Driving on the road infrastructure. These rules and regulations should ensure liability issues are addressed as a result of an incident with an automated vehicle (Automation Level 1 and above) and identify the responsible parties e.g. NRAs, vehicle user or OEMs. Furthermore, national rules and regulations may vary, hence, EU harmonisation is necessary. Otherwise, it is not clear who owns the data, who has access to data and who has permission to share the data - for what purpose and to whom. The survey results are presented in Table 4.7 below (Meland, S. and Bjerkan, K.Y., 2017)

Table 4.7 NordicWay survey of legal-related issues.

	Critical [%]	Important [%]	Not important [%]	Not relevant [%]
Privacy	30	48	22	0
Liability	12	47	29	12
Lack of legal framework	5	54	29	12
Various national regulations	0	70	25	5

Commercial and Organisational Barriers:

The impacts of C-ITS in the road infrastructure and their actors are unclear. There is lack of knowledge of its potential benefits, investment and/or operational cost and what kind of business models will be created in the future. The key findings are highlighted in Table 4.8 below (Meland, S. and Bjerkan, K.Y., 2017)

Table 4.8 NordicWay survey of commercial/organisational-related issues.

	Critical [%]	Important [%]	Not important [%]	Not relevant [%]
Number of users of service	41	54	5	0
Business models	35	46	13	6
Operational cost	30	40	30	0
Potential benefits from deployment	23	55	22	0
Willingness to pay for service	23	55	16	6
Investment cost	23	47	30	0
Network coverage quality	12	88	0	0

The aforementioned results were particularly useful for the consortium since they enable it to include interview question pertinent to barriers in achieving fully Digitalisation and Automated Driving on EU road networks. Furthermore, these results are an additional validation against the DIRIZON interview key findings, where similar issues were identified.

In 2017 the continuation of NordicWay, namely NordicWay2, started as part of the C-Roads initiative. Here the NordicWay deployments are harmonised with the services under deployment in other parts of Europe. The project will run until 2020 and is a C-ITS pilot project that enables vehicles, infrastructure and network operators to exchange safety hazard or other relevant information from roads in Nordic countries. The consortium includes public and private partners from Finland, Norway, Sweden and Denmark. The services that will be covered include dynamically controlled zones, in vehicle signage, signalized intersections, probe vehicle data, roadworks warnings and hazardous location notifications (NordicWay2, 2019a). In dynamically controlled zones, real time traffic policy protocols are distributed to road users so as to adjust their behaviour in the infrastructure accordingly. Signalized intersection service provides information to road users to safely and efficiently cross signalized intersections. Hazardous notifications include information about any type of hazard, its type and its expected duration.

These services will be tested in the following demonstration sites presented in Table 4.9 (NordicWay2, 2019b)

Table 4.9 NordicWay2 demonstration sites

Country	Pilot study
Norway	Norwegian open test site for C-ITS technology: E8 motorway from Skibotn to the Finnish border (testing period 2018 - 2020)
	Norwegian C-ITS services for challenges on high volume highways: E6 motorway between Oslo and Svinesund (2019 - 2020)
Denmark	Sharing information from the Danish Traffic Centre: Main road network in Denmark (2019 – 2020)
Sweden	Information on Green Light Optimal Speed Advisory GLOSA (Signalized Intersections) Drivers receive speed advice when approaching and passing traffic light-controlled intersections: Göteborg, Uppsala and greater Stockholm (2019-2020)
	Simulator of Emergency Vehicle Approaching (Linköping) (2019-2020)
	Information on Time to Green (Signalized Intersections) Drivers receive information about time-to-green (and/or time-to-red) when approaching signalized intersections: Göteborg, Uppsala and greater Stockholm (2019-2020)
Finland	Arctic Challenge - Automated Driving in artic conditions: E8 motorway (10 km test section) 2018-2019

4.3.2.3 *Other Digitalisation/ C-ITS pilot studies across Europe*

C-ITS technologies and hence the Digitalisation of road infrastructure has also been studied in Europe though other projects. Although, a detailed description of all of these projects is not presented in this report, these are summarised in Table 4.10 and they are sorted by year to facilitate understanding of the current status within this area.

Table 4.10 Digitalisation/ C-ITS pilot studies across Europe

No.	Project name	Period	Description	Participating countries
1	simTD	2008-2014	(Safe and Intelligent Mobility - Test Field Germany). Initial development and study of V2X communication.	Germany
2	DRIVE C2X	2011 – 2014	Accelerate Cooperative Mobility. Assessment of C-ITS in EU through field operational tests.	Finland, France, Germany, Italy, the Netherlands, Spain, Sweden
3	FESTA	2011-2014	(Field Operational Test Networking and Methodology Promotion). Develop and promote a framework for data sharing and support the efficient sharing of Field Operational Tests.	Germany
4	FOTsis	2011-2015	European Field Operational Test on Safe, Intelligent and Sustainable Road Operation	Germany, Greece, Portugal, Spain
5	CHARM	2013-2017	Development of next generation of traffic management for smart cars. A collaboration programme between Highways England and Rijkswaterstaat.	Netherlands, UK
6	C-ITS Corridor ECo-AT	2013-2017	*Described Herein*	Austria, Germany, the Netherlands
7	CoInCiDE	2015	Cooperative and Intrinsically-Correct Control of Vehicles in Diverse Environments	Germany
8	NordicWay	2015-2017	*Described Herein*	Norway, Sweden, Denmark, Finland
9	CODECS	2015-2018	COoperative ITS DEployment Coordination Support. Sustaining C-ITS deployment in Europe though engagement of relevant actors.	Germany, the Netherlands, Belgium, Denmark, Czech Republic, Spain
10	HIGHTS	2015-2018	High Precision Positioning for Cooperative ITS	France, Germany, Luxembourg, the Netherlands, Sweden

No.	Project name	Period	Description	Participating countries
11	ROADART	2015-2018	Research On Alternative Diversity Aspects foR Trucks. ITS communication units into trucks to optimise their safety on the road	Germany, Greece, the Netherlands
12	SocialCar	2015-2018	Intelligent Transport Systems for carpooling in urban and peri-urban areas.	Belgium, Croatia, Hungary, Italy, Luxembourg, Poland, Slovenia, Spain, UK
13	SADA	2015-2018	Smart Adaptive Data Aggregation	Germany
14	Aurora	2016-2018	The Arctic intelligent transport test ecosystem	Finland
15	Cloud-LSVA	2016-2018	Integrating big data, video annotation and cloud-based technologies for improved ADAS and Digital Mapping	Belgium, France, Germany, Ireland, the Netherlands, Spain
16	InterCor	2016-2019	*Described Herein*	Netherlands
17	IMAGinE	2016-2020	Intelligent Maneuver Automation-cooperative hazard avoidance in real time	Germany
18	InLane	2016-2018	Lane Navigation Technology (digital mapping)	Austria, Belgium, France, the Netherlands, Spain
19	SCOOP@F	2016-2018	Connecting Europe Facility TRANSPORT (See section	Austria, France, Portugal, Spain
20	AVEthics	2016-2019	Recommendations for a societally acceptable ethics policy for an automated vehicle in ethical dilemma situations	France
21	KoMOD	2017-2019	Cooperative Mobility in Digital Test Bed Dusseldorf	Germany
22	MuCCA	2017-2020	Multi-Car Collision Avoidance using Connectivity and autonomy to minimise the damage in high speed, multi-vehicle traffic accidents	UK
23	NordicWay 2	2017-2020	*Described Herein*	Norway, Sweden, Denmark, Finland
24	SAFE STRIP	2017-2020	SAFE and green Sensor Technologies for self-explaining and forgiving Road Interactive aPplications	Belgium. France, Germany, Greece, Italy, Spain
25	SOCRATES 2.0	2017-2020	(System of Coordinated Roadside and Automotive Services for Traffic Efficiency and Safety 2.0).	Germany

No.	Project name	Period	Description	Participating countries
			Innovative traffic information and navigation services.	
26	FRAME NEXT	2017-2021	Further development of C-ITS in Europe and enhancement of interoperability of ITS.	Germany
27	IMPACT Connected Car	2017-2019	Six-month acceleration program to bring together the Connected Car community in Spain	Spain
28	CLASS	2018-2020	Edge and Cloud Computation: A Highly Distributed Software for Big Data Analytics	France, Italy, Spain, US
29	5G MOBIX	2018-2021	Driving forward Connected & Automated Mobility. It examines the implications of 5G and its application in the forthcoming Automated Driving.	China, Germany, Greece, Luxembourg, the Netherlands, South Korea, Spain
30	ICT4CART	2018-2021	ICT Infrastructure for Connected and Automated Road Transport	Austria, Germany, Greece, Italy

4.3.2.4 Relevant standards

4.3.2.4.1 DATEX II

DATEX II is a European data exchange specification which has been developed to provide a standardised way of communicating and exchanging traffic information and traffic data between traffic management centres, traffic service providers, traffic operators and media partners. The specification provides for a harmonised way of exchanging data instantaneously at a system level, to enable better management of the European road network. The development of DATEX was initiated in the early 90s to exchange information between traffic centres of motorway operators however subsequently there wasa need to open this information to service providers. DATEX I was linked to the arising standard of road information, ALERT-C for RDS-TMC broadcasting support, however it was limited in its ability to evolve with the development of the modern internet and as such DATEX II was developed in the early years of this millennium. Equally, the increase in ITS services as well as the new digitization requirements arising from self-driving cars, requires increased use of standards

An advantage of DATEX II, is that the sharing and distribution of traffic information and traffic management information are not dependent on language and presentation format and equally the recipient can still choose to combine it with spoken text, an image on a map, or to integrate it into, for example, a navigation service’s route calculation.

The DATEX II organisation is open to all stakeholders in the traffic management domain (road authorities and road operators) that want to participate in the development, maintenance and user support of DATEX II. Some notable points are as follows;

- Some activities of the DATEX II organization are funded by EU CEF Programme Support Action (PSA) Agreement number MOVE/C3/SUB/2015-547/CEF/PSA/SI2.733309 RWS.
- The governance of the DATEX II organization is controlled by the “Rules of Procedure

of the DATEX II organization” (see DATEX II: Rules of Procedure of the DATEX II organisation including rules for Change control and release management, 2017). These rules apply to all partners in the DATEX II organization.

- DATEX II is a multi-part standard, maintained by CEN Technical Committee 278, Road Transport and Traffic Telematics, see www.itsstandards.eu.
- The first six parts of the CEN DATEX II series CEN/TS 16157 have already been approved as Technical Specifications in 2011-2015. The first three parts and the seventh part of the CEN DATEX II series have meanwhile been approved as European Norms CWEN/EN 16157. Two new parts (part 8 and 9) are currently approaching the final ballot stage.
    1. Context and framework (CEN/TS 16157-1:2011).
    2. Location referencing (CEN/TS 16157-2:2011).
    3. Situation publication (CEN/TS 16157-3:2011).
    4. Variable Message Sign (VMS) Publications (CEN/TS 16157-4:2014).
    5. Measured and Elaborated Data Publications (CEN/TS 16157-5:2014).
    6. Parking Publication (CEN/TS 16157-6:2015).
    7. Common data elements (EN 16157-7:2018).
    8. Traffic management publications and extensions dedicated to the urban environment.
    9. Traffic signal management publications dedicated to the urban environment.

The available data for exchange and distribution are shown in Table 4.11 where it can be categorised into five groups, road events, road operators’ actions, measured data, transport services and other services (DATEX II, 2019b).

Table 4.11 DATEX II available data

Data type	Data provided
Road events	Abnormal traffic e.g. queues, accidents, public event, on-road activities, obstructions e.g. people, animal and vehicle presence, trees, rocks cable falls, incidents e.g. VMS out of order, tunnel ventilation not working.
Road operators’ actions	Road closure, traffic diversion, roadworks, recovery vehicles, remaining travel times.
Measured data	Traffic values e.g. flow, speed, traffic status e.g. free flow, capacity, weather conditions e.g. wind, temperature, humidity, visibility, pollution, quality of road surface.
Transport services	Public transport schedules, cancellation or delay
Other services	Petrol stations, Charging points, Parking availability

It has already been discussed and decided to create an extension of DATEX II to support Management for Electronic Traffic Regulations (METR) (WG17 “Urban ITS” of CEN TC278). DATEX II will be used to exchange very detailed digital traffic regulations and to further enhance the development of Connected and Cooperative Automated Mobility (CCAM). Collaboration with TISA and Amsterdam Group in the field of mapping SRTI is available and further mapping is currently under development (DATEX II, 2019c) .

DATEX II is widely referred in the Delegated Regulations established under the ITS Directive 2010/40/EU such as

- Delegated regulation (EU) No 2017/1926 - Provision of EU-wide multimodal travel information services;
- Delegated regulation (EU) No 2015/962 - Provision of EU-wide real-time traffic information services;
- Delegated regulation (EU) No 2013/886 - Data and procedures for the provision, where possible, of road safety-related minimum universal traffic information free of charge to users;
- Delegated regulation (EU) No 2013/885 - Provision of information services for safe and secure parking places for trucks and commercial vehicles;
- Delegated regulation (EU) No 305/2013 - Harmonised provision for an interoperable EU-wide eCall.

A more detailed list of the various Standards, directive and regulation dedicated for C-ITS technologies are presented in Table 4.12 This includes standards and technical specifications for vehicle probe data, appropriate standards for data formatting, and regulations and directives for data cyber security and privacy.

Table 4.12 Relevant standards, directives and regulations in the Digitalisation area

Item	Reference	Standard/ Directive/ Regulation	Description
Vehicle probe data	ISO 22837:2009	Standard	Vehicle probe data for wide area communications
	ISO 24100:2010	Standard	ITS, Basic principles for data protection
	ISO/TS 25114:2010	Standard	ITS, Probe data reporting management (PDRM)
	ISO/TS 29284:2012	Standard	ITS, Event-based probe vehicle data
	SAE J2735	Standard	Dedicated Short-Range Communications (DSRC) message set dictionary
	ETSI TS 102-637-2	Technical Specification	Vehicular Communications and standard message formats for transmission
Data Format	DATEX II	Standard	*Described Herein*
Data Security	Regulation (EC) No 460/2004	Regulation	*Described Herein*
	Regulation (EC) No 910/2014	Regulation	eIDAS (electronic IDentification, Authentication and trust Services) on a framework for electronic signatures
Data Privacy	Regulation (EC) No 2016/679	Regulation	The protection of natural persons with regard to the processing of personal data and on the free movement of such data,
	Directive 95/46/EC	Directive	Privacy of probe data
	Directive 2009/136/EU	Directive	'Personal data and the protection of privacy in the electronic communications sector

4.3.3. Automated Driving

Pilot tests in the area of Automated Driving started almost 15 years ago in Europe. A list of European projects in the area of Connectivity and Automated Driving can be found in Automated Driving Roadmap (ERTRAC, 2017). These include highly automated urban transport systems, driver assistance systems and Connectivity & communication projects amongst others.

Hence, in this section a set of representative pilots and research projects is presented to investigate the current and expected Level of Automated Driving in Europe. With respect to Automated Driving, the six Automation Levels are briefly described in Section 4.3.3.1 where the corresponding actions from both the driver and the vehicle are highlighted.

This is followed by a summary of particular projects, with a detailed list of European projects is summarised for reference. Subsequently, existing standards for automated vehicles are discussed in the last subsection.

4.3.3.1. Levels of Automation

The deployment of Automated Driving can be a step-change for Europe to improve safety, and to reduce traffic jams and harmful emissions. It is expected to lead to “Vision Zero” plan, i.e. zero fatalities on EU roads by 2050 (On the road to automated mobility: An EU strategy for mobility of the future, 2018). However, automated vehicles currently do not have the ability to operate without drivers’ supervision. There are many technical but also legal issues to be solved to ensure that self-driving vehicles are fully able to operate on EU roads.

Six Levels of Automation are defined in SAE (Society of Automation Engineers) J3016 and presented graphically in Figure 4.1 as described in Raposo, A. et al., (2017).

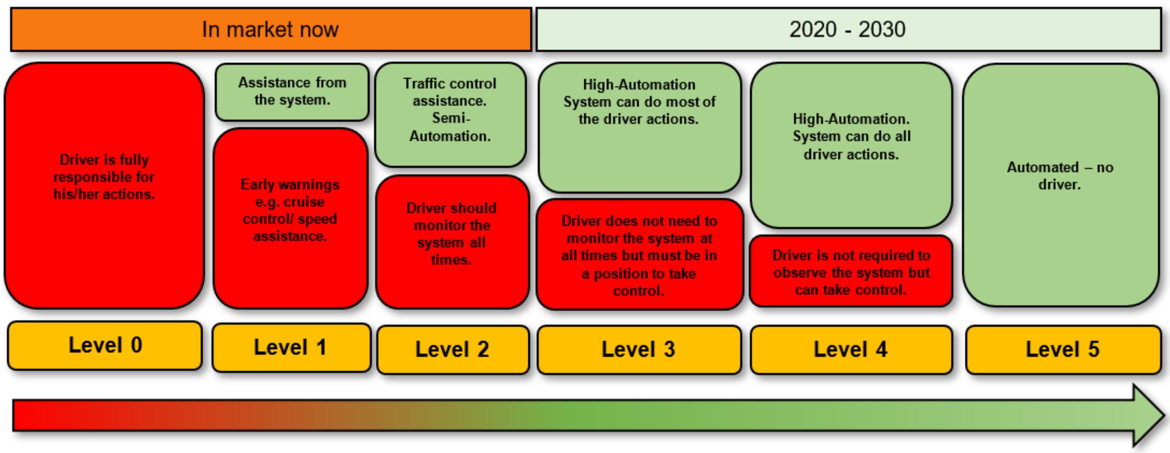

Figure 4.1 Automation Levels

The Automation Levels can be further classified into “Driver only”, “Hybrid” and “Vehicle only” implementation. Automation Levels belonging to Level 0, are “Driver only” while only self-driving cars exist in Level 5. To this extent, all the intermediate Levels are classified as hybrid. Three Automation Levels, Levels 0 to 2 are currently available in the EU market. In Levels 1 and 2, the vehicle assists the driver on the road infrastructure.

Automated vehicles that can perform a limited number of self-driving actions have already been tested and some of them are expected to be available by 2020 (Automated Driving Roadmap, 2017).

Although automated vehicles are not required to be connected, it is expected that connected vehicles will be a major enabler for driverless vehicles. Highly connected and automated vehicles will be able to communicate with other vehicles and the infrastructure to adjust their manoeuvres, leading to a smarter and safer traffic system.

The six Automation Levels together with their driving limitations are described below as defined in SAE (Society of Automation Engineers) J3016

Level 0 - No Driving Automation

'The performance by the driver of the entire DDT, even when enhanced by active safety systems'. In effect the driver is fully responsible for all his/her actions on the road infrastructure, i.e. longitudinal and lateral control of the vehicle and monitoring the environment during his/her travel journey.

Level 1 - Driver Assistance

'The sustained and ODD-specific execution by a driving Automation system of either the lateral or the longitudinal vehicle motion control subtask of the DDT (but not both simultaneously) with the expectation that the driver performs the remainder of the DDT'.

At this Level, the system assists the driver in his/her actions on the road infrastructure by controlling the longitudinal or lateral movement of the vehicle. However, the driver is responsible for other actions such as, for example, detection of an object and/or an event and the corresponding response. The driver also supervises the assistance system at all times and can activate or deactivate it as and when required. Typical examples include Adaptive Cruise Control (ACC), parking assistance with automated steering and lane keeping assistance (Bartels, A. et al. 2015).

Level 2 - Partial Driving Automation

'The sustained and ODD-specific execution by a driving Automation system of both the lateral and longitudinal vehicle motion control subtasks of the DDT with the expectation that the driver completes the OEDR subtask and supervises the driving Automation system'.

Similar to Level 1, in this Level the system can control the longitudinal or lateral movement of the vehicle with the driver constantly supervising the environment for any obstacles. Under certain circumstances, the driver can relinquish control of the steering wheel. Examples of this Automation Level are park and traffic jam assistance.

Level 3 - Conditional Driving Automation

'The sustained and ODD-specific performance by an ADS of the entire DDT with the expectation that the DDT fallback-ready user is receptive to ADS-issued requests to intervene, as well as to DDT performance-relevant system failures in other vehicle systems and will respond appropriately'.

At this Level, the system is able to control all the driving aspects of the vehicle. It can also perform safety functions, deal with traffic jams on motorways and observe the environment during the travel journey. The driver is not required to monitor the system at all times but needs to observe and/or take control of the vehicle when required. Examples of this Automation Level are traffic jam chauffeur, highway chauffeur and truck platooning.

Level 4 - High Driving Automation

'The sustained and ODD-specific performance by an ADS of the entire DDT and DDT fallback without any expectation that a user will respond to a request to intervene.'

The system is high-automated as in Level 3. However, the system in Level 4 does not require a driver to provide a fall-back to the automated system, however the system can be deactivated when the vehicle's ODD is no longer met. It can also be fully deactivated when the driver desires the full control of the vehicle. The driver may perform secondary actions (e.g. destination or navigation input) or can take control in emergency situations when the design conditions are no longer met. The secondary actions can be performed either by deactivating the system or with the automated mode active. Examples of this Level of Automation include highway pilot, personal rapid transit (PRT) and cyber minibuses.

Level 5 - Full Driving Automation

'The sustained and unconditional (i.e., not ODD-specific) performance by an ADS of the entire DDT and DDT fallback without any expectation that a user will respond to a request to intervene'.

At this Level, the system is fully automated and responsible for all the vehicle actions in the infrastructure. The presence of the driver is not required in any scenario. Examples of these are fully automated cars, trucks and taxis.

4.3.3.2. National and International Pilots/ Projects

Herein, a short description of the most notable projects are presented while a full list of other significant projects is presented in Section 4.3.3.2.4.

4.3.3.2.1 INFRAMIX (Preparing road infrastructure for mixed traffic flows)

INFRAMIX is a three-year research project which started in 2017 and aims to prepare the road infrastructure to support mixed vehicle traffic flows introducing new methods and tools (INFRAMIX, 2018a). To this end, a hybrid road infrastructure is proposed to facilitate the transition from current traffic conditions where only conventional and unconnected vehicles exist on road infrastructure to the deployment of fully connected and automated vehicles.

Three Use Cases will be examined within this project, namely; dynamic lane assignment to Automated Driving, roadworks & construction sites and bottlenecks. Mixed traffic conditions are expected to cause traffic degradation in the existing flows. Thus, the INFRAMIX project suggests the assignment of a dedicated lane for automated vehicles to avoid potentially dangerous situations with conventional vehicles. The main uncertainty identified from the project is how to maintain or improve the traffic conditions and avoiding safety concerns due to the presence of automated vehicles. Within this scenario, a set of parameters are to be considered such as penetration rate of automated vehicles, peak traffic conditions, speed limits per lane and weather conditions. All the pilot tests will be implemented on dedicated national motorways. Potential benefits are the evaluation of the proposed scenario i.e. the dedication of a lane to an automated vehicle and further investigation of traffic efficiency and safety.

The objective of the roadworks & construction sites scenario is to efficiently coordinate mixed traffic flows on motorways when roadworks take place. This can be implemented by providing a number of infrastructure support services to on-road vehicles. For instance, real-time information about temporary yellow lanes, lane closures, identification of roadworks obstacles (cones, staff etc.). The outcome of this test is to evaluate the impact on safety and traffic flow based on V2X communication during roadworks.

Despite the fact that a dedicated lane to automated vehicles is proposed in the first scenario, mixed traffic conditions in the same lane cannot be avoided in certain circumstances. Thus, a variety of control tests will be examined within this scenario such as onramp merging, lane closures, tunnel and bridge merging. The traffic degradation will be measured and evaluated, and recommendations will be made.

As part of the INFRAMIX project, two pilot tests have been scheduled, one in Spain and one in Austria. The Austrian test will take place on the A2 motorway that connects Laßnitzhöhe and the City of Graz and it will be operated by *ASFINAG*. The Spanish test will be done in the Mediterranean Corridor between Barcelona and the French border and it will be run by Autopistas.

The INFRAMIX project enables the DIRIZON consortium to explore the current trends in the area of Automated Driving as well as to highlight the forthcoming critical issues as a result of mixed traffic conditions. Mixed traffic conditions are also a main barrier as identified in the interview. Hence, the DIRIZON consortium has incorporated the consideration of mixed traffic flows in the Use Cases to facilitate its deployment.

4.3.3.2.2 AUTOPILOT (Automated Driving Progressed by Internet Of Things)

AUTOPILOT is a three-year research project which commenced in 2017 and is due for completion in 2019. Its aim is to connect autonomous driving vehicles with IoT (Internet of Things) technology to enhance mobility services and introduce new business models (socio-economic benefits). Within this project, six large scale pilot tests will be examined in six countries. The proposed Use Cases are summarised in Table 4.13 and include urban driving, automated valet parking, highway pilot, platooning and real time car sharing. A short description of each Use Case and the services that will be tested is provided in Table 4.13, however more details can be found in AUTOPILOT (2019a) and Schmeitz A. et al., (2017).

Table 4.13 AUTOPILOT Use Cases.

<table>
<tr><th>Use case</th><th>Location</th><th>Description</th><th>Services</th></tr>
<tr><td>Urban driving</td><td>Eindhoven (Netherlands), Livorno-Florence (Italy), Versailles (France) Vigo (Spain), Tampere (Finland), Daejeon City (Seoul)</td><td>Fully automated vehicle will drive from point A to B without further actions from the driver. The objective is to identify any bottlenecks of the system.</td><td rowspan="5">Hazardous locations & warnings on the roadway
roadworks, surface road quality
V2X communication (e.g. other vehicles, infrastructure services, pedestrians, cyclists etc.)
obstacle detection
accident avoidance traffic safety
vehicle positioning
GPS data
platoon management
interaction with traffic management
real-time HD map data and services (e.g. for vehicle's localisation)
pedestrian alert
available parking lots
vehicle's sensors and remaining travel times</td></tr>
<tr><td>Automated valet parking</td><td>(Eindhoven (Netherlands), Vigo (Spain), Tampere (Finland)</td><td>The driver will not take part to any parking related actions. The vehicles will be dropped-off by drivers in dedicated locations and it will be retrieved back from them when needed.</td></tr>
<tr><td>Highway pilot</td><td>Eindhoven (Netherlands), Livorno-Florence (Italy)</td><td>The aim of this Use Case is to provide probe data directly into vehicles to efficiently manage the road hazards and enhance traffic safety.</td></tr>
<tr><td>Platooning</td><td>Eindhoven (Netherlands), Versailles (France)</td><td>Vehicular platoons will be tested that will comprise highly automated or driverless vehicles with automated steering and distance control though V2v communication.</td></tr>
<tr><td>Real time car sharing</td><td>Eindhoven (Netherlands), Versailles (France)</td><td>Commercial and individual car will be shared.</td></tr>
</table>

The AUTOPILOT project will also explore various new business models within the area of Automated Driving, car sharing and IoT (AUTOPILOT, 2019b). Distribution of traffic related data to automated vehicles will optimise their travel journeys by redistributing the traffic along alternative routes. Furthermore, IoT services will assist automated vehicle's sensors to detect possible obstacles on roads e.g. pedestrians, other vehicles. For example, pedestrians can be equipped with smart devices connected to on-road vehicles and infrastructure, thus, addressing the issues of conceptual barriers e.g. public acceptance of Automated Driving.

The HD (High-Definition) maps for Automated Driving vehicles will be evaluated and they will be equipped with data collected by all connected vehicles. To this extent, IoT services and smart devices will be connected to HD maps where together with vehicle's sensors, data will be automatically updated in dynamic fashion. In this way, the traffic efficiency of automated vehicles will be increased. Finally, AUTOPILOT 6th sense driving service consists of a set of algorithms which will be implemented to estimate and evaluate possible risks during Automated Driving on road infrastructure.

High Level gaps and needs that are identified within AUTOPILOT project are interoperability, data management and remote management issues. Interoperability refers to the ability of a vehicle to communicate with other (smart) devices where smart devices are not only other connected vehicles but also other devices such as, for example, smartphones and smart watches. It was also noted that a harmonisation of the services should be ensured to allow for data transfer.

Data management issues considers issues such as; who produces, controls, collects and distributes the relevant data while remote management is the ability of IoT services to remotely operate.

Finally, there are also security and privacy issues which need to be addressed such as, for example, authentication, encryption, authorisation security that need to be ensured.

The DIRIZON consortium exploited the high Level identified gaps from the AUTOPILOT project, including interview questions pertinent to interoperability and existing and new business models. The appropriateness of HD Maps for automated vehicles was also considered in the selection of the DIRIZON Use Cases.

4.3.3.2.3 L3Pilot

L3Pilot is an ongoing large-scale research project which commenced in 2017 and is due for completion in 2021. The ultimate objective of the project is to evaluate, through a set of appropriate Use Cases and pilot tests, the viability of Automated Driving as an efficient and safe means of transport (Hibberd, D. et al., 2018). The L3Pilots will examine four Use Cases/ applications, covering a wide range of Automated Driving situations. These include; parking chauffeur where appropriate parking functions will take control of the vehicle's actions; motorway & urban chauffeur where Automated Driving will be tested in combination with obstacle detection functions; and traffic jams where appropriate functions will take control to facilitate traffic flows.

It should be noted the assumed Automation Level will be Level 3 and Level 4. The successful completion of these tests will provide an insight into and evaluate the traffic safety and the efficiency of Automated Driving. As part of this project, a set of pilot tests will be carried out to evaluate possible cross-border issues arising from Automated Driving. These are shown below, where DIRIZON's interviewed countries are in *italic*:

- *Austria-Germany*
- *Austria-Italy*
- Belgium-*Germany*
- Belgium-*Netherlands*
- *Finland-Sweden*
- France-*Germany*
- *Germany-Netherlands*

The potential benefits/ outcomes from the deployment of this project are:

- Evaluation of negative and positive impacts of mixed traffic conditions (see also INFRAMIX project);
- Real-world implementation of Automated Driving functions, measuring both the driver's reactions and vehicle's response;
- Provision of recommendations and state-of-the-art procedures to avoid traffic degradation when Use Case scenarios related to Automated Driving take place;
- Harmonisation of Automated Driving within Europe, though the implementation of cross-border tests;
- Support and prepare relevant actors/ stakeholders e.g. NRAs to update regulations, develop new standards;
- Investigation of cyber-security, privacy, legal and demographic aspects.

4.3.3.2.4 Other Automated Driving pilot studies across Europe

Apart from the previous described pilot tests in the area of Automated Driving, there are also some other significant projects across Europe. These are summarised in Table 4.14 where their periods of study, a short description and the countries participated on them are presented.

Table 4.14 Automated Driving pilot studies across Europe

No.	Project name	Period	Description	Participating countries
1	CityMobil	2004-2008	Towards Advanced Road Transport for the Urban Environment	Italy, Spain, UK
2	HAVEit	2008-2011	Highly Automated Vehicles for Intelligent Transport	Austria, France, Germany, Greece, Hungary, Sweden, Switzerland
3	EuroFOT	2008-2012	European Field Operational Test. Cars and trucks were equipped with advanced driver assistance systems	France, Germany, Italy, Sweden
4	SARTRE	2009-2012	SAfe Road TRains for the Environment	Germany, Spain, Sweden, UK
5	V-Charge	2011 - 2015	Automated Valet Parking and Charging for e-Mobility	Switzerland, Germany, UK, Italy
6	CityMobil 2	2012-2016	Cities Demonstrating Automated Road Passenger Transport	Finland, France, Greece, Italy, Switzerland
7	Drive Me	2012-2017	Self-driving cars for sustainable mobility	Sweden
8	DAVI	2013	Dutch Automated Vehicle Initiative	The Netherlands
9	AutoNet2030	2013-2016	Co-operative Systems in Support of Networked Automated Driving by 2030	France, Germany, Greece, Italy, Slovakia, Sweden, Switzerland, UK
10	HFAuto	2013-2017	Human Factors of Automated Driving	Germany, the Netherlands, Sweden, UK
11	AdaptIVe	2014 – 2018	Automated Driving Applications and Technologies for Intelligent Vehicles. Enhancement of traffic efficiency and safety though C-ITS technology and interaction between vehicle driver and driver assistance systems.	Germany, Sweden, the Netherlands, Greece, UK, Italy
12	RobustSENSE	2015-2018	Reliable, Secure, Trustable sensors for Automated Driving	Austria, Finland, Germany, Italy, Spain
13	UKAutodrive	2015-2018	Trial of automated vehicle technology	UK
14	COMPANION	2016	Cooperative dynamic formation of Platoons for safe and energy-optimized goods transportation	Spain, Sweden
15	Cruise4U	2016	Automated Driving on motorways.	Czech Republic, France, Germany, Spain, UK
16	UKCITE	2016 – 2018	UK Connected Intelligent Transport Environment.	UK

No.	Project name	Period	Description	Participating countries
			Development of an advanced environment for testing CAV for improving travel journeys, reduce traffic jams and enhance traffic safety.	
17	AUTOC-ITS	2016-2018	Regulation study for interoperability in the Adoption the Autonomous Driving in European Urban Nodes	France, Portugal, Spain
18	CARTRE	2016-2018	Coordination of Automated Road Transport Deployment for Europe	Austria, Greece, Germany, the Netherlands, Sweden, UK
19	DENSE	2016-2019	DENSE - aDverse wEather eNvironmental Sensing systEm	Belgium, Finland, France, Germany, the Netherlands, Spain, Sweden
20	MAVEN	2016-2019	Managing Automated Vehicles Enhances Network	Germany, the Netherlands, UK
21	MEC-View	2016-2019	Mobile Edge Computing Based Object Detection for Automated Driving	Germany
22	AutoMate	2016-2019	Automation as accepted and trustful teammate to enhance traffic safety and efficiency	France, Germany, Italy
23	AutoConduct	2016-2019	Adaptation of the Automation strategy of autonomous vehicles (Levels 3-4) to driver needs and driver state under real conditions	France
24	VI-DAS	2016-2019	Vision Inspired Driver Assistance Systems	Spain
25	WIEN ZWA	2017	Automated Driving test in Vienna and surrounding areas	Austria
26	AUTOPILOT	2017-2019	*Described Herein*	France, Finland, Italy, Netherlands, South Korea, Spain,
27	DRIVEN	2017-2019	Fleet of driverless vehicles using UK-built software	UK
28	L3Pilot	2017 – 2020	*Described Herein*	Austria, Belgium, Finland, France, Germany, Greece, Italy, the Netherlands, Norway, Sweden, Switzerland, UK
29	INFRAMIX	2017-2020	*Described Herein*	Austria, Germany, Greece, Spain
30	CoExist	2017-2020	Working towards a shared road network Enabling cities to get "Automation-ready"	Sweden, Belgium, France, Germany, Italy, the Netherlands, UK

No.	Project name	Period	Description	Participating countries
31	TransAID	2017-2020	Transition Areas for Infrastructure-Assisted Driving	Belgium, Germany, Greece, the Netherlands, Spain, UK
32	BRAVE	2017-2020	Bridging Gaps for the Adoption of Automate Vehicles	Australia, France, Germany, Slovenia, Spain, Sweden, US
33	interACT	2017-2020	Designing cooperative interaction of automated vehicles with other road users in mixed traffic environments	Germany, Greece, UK
34	CONCORDA	2017-2020	Connected Corridor for Driving Automation	Austria, France, Germany, Italy, the Netherlands, Spain
35	TrustVehicle	2017-2021	Improved Trustworthiness and Weather-Independence of Conditionally Automated Vehicles in Mixed Traffic Scenarios	Sweden, Austria, Finland, France, Italy, Turkey, UK
36	Meridian	2017-2022	Cluster of projects to accelerate connected and autonomous vehicle technology	UK
37	ALP.Lab GmbH	2017-2022	Austrian Light Vehicle Proving Region for Automated Driving	Austria
38	PRoPART	2018-2020	Precise and Robust Positioning for Automated Road Transports	Sweden
39	Connecting Austria	2018-2020	Connecting energy-efficient and semi-automated trucks from the motorway to the city	Austria
40	HumanDrive	2018 – 2021	Level 4 automated vehicle test are being tested in collaboration with OEMs and universities.	UK
41	Digibus Austria	2018-2021	Austrian project for Automated Driving in public transport	Austria
42	ARCADE	2018-2021	Aligning Research & Innovation for Connected and Automated Driving in Europe	Austria, Greece, Germany, the Netherlands, Sweden, UK
43	AVENUE	2018-2022	Autonomous Vehicles to Evolve to a New Urban Experience	Denmark, France, Germany, Luxembourg, Switzerland
44	E-CAVE	To start in 2021	Enabling connected autonomous vehicle environments. R&D project to accelerate CAV testing portfolio in the UK though the mediation and sharing of geo-safety data.	UK

A detailed catalogue of Connected and Automated Driving test sites will be produced as part of the STAPLE (SiTe Automation Practical Learning) project in deliverable No 2.1 (STAPLE, 2019). Funded under the 2017 CEDR call "Automation" (as is DIRIZON) the STAPLE project focuses on topic C "Practical learnings for NRAs from test sites". The main objective of STAPLE is to provide a comprehensive review of technological and non-technological aspects of the most relevant Connected and Automated Driving test sites and herein, to understand the impact of these sites on the NRA's core business and functions, such as, for example, road safety, traffic efficiency, customer service, maintenance and construction.

The project is undertaking a detailed investigation of test sites though interviews with test site leads and by conducting site visits in certain cases with the aim of collecting information about the name of the test sites, tests performed (Use Cases), their size, the type of environment (motorway, interurban; intersections etc.), communication systems utilised (ITS-G5, 3G/4G) and the available digital and physical infrastructure support services. The outcomes of the survey will be published in Deliverable No 2.1 "Catalogue of connected and automated driving test sites" together with a searchable database that will provide NRAs with an overview of the most relevant test sites in Europe and beyond.

4.3.3.3. Relevant standards

The relevant standards for automated vehicle are mostly coming from the SAE International (SAE, 2019). Some notable standards are listed in Table 4.15. However, the inadequate standards for automated vehicles is a major barrier in this area as it has identified from the interview key findings within the DIRIZON project.

Table 4.15 Relevant standards in the Automated Driving area (developed by SAE)

Standard	Date
Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems	2014
Dynamic Test Procedures for Verification & Validation of Automated Driving Systems (ADS)	2015
Guidelines for Safe On-Road Testing of SAE Level 3, 4, and 5 Prototype Automated Driving Systems (ADS)	2015
Performance Requirements for Cooperative Adaptive Cruise Control and Platooning	2015
Human Factors Definitions for Automated Driving and Related Research Topics	2016
Automated Driving Reference Architecture	2016
Guidelines for Safer On-Road Testing of Prototype Automated Multi-Vehicle Truck and Bus Systems	2017
Requirements for V2I Weather Applications	2017
Taxonomy and Definitions for Terms Related to Automated Driving System Behaviours and Maneuvers for On-Road Motor Vehicles	2018
ADS-DV User Issues for Persons with Disabilities	2018

4.3.4. Summary and Conclusions from Literature Review

In this section a brief summary of the main findings from the literature reviewed is presented in respect of Digitalisation and Automated Driving along with some general conclusions and recommendations. It should be noted that the findings of the literature review were used to assist in formulating the interview questions and as such the findings of the interviews seek to address these items.

1. Though the various actors whose involvement is required in these areas is known, their roles and responsibilities are still largely unclear and formalising these roles and responsibilities will be critical for future developments.
2. There are numerous C-ITS pilot projects ongoing and planned, testing various technologies and services. This will lead to a harmonised approach to C-ITS applications which will enhance deployment of the technology. However, there is not the same Level of advancement in respect of Automation/Automated Driving.
3. Legislation and/or legislative frameworks are seen as significant barriers to both Digitalisation and Automation/Automated Driving. Not only is legislation required for implementing pilot tests, but issues such as liability, data privacy and access to data need to be addressed as part of a legal framework. It is generally noted that this will be the responsibility the Ministries for Transport, first of all at national Level but ultimately at EU Level.
4. While investment is essential in both digital infrastructure and Automation technologies, at the present time, there is no clear understanding of the investment costs or the operational costs of implementing them.
5. There is lack of knowledge of the potential benefits of Digitalisation and Automated Driving and what kind of business models will be created in the future.
6. A number of standards, guidelines and regulations have been published in respect of Digitalisation, however there is not the same Level of documentation available related to Automated Driving. This is particularly the case for digital traffic regulations. However, notwithstanding this fact, there is a need to harmonise the current standards, guidelines and regulations at an EU Level. Equally, it is important that these form part of a legislative framework.
7. Various issues related to data are apparent. These include a lack of data in a standardised format; sharing of data, ownership of data, quality of data, privacy of data and reliability of data. Addressing these issues requires harmonisation of the data in a standard format and putting in place legislative frameworks for all aspects of data.
8. In respect of Automated Driving, the implications of mixed traffic conditions are largely unknown.

4.4 *Interview key findings*

In this section, the interview key findings are presented and discussed. Representatives (i.e. employees) from organisations from eight of the nine CEDR funding countries were interviewed along with representatives from organisations from two CEDR non-funding countries, i.e. Italy and the Czech Republic

In analysing the key findings from the interview process, the responses from each interviewee are examined and a general overview of the findings is presented under various headings. As such, individual responses to the questions are not provided in this report.

4.4.1. Involvement in Past & Ongoing Projects

Testing is one of the most important issues for the implementation of C-ITS and even more so for Automated Driving. Therefore, all the interviewed organisations consider testing to be an important issue in implementing Automated Driving. To this end, the following sections provide an overview of the interviewed organisations involvement in past and ongoing projects and the lessons learned. It is however clear from the results of this section that these countries are at different level of testing.

4.4.1.1 Austrian Motorway Road Operator (*ASFINAG*)

ASFINAG has been involved in research projects related to mixed traffic management for the past two years. Equally, they are working in conjunction with the automotive industry, working alongside Tier 1 and Tier 0.5 suppliers (companies that supply parts or systems to OEMs) and also OEMs to gain a better understanding of the Automated Driving sector.

ASFINAG has conducted some trials with C-ITS ITS-G5 in addition to the ongoing tests with automated vehicles, however the testing is still only being carried out with drivers taking the decisions because there is a limited legal framework in place. As a result, the tests are limited.

Austria was one of the first EU countries to deploy C-ITS pilot tests, where they have been involved in the ECo-AT project to harmonise and standardise the cooperative ITS applications. This project is also described in the C-ITS Strategy, Austria (2016). Furthermore, Austria is an active member of C-Roads and is participating in various C-ITS pilot tests within this platform as outlined in section 4.3.2. They are also involved in the INFRAMIX project, described in section **Error! Reference source not found.**.2.1, where the ultimate aim is to prepare and assess the uncertainties and risks on the road network in mixed traffic conditions. Further information can be found in the C-ITS Roll-out in C-ITS Deployment in Austria & European Harmonisation Activities (2019).

Austria is also participating in the ICT4CART project (ICT Infrastructure for Connected and Automated Road Transport) together with Germany, Greece and Italy, that is running from September 2018 to August 2021 (ICT4CART, 2019). ICT4CART's objective is to provide a better ICT infrastructure and a distributed IT environment in order to facilitate a fast and safe transition towards higher Levels of Automation (up to Level 4). Four Use Cases will be designed, tested and validated under real-life conditions where key ICT elements for example hybrid Connectivity, data management, cyber-security, data privacy etc. will be assessed.

4.4.1.2 Finnish Transport and Communication Agency (Traficom)

Traficom is currently participating in an ongoing project, namely, Arctic Challenge (2017-2019) that is studying connected and Automated Driving in arctic weather conditions. The project involves pilot tests with automated vehicles in the Aurora test environment located in Fell, Lapland. An expected outcome of the project will be the implementation of an intelligent infrastructure that will be able to produce useful information for vehicles and explore their position based on map, satellite and roadside unit data. The consortium consists of Traficom, private companies and research institutes. This includes for example Lapland University of Applied Sciences (LAPIN AMK), VTT Technical Research Centre of Finland, Indagon Oy software company, Infotripla Oy transport system services, Ukkoverkot (also Ukko Mobile) a Finnish provider of 4G mobile data services, Sensible 4 etc (Arctic Challenge, 2019). At present, the final results of the projects are unavailable.

Traficom is also a partner in the Nordic Way 2 project, a joint project with Sweden, Norway, Finland and Denmark. The Nordic Way 2 project covers a variety of research topics, however, similar to Artic Challenge, the testing of C-ITS and Automated Driving in arctic weather conditions is the main objective.

From the perspective of C-ITS, these projects have shown that a positive impact on road safety can be achieved if the traffic information is shared between vehicles and applications in a cellular network, using Technologies such as 3G 4G, LTE and ITS-G5 on the short communication network. However, not only has the technology shown to be feasible but a clear roadmap is emerging for implementation of 5G communication.

4.4.1.3 Federal Highway Research Institute (BASt)

BASt has been involved in various field tests and pilots in the field of C-ITS. BASt has also been involved in the methodology for evaluating field tests with economic components. Currently, BASt are focusing on Connectivity issues.

Related C-ITS projects in which BASt has participated include the Field Operational Test Networking and Methodology Promotion (FESTA, 2019), simTD Connected Automated Driving Europe (SimTD, 2019), DRIVE C2X (Schulze, 2014) and C-Roads. These projects have however identified a lack of cooperation between the NRAs and relevant actors. Governance issues were also highlighted as not all actors are at the same level of development and implementation.

4.4.1.4 Transport Infrastructure Ireland (TII)

To date, TII has not participated any C-ITS pilot tests though an autonomous driving pilot study has been scheduled on Irish motorways in the near future. This pilot test will be conducted in cooperation with Jaguar Land Rover (JLR), the car manufacturer, based in Shannon, Ireland. TII expects to get more involved in C-ITS projects as part of the C-Roads platform

4.4.1.5 Directorate-General for Public Works and Water Management (Rijkswaterstaat)

Rijkswaterstaat has been involved in numerous research projects in the area of Digitalisation and Automated Driving. It has been involved in projects such as the InterCor project where the C-ITS communication is tested in very specific applications. A main outcome of this project was that a hybrid communication strategy is needed to facilitate Digitalisation and Automated Driving.

Rijkswaterstaat has also conducted tests on currently-available systems, i.e. vehicles that are already on the market, such as Tesla cars, BMWs, and Mercedes In these tests, Rijkswaterstaat has seen the limitations of those systems, in particular, the reliance on current drivers and their unfamiliarity with the limitations of automated systems which can be a real risk for traffic safety. Automotive industries have deployed Level 3 and/or Level 4 automated vehicles but from recent accidents and recent testing, they have seen the limitations of the systems. Hence, the automotive sector is working towards 100% reliability, i.e., zero accidents. However, it was noted that it is a very difficult task for the automotive sectors to programme every single test case that an automatic vehicle system might encounter.

4.4.1.6 Motorway Company in the Republic of Slovenia (DARS)

DARS has been involved in pilot tests pertinent to cellular communication within the C-Roads platform, as described in Section 4.3.2.1

4.4.1.7 Swedish Transport Administration (Trafikverket)

In 2014 Trafikverket started working on an autonomous driving project called DriveMe together with Volvo to study the opportunities of automated road transports and Automation in general. It is intended to test 200 self-driving Volvo cars on 50km of roads in Gothenburg, Sweden. Trafikverket has also tested many automated functions within the same project. Trafikverket is particularly interested in the potential benefits of utilising automated functions and in understanding the system effects of Automation, and the consequences in the context of transportation systems.

4.4.1.8 Highways England (HE)

HE has been involved in numerous C-ITS projects in the past. It is currently participating in HumanDrive where Level 4 automated vehicles are being tested in collaboration with large OEMs and universities. The project focuses on the implications of introducing human-like behaviours and more natural driving to an automated vehicle.

4.4.1.9 The Ministry of Transport of the Czech Republic

The Czech Ministry of Transport has launched several research and development projects funded through BETA programme of the Technology Agency of the Czech Republic. This funding programme covers both road and rail projects. It was noted that the most important realised projects related to roads was “Increasing the road traffic safety trough in-vehicle cooperative systems enabling communication between cars or between cars and intelligent transport infrastructure - BaSIC” (completed in 2013).

The goal of the BaSIC project was to design an implementation protocol for ITS cooperative systems in the Czech Republic. As, part of the project, a live demonstration on the Prague-bypass in actual road traffic conditions was tested to verify the proposed solution. Various scenarios were tested - the communication among vehicles themselves as well as the communication between a pilot car and the intelligent transport infrastructure. All project outcomes and results are used in practice.

In addition, a number of R&D actions have been implemented in the Czech Republic such as C-Roads Czech Republic where activities are being undertaken in both the public sector and private sector. Currently, Automated Driving is tested up to SAE Level 3 on Czech Roads. For successful testing, all levels of vehicle Automation and subsequent implementation of Automated Driving in the Czech Republic is necessary to create conditions for higher-Levels automated vehicle SAE Level 4 and 5 operating in real road traffic conditions. A current important goal is to allow operation of vehicles with the Automation Level of 3 within a legal framework.

4.4.1.10 Autostrada del Brennero (AdB)

AdB is involved in many C-ITS projects. Some pilot tests are examined in C-Roads, Italy, while others are the ICT4CART and 5G-Carmen, COOPERS and Drive C2X projects

Within these projects, AdB has become familiar with the physical installation of ITS equipment such as roadside units. This familiarisation has resulted in AdB staff obtaining the necessary technical skills in the area of ITS technology installation and deployment.

4.4.2. Current Level of Digitalisation

In this section, the current Level of Digitalisation is presented for the interviewed organisations. In general, it was acknowledged, for the most part, that it is difficult to estimate the current Level of Digitalisation in detail over the course of a short interview, however more detail will be determined in the Phase 2 interviews whereby questions will be more focused on specific aspects of Digitalisation.

4.4.2.1 Austrian Motorway Road Operator (*ASFINAG*)

For the last a decade, *ASFINAG* has had an incident database in place and has been maintaining its own databases and data storage facilities and has developed both ITS messages and cooperative ITS messaging compatible with G5 Technology (ITS-G5). It is currently starting the rollout of G5 enabled roadside units for the entire motorway network.

More than 80% of its 2,200km network has CCTV coverage. On the open road, various sensors are installed to enable collection of traffic data, weather data and in some cases ground-based radar sensors for single-vehicle trajectory detection are in place. Tunnels are equipped with acoustic sensors, HD CCTV facilities and various incident detection sensors. Equally, *ASFINAG* provides digital maps of the network which contains landmarks in a digitised format.

ASFINAG are also involved in ongoing research, including the central fusion of digitised data which will be used for traffic observation in the future which will enable them to use V2X data via ITS-G5 by the end of 2019 or early 2020. It is expected that this type of data can also be used for incident management.

4.4.2.2 Finnish Transport and Communication Agency (Traficom)

Traficom indicated that the Digitalisation of the road network in Finland started more or less from the traffic management systems and a lot of work has been done in this area. Finland has a Government-Level Digitalisation plan and a robotization and Automation action plan from the Finish Ministry of Transport with a timeframe for implementation of 2020.

4.4.2.3 Federal Highway Research Institute (BASt)

The current Levels of Digitalisation are difficult to estimate in Germany due to the roles in their federal state structure. However, founded on 13th September 2018, “Die Autobahn GmbH des Bundes” will take over the planning, construction, operation, maintenance and financing as well as the asset management of motorways and federal highways from the federal states as from January 2021. From the federal perspective, this s an attempt to create a solution that is as uniform as possible across the 16 federal states

From a local perspective, BASt has ensured that data relevant to mobility is available to all actors involved in dissemination and value creation. For this purpose, BASt has the Mobility Data Marketplace (MDM), endowing offers in this marketplace with incentives, so that the database grows.

With DATEX II, this data is available in a standardized format. Whoever cannot supply data in this format, can use technical solutions and containers to provide other data formats. Essentially, this is a way for data providers to provide certain data, even if they are not necessarily required to.

BASt shares the goal to ultimately digitise all transport authority regulations. and is also interested in tackling this together with the neighbouring countries and the federal states involved.

4.4.2.4 Transport Infrastructure Ireland (TII)

TII has a GIS platform for the majority of their assets such as pavements, bridges, drainage and other infrastructure elements. This GIS data is primarily used in assisting in asset management.

TII has an ITS strategy in place and ITS equipment is deployed, particularly around the M50 Motorway, the main ring road around Dublin. It is in the process of developing a new strategy, to assess what, if any ITS, will be required in the future, particularly around the rural and/or more remote areas.

While TII are developing an ITS strategy and a CAV strategy they currently do not have a Digitalisation Action Plan. Given the wide range of areas covered by Digitalisation, TII are keen in the first instance to understand what specific aspects of Digitalisation are relevant to themselves. They are also unclear as to what information other Third parties, such OEM's and car manufactures require from themselves and noted that Third parties are not speaking directly to them.

In relation to data sharing, as a result of EU data directives, TII currently makes all the data they collect (traffic counts, speed data etc.) openly and freely available to the Public. There are generally no privacy and/or security issues with this data as it is not personal data. However, data that is provided to TII by Third parties is not available to the public. As such, not all of their GIS platform is available publicly.

4.4.2.5 Directorate-General for Public Works and Water Management (Rijkswaterstaat)

In the Netherlands, it was noted that in terms of physical infrastructure a couple of systems are in place. One such system is the motorway traffic management system which includes elements such as inductive loops, traffic flow measurements and automatic incident detection equipment. These elements enable traffic flow to be measured which can be used to trigger, for example, queuing messages and lane closures. This system is available on approximately one Third of their network, typically those roads with the highest AADT. Secondly, Infrastructure elements such as bridges, tunnels and water locks are digitised with dedicated control systems, particularly those elements which have been upgraded over the last two decades. Older elements, however, still use analogue systems. Other more complex systems, such as rush-hour lanes and dynamic infrastructure are also digitalised. About one Third of Rijkwaterstaat' s backend systems deal with information storage, data storage and data processing which feeds into their traffic management system.

Increasingly, the location of tolls, traffic lights and signs are put into a dedicated format that can be added/read by a digital map and as such they have a generic database of their road network, though the granularity can be limited so, for example, there is not a very reliable layer for every road sign (located to the Third digit) but they can identify the speed at each location on the network. This generic data base is a new tool, in terms of asset management, and assists Rijkswaterstaat to discharge their legal responsibilities in terms of knowing speed limits along a particular stretch of road.

Rijkswaterstaat has its main data feeds on dynamic information in the DATEX II format. It is also preparing to adopt the current data standards for messages - DENM that will be the standard for C-ITS warnings and CAM that is a vehicle message format.

4.4.2.6 Motorway Company in the Republic of Slovenia (DARS)

Infrastructure elements that are currently digitised include: roadside units/ devices such as weather stations, traffic counters, cameras and other sensors and VMS, road geometry and road elements such as road axis and relevant on-road objects (bridges, tunnels and traffic signs).

4.4.2.7 Swedish Transport Administration (Trafikverket)

The basic information of infrastructure elements is digitised on Trafikverket's road network and can be found in roadmaps. Trafikverket has built its own maps and these maps include digital information, such as for example, ITS equipment, VMS on traffic signs, traffic lights, tunnels, speed limits, regulations, temporary regulations, type of roads, number of lanes and road direction. In Sweden, there is also a national road database that has not only information about the national roads but also information for the municipalities and all other roads holders/ authorities. This results in the basic information for the whole road network in Sweden being defined.

However, not all the digital information is available to external users. Trafikverket is planning to make the information available to Third parties in 2021 through a data exchange platform. To this point, Trafikverket believes that there is a lot of information that can be used from various people for various purposes, but it is not aware of what kind of information is specifically available. Trafikverket initially wants to provide all the physical and digital infrastructure elements in digital format in 2021 which will be read by vehicles or by any mobile devices.

Trafikverket intends to focus on how this information should be available to Third party considering cyber security and security issues in general. Hence, Trafikverket is going to aggregate this data in a context that it does not jeopardise the regulations (such as through GDPR for instance). Trafikverket is looking at the possibility of having connected road infrastructure in 2025.

In terms of messaging, Trafikverket notes that previous studies have shown that the existing communication technologies such as for example, 3G and 4G works properly and has good coverage in Sweden.

4.4.2.8 Highways England (HE)

In England there are seven regional control centres and one national control centre that manage the road network using technology such as for example, variable message signs and speed limit indicators. There are a lot of Building Information Models (BIM) and information related to location and existing technology on the road infrastructure available on newer schemes. However, how that information could support an autonomous vehicle on the road is a question that needs to be answered, and also their role in that process. Critical safety traffic information is recorded with more or less 100% coverage over the network, with the network being equipped with message signs, CCTV cameras, and inductive loops and weather stations where everything is recorded into a GIS environment. However certain information, like weather station data, is not so well recorded and the information available is fragmented.

One of the major ways that HE is digitising the road network is through the use of LIDAR. They have a lot of aerial and ground data from LIDAR and collecting this type of data is expected to continue for the next three years. This is an ongoing strategy to keep the Strategic Road Network (SRN) updated and virtualised for its actors. For example, this will assist OEMs if they want to test a new technology in a virtual environment.

4.4.2.9 The Ministry of Transport of the Czech Republic

Their main activities in the area of Digitalisation are within the C-Roads platform where C-ITS is under implementation on the Czech Roads. Within the C-Roads Czech Republic project, C-ITS systems will be deployed not only on the D1, D5, D11 motorways, but also in cities and urban public transportation areas or on railway crossings. Eight main partners are involved including AŽD Praha, ČVUT, INTENS Corporation, O2 Czech Republic, T-Mobile, ŘSD, SŽDC and Brněnské komunikace.

Testing of existing and new mobile technologies for the mutual communication between vehicles equipped with cooperative technologies will be an important part of the project. This includes LTE-V testing in the T-Mobile and O2 network which will verify the technical capabilities of hybrid vehicle units for automatic data communication between vehicles. BKOM will focus on C-ITS equipment of the access radial roads to Brno, INTENS is dealing with technical coordination and standardisation and ČVUT focuses primarily on the evaluation of test outputs. Testing is already under way on a motorway section of the Prague Ring Motorway between Mirošovice and Rudná (parts of the D1, D0 and D5 motorways) where communication units were installed on the infrastructure and on selected vehicles belonging to ŘSD.

Czech C-Roads will deploy hybrid communication based on ITS-G5 and cellular technologies. A detailed Use Case catalogue covering all Use Cases and their respective scenarios has been developed within the C-Roads. The Use Cases that are going to be implemented within the project are: road works warning, in-vehicle information, probe vehicle data, slow and stationary vehicles, emergency vehicle approaching, traffic jam ahead warning, intersection signal violation, public transport preference, hazardous location notification, weather conditions warning, railway Level crossing, public transport safety and electronic emergency brake light.

The C-Roads Czech project does not target only C-ITS motorways. Road traffic data exchange between vehicles themselves and road infrastructure also considers Public Transport vehicles. The cities of Ostrava and Pilsen are among the first European cities where C-ITS is implemented within the fourth stage of the C-Roads Czech Republic project.

4.4.2.10 Autostrada del Brennero (AdB)

AdB has developed a C-ITS server that makes use of the information from the Traffic Control Centre and DATEX II and transmits the information to roadside units. AdB has 53 roadside units at the moment, soon to be increased to 60 units.

AdB is developing a hybrid communication, as specified in C-Roads with its telecommunication partner, Italian Telecom, who are working on cellular communication. Moreover, AdB is focusing on cross-border issues where discussions with ASFINAG are taking place on how to evaluate cross-border interoperability tests and what can be tested, such as, for example, truck platooning and highway chauffeur.

4.4.3. Expected Level of Digitalisation

The action plans of all organisations in the area of Digitalisation are discussed in this section. That sections covers any action plans, their corresponding timeframe and the future of the Digitalisation of road infrastructure up to 2025 and beyond to 2040.

4.4.3.1 Austrian Motorway Road Operator (*ASFINAG*)

ASFINAG has already taken the necessary steps to facilitate digitalised content management. There is a timeline of two years to obtain more information and to develop a different approach in a new kind of traffic management. With respect to future applications, *ASFINAG* intends to have V2X and ITS-G5 message information in place by end of this year and are working on deploying services for connected and automated vehicles within the next 3 to 4 years. *ASFINAG* also provides traffic information, over their DATEX II feed to service providers such as TomTom, HERE and INRIX.

Looking ahead, *ASFINAG* is of the opinion that NRAs will start digitalising their traffic data and creating their own incident management data as well as learning how to collect data in general from the networks. Up to 2025, *ASFINAG* believes that a communication path will start in which all actors will provide information via visible message signs. They are of the opinion that at this stage it is not important which technology will be used but rather vehicle-to-infrastructure communication needs to be deployed in a step-by-step manner to get some initial insights into how it works and what needs to be further developed.

A higher penetration rate of connected and automated vehicles is expected beyond 2040. New strategies will be developed and a new kind of Digitalisation of NRA business with respect to V2V communication will emerge whereby the infrastructure will provide less data transmission and automated vehicles providing more data for utilisation by the NRAs.

4.4.3.2 Finnish Transport and Communication Agency (Traficom)

Traficom, from a data analytics perspective, is moving from decision support to actually making predictions using artificial intelligence, whereby they utilise machine learning techniques of the produced data for predictive analytics of traffic data.

Traficom argues that from that predictive information, it can estimate what actions, such as maintenance strategies, can be implemented on their road infrastructure. A lot of data is expected to be received from the road infrastructure and users though cloud networks to assist in the data analysis.

4.4.3.3 Federal Highway Research Institute (BASt)

From the ministry's point of view, there is an ITS action plan, for Digitalisation of road infrastructure which refers back to the ITS Directive. The measures announced there will be implemented, but the plan dates back to 2011, and therefore has already existed for a number of years.

The Action Plan was created as a reflection of the ITS Directives. The Commission was given the right to adopt delegated acts for seven years. Very recently, a work programme was adopted to extend this right over time which implies that within the unchanged scope of the ITS Action Plan at European Level, the Commission has the right to adopt delegated acts for a further five years. From this perspective, and at the same time with regard to developing a possible platform for connected, cooperative and automated mobility, the Federal Ministry of Transport and Digital Infrastructure (BMVI) will also launch an expert group next year in 2019.

The Mobility Data Marketplace (MDM) is initially designed for the exchange of dynamic traffic data. Ultimately, what BASt considers as central point is the highly accurate dynamic reference map. BASt sees a responsibility for the public sector here, especially when it comes to equipping this dynamic event layer. There is a range of information, which is generated from the infrastructure and which must then be integrated.

BASt will have made considerable progress in many areas of Digitalisation by 2025. It will see a significant improvement in the availability of communication compared to the present day. The 4G network will be seamlessly expanded, and the first 5G applications will emerge. It expects to have started digitisation as part of a wider movement and agreed on the relevant formats that will go with it. This preparatory work corresponds to application-oriented standardization. However, it is noted that this would not be finalised by the end of 2025 and the work will be continued until 2040 though it was noted that it is difficult to make forecasts more than two decades into the future.

4.4.3.4 Transport Infrastructure Ireland (TII)

As a priority, TII is currently focusing on the further improvement of physical infrastructure elements, namely both on the road and the communications infrastructure and the requirements for the same. This is considered particularly important when planning new roads. In this regard, Physical infrastructure comprises not only lane marking, gantries and VMS but also parts of the communications network such as fibre optic cables on the verges of roads, safety barriers, signage and power requirements to name but a few.

Subsequently, it will focus on the digital infrastructure and the relevant data that is transmitted and how this data is transmitted and used after which a digital infrastructure action plan will follow with regard to data management and governance.

However, it is unclear at present what digital technology is required such as the type of communication technology 3G, 4G, 5G, ITS-G5 or a hybrid of both and TII is reluctant to invest when uncertainties remain in respect of the most appropriate ITS technology/ equipment to use.

Equally, TII is also trying to understand the user’s and the vehicle requirements.

4.4.3.5 Directorate-General for Public Works and Water Management (Rijkswaterstaat)

In the Netherlands, Digitalisation is a topic in Rijkswaterstaat that is much broader than roads alone as Rijkswaterstaat is also responsible for all water works, the shipping network, water protection, dykes and levees. Rijkswaterstaat has an action plan for Digitalisation entitled I-Strategy which covers the period up until 2025, but there is a longer-term vision behind that plan. They also have a number of strategic documents; specifically, for traffic management such as the Traffic Management Roadmap.

Rijkswaterstaat believes that the automotive industry will struggle to use a high-speed connection for all kinds of applications because if, as long as there is a human in the loop there is a very much limited amount of information that a human can process. The industry will also struggle to really provide self-driving services or self-driving Use Cases because it can be difficult and will take time. The first thing Rijkswaterstaat sees is that OEMs will be able to provide the road users with some kind of autopilots.

While 5G is considered a quicker and faster version of 4G and provides a higher internet speed, Rijkswaterstaat does not think that 5G will need to be that much of a gamechanger because there is a limit to the Connectivity speed needed for data transfer. Rijkswaterstaat believes that what is really needed is a low latency and high reliability and full coverage connection. In the event that 5G is a gamechanger, road users would still need full coverage and a very low latency to be able to process live video from a vehicle and be able to run a distant, while centralised, artificial intelligence control unit on it.

Rijkswaterstaat argues that the connection/communication issue is more of a telecom sector problem that it will not be able to really solve. This can be justified by the fact that the public has up until now been quite far removed from full coverage at 4G and the investments need to be made by the telecoms sector who have a very tough business case to fulfil and are now looking at the automotive sector, and the transport sector to provide that business case but Rijkswaterstaat does not think that is going to happen.

4.4.3.6 Motorway Company in the Republic of Slovenia (DARS)

A Digitalisation action plan (C-ITS) will be developed as part of C-Roads where the first phase will start 2019.

4.4.3.7 Swedish Transport Administration (Trafikverket)

Trafikverket is currently preparing a well-functioning platform for data exchange. Trafikverket does not only provide data to users but also, it is collecting data for its business purposes. Trafikverket wants to define what kind of data it would like to have it in the platform. Trafikverket has established the processes and routines, which are good enough and robust enough to assure a constant exchange of good data for use by various parties. It has to address security integration issues, GDPR issues and car interpretations, regarding data, and organisational data when it is needed, and it is expected this will happen in 2025.

However, Trafikverket also has connected infrastructure where 5G communication technology will be introduced in 2020. For instance, when it comes to goods transportation, Trafikverket sees lot of concepts coming in 2025 such as driverless trucks and the control towers, which are very low in maintenance, which can help goods transport. there will be much more signals. Beyond 2040, Trafikverket expects more business models for affordable mobility for people and also safer mobility and environmentally-friendly types of innovations in cities.

4.4.3.8 Highways England (HE)

HE expects, from a road infrastructure perspective, to be in a better position to understand exactly what is happening on the road. Digitalisation of its road network would mean that whatever is happening on the network would be in the digital twin. That digital twin can then be passed on to others such as the car manufacturers and its maintenance contractors.

HE has a Digitalisation action plan in place which considers moving some of the services they operate to cloud-based services. Most of these services are currently being automated and it is expected that these services will help anyone with a vested interest or a need to enter site data or make a change to have that process carried out quicker, automated and to a much better validated state.

HE is particularly interested in developing a BIM with digital roads that will be available in the cloud. That service is expected to support future autonomous vehicles as they are using the road. However, that service is not available at the moment and its deployment needs further investigation.

In terms of their traffic data, HE follows the European ITS standards. However, it is still very unclear to HE, which standards will be followed, and it is acknowledged that further investigation into the standards is required as it progresses to full Digitalisation of road infrastructure.

HE noted that it is unsure if 5G communication will exist by 2025 and if it is a gamechanger though they have seen a lot of evidence that actually 5G is promising.

4.4.3.9 The Ministry of Transport of the Czech Republic

There is no specific Transport Digitalisation Action Plan in the Czech Republic. However, the topic of Digitalisation is covered in the Czech Republic up to 2020 (with prospect of 2050) within the national ITS Action Plan, the ITS Road Development Action Plan. This is a strategy document for the use of diagnostic, information, control and security technologies, based on ITS, GNSS and Earth observation detection systems.

This document analyses the development status of ITS and points out persistent problems in ITS operation in the Czech Republic, thereby providing a comprehensive overview of the current situation. The Action Plan also sets out a vision of the ideal state of ITS operation and on that basis proposes the measures necessary to progressively improve the current situation, not only from a technical point of view but also from an organisational point of view, in order to improve the interdependence of the individual transport modes. This vision gives rise to the global goal of ensuring smooth, safe and energy-efficient transport.

Up until 2025, the Czech Republic expects Automation Level 3 and autopilots in certain situations. It was noted that this is hard to predict, but under the current circumstances it is likely this will be more realistic up to 2030. At this point it is anticipated that Automated cars will be on the road but in mixed traffic conditions with C-ITS fully implemented. Equally, while it is expected that many people will still like to drive their own car on their own, a driver can be fully informed in advance of a risk situation in road traffic due to the availability of early-warning messages. Therefore, the driver will be able to react in a timely manner and to take the best action at an early stage (according to their abilities and skills).

4.4.3.10 Autostrada del Brennero (AdB)

Along the Brenner Motorway, the Digitalisation of road infrastructure started in 2011. AdB’s current plans are mainly related to relevant European projects, especially the C-Roads platform. There is also a national plan, called Smart Road Decree, which is a set of guidelines that will support the preparations of operators and manufacturers (such as for example, a list of ITS related services which will be implemented until 2025 and 2030).

Within 6 years, up to 2025, it is expected that Italy will be ready for ITS-G5 and 5G communication technology at the maximum Level of development. Many road operators will be digitalised to a high degree. ITS-G5 is feasible now, while 5G is possible in certain sections of road. The biggest issue will be deployment but having the road network prepared by 2025 for Digitalisation is not seen as a problem, however it is acknowledged that further investment is required, and legal issues need to be solved.

4.4.4 Current Level of Automated Driving

Similar to the current Level of Digitalisation on road infrastructure, in this section, the current action plans and systems/ processes that are currently in place are presented for the interviewed organisations.

4.4.4.1 Austrian Motorway Road Operator (*ASFINAG*)

ASFINAG has some ideas in the area of Automated Driving but the real action plan is quite difficult to define since the technology is not fully deployed. It is currently trying to be active in ongoing platforms such as C-Roads, The CAD CAV forum and Air Truck. Nevertheless, *ASFINAG* has research projects ongoing for the next 3 to 5 years, and in parallel, it has internal strategic working groups to try to develop an action plan for Automated Driving. However, it's still difficult since not all the information is available. It is also participating in projects related to traffic management and physical elements which can be part of HD Maps. These are all related on how to get the information which *ASFINAG* currently has in an even more digitalised way, and how to prepare it for automatic vehicles, or connected vehicles.

ASFINAG has started the deployment of C-ITS ITS-G5 on the whole Austrian network though currently operates a living lab around Vienna and Graz with each lab covering about 20 km.

4.4.4.2 Finnish Transport and Communication Agency (Traficom)

In the area of Automation, there is a specific action plan for the Government Agency which Traficom is about to study and prepare for Automated Driving. The timeframe of the first phase of that action plan has just ended and the next phase is commencing. This was a two-step action plan where the first actions are to be taken by 2019 where recommendations were made for 2019 and 2020. An evaluation of the first step will be started this year to establish the next steps.

4.4.4.3 Federal Highway Research Institute (BASt)

The Federal Ministry of Transport and Digital Infrastructure has published a strategy on Automated and Connected Driving in 2015 (Strategy for Automated and Connected Driving, 2015). A strategy implementation report has been published in 2017 (Report on the Implementation of the Automated and Connected Driving Strategy, 2017). BASt has published a collection of the research questions in the context of Automated Driving which has been pivotal for the Round Table on Ministry Level (Bericht zum Forschungsbedarf Runder Tisch Automatisiertes Fahren - AG Forschung, 2017). Within BASt itself, several sections are dealing with Automated Driving as such and its different sub-aspects (e.g. sections Automated Driving and Connected Mobility within Automotive Engineering Department, sections Highway Equipment as well as Traffic Management and Road Maintenance Services within Traffic Engineering Department). A number of testbeds in different Operating Environments is available for testing Automated Driving (Digital Motorway Testbed A9, Cross-Border: Franco-German-Luxembourg Digital Testbed, Digital testbeds in various German cities, see https://www.bmvi.de/EN/Topics/Digital-Matters/Digital-Test-Beds/digital-test-beds.html).

4.4.4.4 Transport Infrastructure Ireland (TII)

TII is currently developing a CAV strategy for the national roads with short, medium- and long-term actions and it intends to update the strategy as required. The short-term strategy spans over one to two years while a five-year period is considered for the medium-term strategy. Primarily, they are investigating what they need to do with respect to the physical infrastructure which includes both on the road and communications infrastructure. Subsequently they will investigate the digital data requirements, but they are waiting for European Standards to inform them in this regard. At present, TII's remit in respect of their CAV strategy is to facilitate the deployment of CAV and it plans to publish the strategy within the next year or so. To assist them in this approach TII are looking to carry out a C-ITS project.

It was noted that there are currently no infrastructure elements on Irish roads or systems/processes that can support Automated Driving, though they are looking at these areas for future roads. TII does not yet fully understand the impact of CAV on user behaviour and notes that this can be hard to predict. For example, potential questions arise such as does CAV result in more cars on the roads and are CAV going to detract users from the public transport system? This could have negative impacts on demand as road space is a limited resource. Another noted area of uncertainty is user acceptability. The Road Safety Authority are conducting surveys on aspects of CAV in areas such as social acceptability, ethics and safety but in a survey conducted last year the majority of respondents indicated that they would not trust an automated vehicle. As such it will take time to achieve social acceptability.

4.4.4.5 Directorate-General for Public Works and Water Management (Rijkswaterstaat)

The Netherlands do not have a separate roadmap for Automation however they do have some more generic concepts on how they see Automation coming into their system.

From the perspective of Rijkswaterstaat, there are not many systems/ processes currently in place to facilitate the use of automated vehicles on the road network. However, there is a legislative framework in place for allowing Automated Driving tests.

Automated vehicle tests on the Dutch road network can only be conducted using a vehicle type approved vehicle, which must be approved by the Dutch Ministry and Road Manager to enable testing to be conducted in line with safety and security requirements.

Although Rijkswaterstaat has a quite broad generic data feed that is publicly available, at the moment it does not provide anything specifically aimed at automated vehicle tests. Rijkswaterstaat also has test labs at European Headquarters, but it does not have OEMs to bridge its testing on its road network. Rijkswaterstaat are currently at the level of discussing with the relevant actors on what would be needed to facilitate Automated Driving.

A main reason why it does not have anything specifically in place for automated vehicles is because it does not know at this point what type of information automated vehicles will require. Equally, there remains the question of how to justify a business case to invest in generating and supplying the data when it is currently uncertain whether that is in the remit of the NRA or the private sector. Equally, it was noted that while having a highly developed road management system can be advantageous, it can also be a disadvantage because if they are preparing or developing new operations it can be difficult to change their course of operations.

Change would also incur a large investment in this area and Rijkswaterstaat does not have a clear view on what they would need to change on their operations.

4.4.4.6 Motorway Company in the Republic of Slovenia (DARS)

In Slovenia, the systems/ processes, that are currently in place to facilitate the use of automated vehicles on the road network are central traffic information systems, tunnel systems, VMS systems and C-ITS interfaces to generate different traffic messages from different sources. All of these systems were developed within the C-Roads pilot projects.

4.4.4.7 Swedish Transport Administration (Trafikverket)

Trafikverket does not have an action plan for Automated Driving. However, it is focusing on Automation and Digitalisation to make sure that it is moving towards its goals, particularly on how to provide accessibility to all in a sustainable society. Automation is viewed as just one component that can be used to achieve this course. Trafikverket’s objective is not to make sure that it builds its roads for cars which are automated but to make sure that people can move seamlessly.

4.4.4.8 Highways England (HE)

HE does not have an action plan in place for Automated Driving. However, England was and is involved in many C-ITS and Automated Driving projects mainly though the TRL global centre for innovation in transport and mobility, the Meridian mobility cluster and C-Roads UK.

HE has not done anything specific in relation to automated vehicles. They note that there is not currently any technology that would support the functionality of any part of Automated Driving and there is no infrastructure that supports the necessary communication requirements. There are some messages that can be picked up by gantries, but the communication standards are very basic, and HE believes that it will not be able to leverage the full efficiency out of the road network, if it does not have decent Connectivity.

There is a UK site project which is using ITS-G5, LTE (Long Term Evolution) and LTE-V. The PC5 is the vehicle-to-vehicle infrastructure system and the A2/M2 project is using ITS-G5, which is also looking at hybrid technologies. Furthermore, the freight platooning project is using a standardised version of the platooning system that’s being produced by one of the big manufacturers that is working off a European standard. Hence, in this regard, from the vehicle side, HE is following the standards provided by car manufacturers’ OEMs.

4.4.4.9 The Ministry of Transport of the Czech Republic

In 2017 the Czech Ministry of Transport established the “Platform for fully automated vehicles” with the main goal to define a general vision and the goals for Automated Driving at the national level agenda. 200 actors from industry, public sector and academia participated in the platform. Divided into different working groups the stakeholders discussed legal aspects, social and ethical issues, the technology of Automated Driving, transport and digital infrastructure, security and spatial data, piloting and conformity assessment. Based on the contributions the “Vision of autonomous mobility deployment” was elaborated by the Czech Ministry of Transport, which was approved by the Czech government in October 2017. The document is part of the wider strategy of the Czech government to support further development of the Czech automotive industry and contains several main areas to focus in the upcoming years.

The next step in the implementation of the Vision is the elaboration of an “Automated Driving Action Plan” and the approval of the Czech government. This was planned for the end of 2018, but at the moment the Third round of internal consultation is on-going, therefore this step has not been finalised. This Action Plan will include around 50 measures (technical, organisational, legal, societal oriented). A version approved by the Czech government should be published in March/April 2019. The Action Plan will cover a timeframe up to 2030.

Automated vehicles up to SAE Level 3 are being tested in the Czech Republic. The very first automated car (with a human driver able to take over control in case of a need) was under operation on the motorway between Prague and Liberec in 2015. There is no dedicated testing infrastructure for testing of automated vehicles on public roads. It was noted that the testing for Automated Driving up to SAE Level 3 has not been problematic to date.

Higher levels for Automated Driving are currently under preparation. At the moment, an opportunity to allow testing of automated vehicles of SAE Level 4 on motorways and SAE Level 5 in cities is being verified and the legal process has started. The goal is to create an environment where Automated Driving is working but there are many non-technical issues to solve in this context, like organisational, legal and reliability aspects.

According to the current legislation of the Czech Republic, the responsible person (driver) must be in the car to handle respective vehicle controls – devices that are not handled by a person is not permitted. Currently there are certain requirements in place for operating vehicles on roads (i.e. vehicles must be approved). However, it is permitted to use not type-approved road vehicles on infrastructure but only with approval of the Ministry of Transport when conducting test runs during development phase, production or approval of road vehicle, its systems, components or independent technical units. The Ministry of Transport may allow operation of a vehicle if the applicant documents the ability (from the perspective of technical equipment, staffing and organizational structure) to ensure that road safety, environment or health and life of humans will not be threatened in the course of test runs. The Ministry of Transport may also set the conditions for test runs.

4.4.4.10 Autostrada del Brennero (AdB)

At the moment the major topic for AdB is connected vehicles, however it is trying to facilitate Automated Driving in the future, though it has not been their main focus at present.

4.4.5 Expected Level of Automated Driving

In the previous section, the current Level of Automated Driving is presented. In this section, the future plan of the organisations with respect to Automated Driving in timeframe up to 2025 and up to and beyond 2040 is presented.

4.4.5.1 Austrian Motorway Road Operator (*ASFINAG*)

ASFINAG expects that highway pilot will be able to have simple lane-keeping and lane changes if the traffic flow is not that high by 2025. Beyond 2040, *ASFINAG* sees much more functionalities such as for example Level 3 and Level 4 vehicles entering and exiting the motorway and being capable of dealing with a combination of different situations on motorways such as highway pilot, and poor weather situations (i.e. poor light, rain). However, *ASFINAG* believes that, in reality, it will still take a lot of time before Automation Level 5 is available, even up to 2040.

4.4.5.2 Finnish Transport and Communication Agency (Traficom)

Traficom believes that it will be an advance step if the vehicles will be moved from Level 2 to Level 3 up to 2025. Level 4 will be more common in the next decade, i.e. after 2025. Traficom is not sure if Level 5 can be achieved in the future, considering the current research and professional studies ongoing. However, it believes that a high-Level, Level 4, can be available in the future.

Traficom acknowledges that the key issue for Automated Driving is that the automated vehicles will be connected to the whole public transport system. If the automated vehicles are not connected to the services, it argues that Automated Driving could have a negative impact on the traffic system.

4.4.5.3 Federal Highway Research Institute (BASt)

According to BASt, an evolutionary process for Automated Driving will take place with the first applications on the market by 2025. By 2040, these applications will have become standard. BASt are of the opinion that If you agree on certain specifications and the technical progress is scalable, then you have the best prerequisites for a strong impact of the technology.

BASt, believes that a regulatory framework (guiding boundaries) will continue to be important in the future but wonders whether the regulatory framework needed for this area and for society will be much smaller in the coming decades than it is at the moment. The depth of regulation will potentially decrease sharply. This is because technical progress has accelerated, and it takes time to draw up an appropriate framework. This speed is a great challenge, which the public sector can may find difficult to cope with.

4.4.5.4 Transport Infrastructure Ireland (TII)

TII believes that by 2025 vehicles will be connected but is unsure whether they will be automated, and more than likely mixed traffic conditions will occur between 2025 and 2040. A full fleet of connected and automated vehicles may exist at Level 4 after 2040.

4.4.5.5 Directorate-General for Public Works and Water Management (Rijkswaterstaat)

Rijkswaterstaat does not currently have an action plan for Automated Driving, nor a separate roadmap for Automation though it does have a plan in terms of its provision on the future traffic management. It has some more generic concepts on how it understands Automation coming into their system.

Rijkswaterstaat believes that robot taxis will be introduced first, though possibly outside Europe where there is more of an inclination to make drastic changes to their mobility networks. It is believed that European manufacturers will firstly introduce partially automated vehicles, hopefully to Level 4 that will provide road users with autopilot functionality, so vehicles will be able to do either not-too-complex driving on the motorway network in normal situations or traffic jam assistance in certain situations.

Those functionalities will slowly expand their scope and become available for more and more situations and OEMs will slowly add new functionalities. In terms of fully-automated vehicles, Rijkswaterstaat believes that Level 5 Automation will probably happen somewhere between 2030 and 2040.

Rijkswaterstaat believes that the self-driving system is going to be quite optional by 2025 and the real game-changer will be, in specific, organised areas where people have robot taxis coming onto the scene. Another real game-charger might also be vehicle sharing.

4.4.5.6 Motorway Company in the Republic of Slovenia (DARS)

In Slovenia, an action plan pertinent to Automated Driving has not been established yet. However, DARS believes that automated vehicles will be introduced in certain areas of transport by 2025. It also expects that up to 20% of vehicles on its road network will be automated by 2040.

4.4.5.7 Swedish Transport Administration (Trafikverket)

Trafikverket believes that in 2020 to 2040 Automated Driving will be realised in its cities. Trafikverket expects there will be co-existence between vehicles driving on those streets and together with the vulnerable users like pedestrians and bicycles. Trafikverket also sees that people will not need to own a car. Instead, they can get access to different types of vehicles, for various use depending on what they need at that time. Thus, a much better use of transportation system will emerge where there are more types of public transportation systems in operation.

4.4.5.8 Highways England (HE)

HE has currently no plans for Automated Driving. HE would like to get involved in those types of initiatives with the ultimate objective to understand how Automated Driving can improve road safety and traffic flows. They feel the big prize of delivering Automated Driving is to work towards a near-zero road fatalities on its road network. For instance, if vehicles have got automated braking, they’re able to maintain a safe headway between the vehicles in front.

4.4.5.9 The Ministry of Transport of the Czech Republic

In 2017, the Czech Ministry of Transport established the “Platform for fully automated vehicles” with the main goal to define a general vision and the goals for Automated Driving at the national Level agenda. 200 actors (from industry, public sector and academia) participated in the platform. They are divided into different working groups discussing legal aspects, social and ethical issues, technology of Automated Driving, transport and digital infrastructure, security and spatial data, piloting and conformity assessment.

Based on the contributions, the “Vision of autonomous mobility deployment” was elaborated by the Czech Ministry of Transport, which was approved by the Czech government in October 2017. The document is part of the wider strategy of the Czech government to support further development of the Czech automotive industry and contains several main areas of focus in the upcoming years.

Next step in the implementation of the Vision is the elaboration of an “Automated Driving Action Plan” and the approval of the Czech government. This was planned for end of 2018, but at the moment the Third round of internal consultation is on-going, therefore the finalisation of this step is postponed. This Action Plan will include around 50 measures (technical, organisational, legal, societal oriented). A version approved by the Czech government should be published in March/April 2019. The Action Plan will cover a timeframe up to 2030.

At present the “Catalogue of road sections, determinated for automated vehicles in regular road traffic”, is under development. The Czech Ministry of Transport launched this activity which is being carried out by the Transport Research Centre, a public research organisation funded through the agency of “State Fund for Transport Infrastructure”. The purpose of the catalogue is to allow automated vehicle tests in road traffic situations in normal conditions of use in the Central European region.

This catalogue will consist of test areas which will be divided into test segments and test sectors. Test segment represents road segment with unified parameters from the perspective of construction, road signs, ITS, and transportation (e.g. speed limit). Test sector constitutes a part of a city or a town allowing testing specific type of behaviour, e.g. housing estate for tests of the priority to the right under more difficult conditions or shopping centre's parking lot for tests of specific road traffic.

Test segments and sectors usually create a unified and connected circuit however, they might contain separated sectors and/or segments. There are 2 test areas under consideration: 1 in Bohemia and 1 in Moravia and Czech Silesia. It is proposed to test a particular road situation including circuits around specific places, e.g. railroad crossing, tunnel.

4.4.5.10 Autostrada del Brennero (AdB)

AdB believes that it is too early to estimate the future of Automated Driving by 2025 since there are a lot of gaps and uncertainties in this area. However, they feel that Automated Driving is feasible for 2040, depending on political and legal issues and the willingness of the decision makers.

4.4.6 Current Level of Interoperability for Automated Driving

In this section, the current level of interoperability for Automated Driving is presented between the interviewed organisations and Third parties. The barriers of interoperability are also discussed and the main organisational changes that they need to implement to overcome these problems.

4.4.6.1 Austrian Motorway Road Operator (*ASFINAG*)

Though there is a common understanding of ITS-G5 communication, which exists in the Amsterdam Corridor (ECo-AT project) and *ASFINAG* collaborates with some partners and Third parties for testing ITS-G5 messages with the PKI around Vienna, they believe that interoperability is one of the biggest challenges in the upcoming years. *ASFINAG* has started testing ITS-G5 and it wants to do address interoperability issues related to services for Automated Driving in the area of Graz in the next year. They note that there is also a need have interoperability with cellular service interfaces.

They note that there are two sources of traffic information, one from vehicles and the other from traffic management centres. However, it is still necessary to get a clearer picture of interoperability. The problem, as they see it, is that both the road operators and the vehicles have different sources of traffic information. This means that the vehicles may get some misleading information or not-aligned information or receive conflicting messages/advice from different sources which could have a negative impact on the traffic flow.

To overcome this, they suggest that data has to be provided for free or at least for the minimum fee, particularly for road safety data which should be widely available for common use.

4.4.6.2 Finnish Transport and Communication Agency (Traficom)

Traficom has an automated collaborative group which has discussions with private industries and research to resolve any interoperability issues and research centres, industry and OEMs collaborate with Traficom though their involvement on projects. Hence, Traficom believes that it has a quite close collaboration with Third parties.

Areas in which Finland is cooperating in this regard are the EU EIP 4.2 - Facilitating Automated Driving, which Finland is leading. It is also working closely with L3Pilot where OEMs and Port Authorities are working together on the solutions for Digitalisation and infrastructure. Traficom believes that there is good interoperability and collaboration in the area of Automated Driving and further note the importance of this.

Traficom notes that industrial partners do tend to keep their own data from the field operational tests and as such there is some lack of interoperability in respect of data. Equally, this lack of interoperability with respect to data can also be explained by the fact that it does not know what kind of data will be needed or what kind of infrastructure will be needed to support that data.

4.4.6.3 Federal Highway Research Institute (BASt)

BASt note that they are aiming to create harmonised and coherent collaborations amongst its actors. These collaborations focus on how the infrastructure can support the deployment of Automated Driving, such as for example, the ODD.

On the other hand, the departments which are more active on the vehicle side work closely together with industry to prepare requirements that arise from the state perspective and regulatory environment. These include, for example, questions of takeover times i.e. at the point at which the vehicle is no longer to be driven automatically and the human driver has to take over again. It then becomes a question as to whether these times can be trusted, and can they be taken or are they taken from various literatures and publications and/or can they be confirmed by independent tests? BASt sees this as one of their central tasks to overcome.

They noted that every sector, both industry and the public sector, starts from their point of view. However, all this needs to come together in connected and automated traffic, which ultimately has a systemic character, but it is not yet clear, and foreseeable, how overall responsibility will be organised in this system. There are cross-sectoral responsibilities and they note that it is a good first point to have cultural openness, to talk to each other and to tell each other what is going on and thus create certainty on how everything fits together. This transparency is something that is not only required but must also be desired by the relevant actors.

They also note that for institutions that are not in competition, interoperability is easier to achieve than for other actors. However, a lot of work still has to be done before they have a common understanding. For example, the ODD is the core for licensing, but there is no industry reference point, so vehicle's ODD has to be guessed at the moment.

4.4.6.4 Transport Infrastructure Ireland (TII)

TII noted that there is no interoperability between themselves and Third parties. At present, they don't know who will be collecting the data, but it is expected that roles and responsibilities related to data management are expected to come from their digital and data strategy.

4.4.6.5 Directorate-General for Public Works and Water Management (Rijkswaterstaat)

Rijkswaterstaat is uncertain if there is lack of interoperability with respect to Automated Driving. It believes that the developers will be questioning whether Europe is consistent or not. For example, if a phone is sold in all of the European countries, the manufacturer should provide it in all the different European languages and if a user opens the phone for the first time, he/ she chooses his/ her language, but in essence there is no difference between the phones. Rijkswaterstaat thinks that the same approach should be applied to an automated vehicle operating in a specific country. For example, if a road user was to drive in France, Italy and Great Britain, where the physical appearance of the infrastructure is different, then all those items should be integrated in an online vehicles system along with traffic regulations signage. The challenge then for the road authority is to develop a single standard for providing the digital representation of those systems.

Rijkswaterstaat argues that it would be really valuable to find a way or some language that would actually provide the physical and digital representation data on. Thus, this is one of the problems that Road Authorities should solve and find a joint centre for data provision and do the digital representation.

4.4.6.6 Swedish Transport Administration (Trafikverket)

Trafikverket believes that the current Level of interoperability is the same as in most of the European countries. Trafikverket allows data transfer through its channels and service providers such as TomTom, HERE and WAYS who are usually downloading the data they need from its open source in standard format.

Trafikverket argues that there is no lack of interoperability between the data that it has and can be provided to whoever wants to use it. However, interoperability is needed for Automated Driving.

4.4.6.7 Highways England (HE)

In terms of interoperability, HE utilises DATEX II standard/ platform for the data that it needs, and it publishes its data, in XML format, on the government data portal. It also has a number of ways of exchanging data.

In general, they feel the Level of interoperability is good since HE has developed long-term relationships with different providers over the years. All its data is available to be used, free of charge.

The issue at the moment is the possible shortcomings in Connectivity so they won't be able to leverage the full efficiency out of the road network that that could be possible if they did have that Connectivity.

4.4.6.8 The Ministry of Transport of the Czech Republic

In the case of the Czech Republic, at present, there is little cooperation and data exchange except from C-Roads. In the future, the Ministry of Transport believes that it is necessary to establish more cooperation and data exchange. An important issue is the reliability of data in order to facilitate and enable the vehicles' ODD. The road operator must also receive the substantial information required to manage their roads and to set appropriate actions in case of incidents.

It believes that more testing is needed to understand what information is provided, what incidents happen and what adaptions are necessary. Based on this operational requirements/operational chain of the road traffic process, it will be clearer what kind of information is provided from which entity to which entity and to what Level of detail.

4.4.6.9 Autostrada del Brennero (AdB)

In the case of C-ITS services, interoperability in Italy means that AdB has to collaborate with other motorway operators. AdB is also trying to liaise with the Austrian operator, ASFINAG and the A4 motorway operator.

There are different aspects to be considered in relation to the topic of interoperability. Firstly, AdB believes that the mindset has to change, i.e. NRAs and relevant actors should be more cooperative. In principle, information could be exchanged, but the mentality shift is crucial. AdB has already started collaborating with other actors, however, a closer collaboration is necessary from all actors to facilitate the deployment of both Digitalisation and Automated Driving on the Italian road network.

At present, AdB has a cooperation with operators and OEMs/ car manufacturers. However, the other involved actors are not used to sharing their data with others. Now, they are obliged to do so, and a sort of a cooperation and exchange is needed.

They note that technical interoperability will allow seamless driving across the (institutional and national) borders but at present AdB has a basic Level of interoperability. and they believe that not all the motorway operators are ready to change yet.

They also note that interoperability is not only a technical issue, but Legal frameworks and internal organisational procedures are also an issue because relevant actors are sharing both their own and Third-parties' data. AdB note that they cannot provide any service without any Third parties, hence, interoperability is essential in this area.

4.4.7 Barriers Faced in Achieving Full Digitalisation

In the following sections the barriers in achieving full Digitalisation of road networks are summarised. In this instance the barriers are presented in general terms and not specific to each organisation interviewed. It should be noted the barriers identified may not be as important to some organisations over others as it is clear that the current Levels of Digitalisation vary between organisations and some organisations (and countries) are at a more advanced Levels of testing and implementation than others.

While NRAs are currently playing a role in this area and take responsibility as required (Section 4.4.9), 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. Finally, the question about how it can be ensured that shared data is only used for the envisaged purpose and not against the original aim of sharing data is vital.

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). Legal and regulatory issues are noted as an issue 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.

Most interviewees identified insufficient collaboration amongst the relevant actors as a barrier. This is not only a coordination issue, but all actors need to understand each other's needs and requirements and be willing to collaborate. In some cases, it is noted that 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. It was noted that in some cases OEMs have been very secretive on what they will actually provide in terms of Connectivity and their vehicles, what interface they will use and what services and applications they will introduce in their vehicles. The relevant actors should be aware of the vehicles' ODD in order to develop the appropriate technology. In some cases, it was further noted that the data needs are unclear as vehicle manufacturers are not talking to the NRA's. 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.

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.

Achieving public and social acceptability is considered a barrier as ultimately public perception of the services that can arise out of a fully digitalised network will impact the users/customers journeys.

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. In some cases, it was noted that NRAs need to be clear on what they are investing in and how that investment can benefit their operations in advance of making an investment. At present it appears unclear as to the initial investment required but also the ongoing investment that will be required as their operations will change significantly. Equally, in terms of investment, consideration needs to be given to socio-economic aspects, so the investment cannot be considered as standalone decision but must be made in conjunction with the societal impacts.

The new business models for NRAs from the deployment of Digitalisation are unclear, as at present there is no actual, empirical, factual proof of those business cases.

Lack of European interoperability is identified as a barrier in some cases. This is particularly relevant when sharing data across borders. Individually, it was noted that some countries experience reasonable Levels of interoperability within their own jurisdictions.

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. While work is ongoing in this area, and in one particular case it is noted that the NRA and Third parties are trying to develop one single traffic management strategy and traffic control algorithms, this issue still needs to be resolved.

In general, while there are numerous C-ITS tests ongoing, further testing, in different scenarios, is required to fully understand the impacts, benefits and risks of Digitalisation of road network.

4.4.8 Barriers Faced in Achieving Full Automated Driving

In the following sections the barriers in achieving Level 4 and Level 5 Automated Driving are summarised. As in the previous section, the barriers are presented in general terms and not specific to each organisation interviewed. Similar to the different Digitalisation levels between countries, certain countries are at a more advanced Level of testing and implementation than others, though in general there are more uncertainties in relation to Automated Driving. It is also worth noting that similar barriers are identified for Automated Driving as for Digitalisation.

Lack of interoperability and collaboration is also identified as a barrier to Automated Driving. The processes that take place between the organizations in order to exchange information are essentially those that flow to a common good. Hence, actors involved in Automated Driving on the road network should also collaborate with each other to arrive at a common solution. 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.

Automation faces the challenge of how to increase or how to define an operational design domain (ODD) that is actually feasible within regulations or a within a regulatory framework, which is currently lacking. Equally the ODD must exist within the informal rules of traffic that are in place on an everyday basis.

A lack of existing standards for automated vehicles was identified as an issue as NRAs may not be able to improve traffic safety. For example, different manufacturers are using different software which is not transferable across all automated vehicles.

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.

As in the case of Digitalisation, while NRAs are currently playing a role in this area and take responsibility as required the precise definition and allocation of roles and responsibilities to NRAs and relevant actors is still unclear.

Uncertainties exist in respect of mixed traffic conditions and the transition period is considered to be quite complicated and challenging as a mixture of old cars, newer cars and connected vehicles will be operating on the road together. A greater understanding of the requirements for this mixed traffic condition will be necessary going forward.

Full Automation requires systems to be in place on all road types (motorways and local roads) and automated vehicles should be able to transition seamlessly from one road type to another. However, how to resolve this issue is still a concern.

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.

A skilled workforce is essential however at present it is unclear what skills are required.

As in the case of Digitalisation, similar financial barriers exist, such as the initial cost of investment and operational cost exist at present. Equally where to invest is a concern.

Public perception also needs to be addressed as public trust in automated vehicles is essential to achieve full Automation on the road network. A recent study in one of the countries partaking in the interviews indicated that the majority would not trust automated vehicles. Equally important it will be 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.

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. At present there is lack of a clear roadmap and timeframe for Automated Driving. It is evident that while a number of countries have Digitalisation action plans in place, this is not the case in respect of automated vehicles/driving.

In some cases, the ODD could be a barrier under certain conditions. Nordic countries, for example, would require that the vehicles can operate all year around in various weather extremes. So, in effect the ODD may not be the same across each country.

It was also noted that at present automated vehicles do not know what to expect from the road infrastructure as their horizons are limited – in other words while they may have a general idea of the map and where they are located on the map, their current horizon is limited to 300m to 400m but in reality they would require complete information for up to 1km ahead so they can react in time to incidents (without input required from the driver).

The role of vehicles is to produce data and receive the traffic messages as well as to correct them when needed. The complete chain of this process/operation has to be defined.

4.4.9 Roles and Responsibilities of NRAs and Actors in the Area of Digitalisation

In this section, the main division of roles and responsibilities between the NRAs and Third parties in the area of Digitalisation and service provision is discussed. The evolution of actors in the implementation of Digitalisation on the road network is also presented. In general, it is noted that the roles and responsibilities within the area of Digitalisation are not clearly defined and equally these are viewed differently across countries.

4.4.9.1 NRAs' roles and responsibilities

One of the NRAs' first objectives is to promote the common good and to this effect NRAs should contribute in providing data. In cooperative services, for example, NRAs should provide information about construction sites and provide the necessary data as OEMs will not be able to provide this type of information themselves. Subsequently the OEMs will use this information in their business processes.

For example, in the Netherlands it is noted that there is a traffic industry that is developing the road network technology. As part of this development, Rijkswaterstaat (NRA) is testing and procuring technology and providing a digital map of the whole road network. The private sector companies copy this map and use it in providing their infrastructure and services. This approach focuses on a more co-operative public/private-traffic management system on a strategic level, based on common operational features and joint predictions of what will happen in the network.

Certain organisations, largely led by government, see themselves as the enablers of the digitalised ecosystem. Hence, they are funding their own investments and trying to find the right answers by funding research and development and then looking to industry to find solutions and to develop new business models and new services. It was noted that his approach may be different to other NRAs who are providing more services themselves and working themselves on the industry side towards digitalised ecosystems.

It is generally acknowledged that the NRA's main 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.

It is also noted that there should be joint responsibility for providing data, and in particular safety-relevant data, and also exchanging it and also providing it to vehicles. There should be at least an alignment of information which is provided to vehicles and they should have a common ID. It should be a consistent and interoperable communication towards different road users, so as to avoid different behaviour on the roads. Stakeholders also need to work together to agree on the kind of Digitalisation and Connectivity needed on the road network and to develop a joint road map.

4.4.9.2 Third parties' roles and responsibilities

It was noted that the main responsibility of Third parties is to provide data to NRAs, such as for example, problems that they have encountered on NRAs networks. This ultimately helps the NRA achieve good quality customer services. While NRAs are involved in research and development projects, it was generally felt that the role of OEMs is vital in the area of Digitalisation since they provide a lot of research and development that NRAs cannot do themselves.

There is a whole series of strong technological advances happening at the moment, such as for example, the effort to create and promote new standards and the evolution of mobile radio standards towards 5G. It is important that NRAs have Connectivity at all relevant points, 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.

The road operator interviewed acknowledged that it is the main responsibility of the telecom providers' is to transmit accurate data and services. They have already done this, but in the future, this must be in real time with lower latency. However, this requires that there is a sufficient robust communication infrastructure in place in order to transmit this data in an accurate and quick way.

Network operators need to transmit certified and validated information in order to ensure consistent information is used across the network. This data needs to come from the road operator and must be reliable and consistent to ensure different service network providers are not sending out different messages/responses.

4.4.10 Roles and Responsibilities of NRAs and Actors in the Area of Automated Driving

Similarly, the roles and responsibilities of NRAs and relevant actors in the area of Automated Driving is presented below. As in the case of Digitalisation, the roles and responsibilities must be more clearly defined.

4.4.10.1 NRAs' roles and responsibilities

Automated vehicles should follow certain criteria when they use the road network. Hence, NRA's main task is to ensure that everything is compatible with regulations, and legislation. However, the NRAs do not see themselves as responsible for the legislation pertinent to Automated Driving which is set by the government (i.e. the Department of Transport).

For example, The Czech Republic is about to create a legal framework, a strategy and a policy, (based on a common vision) in regard to Automated Driving. This is the basis for the decision on which activities (and research and innovation projects) will be supported in the future. No products and services will be provided, but rather the framework will be provided for implementation.

In general, NRAs are trying to facilitate Automated Driving, but nobody has told them what infrastructure information they need to provide. For instance, some NRAs are not aware of OEMs' plans in the area of Automated Driving. NRAs believe that more testing and pilot studies in the area of Automated Driving are needed to assess, with evidence, the roles and responsibilities of NRAs since they are currently unclear. However, notwithstanding this fact, automated vehicles can operate without that information from the infrastructure by using vehicle-to-vehicle and/ or vehicle-to-everything communication.

In some cases, it was noted that the NRA is not responsible for any ethics, legal, insurance, governance and communication issues. These are responsibilities of the corresponding Road Safety Authority and the Government. The NRA is only involved in the network management, risk management and standards pertinent to road design.

4.4.10.2 Third parties' roles and responsibilities

It is generally noted that the vehicles themselves and development of the automated vehicles and automated functions is the full responsibility of Third parties, i.e. developers and OEMs. NRAs acknowledge the importance of OEMs in this area as they act as the innovators and are capable of carrying out extensive research and development which is extremely valuable to the NRAs.

However, the NRAs should decide on how Automated Driving can be integrated into their traffic system. When OEMs are ready for the use of automated vehicles, NRAs will need to engage with them to decide on how they are to be introduced into the traffic system as the places where their products can and cannot be used is not the sole responsibility of the automotive industry.

In Automated Driving, OEMs are responsible for providing a safe-driving automated vehicle. OEMs need to define the vehicle ODD. In this regard, NRAs could then identify what part of their network could be used by automated vehicles. Road Authorities will eventually play a role in regulating where and when certain automated functions can or cannot be used. This decision is typically taken jointly at government Level with NRAs acting as the government agency responsible for the road network.

The road operator noted that its role in the area of Automated Driving is the provision of technical and communication support to relevant actors. In the future, they expect that the role of traffic experts and traffic management will be increased.

From the governmental side, their roles and responsibilities are creating the legislation and governance that allows OEMs to fulfil their responsibilities providing an innovative, safe and attractive product to customers of their network. In some cases, governments are also responsible for communication strategies (i.e. 5G or ITS-G5), although they take direction from the European Commission.

4.4.11 Impacts from Digitalisation

In this section the impacts towards full Digitalisation of the road infrastructure that are identified from the interviews are summarised below.

It is expected that Digitalisation will help NRA operations, particularly in relation to incident management, and as such have a positive impact on traffic safety. As a result of a successful implementation of Digitalisation on the road network, the road authorities would have a much clearer picture of what is happening on the road, in real time, and be able to respond quicker to incidents, resulting in reduced congestion, or improved traffic flow, and ultimately safer roads.

Equally, road authorities will be able to provide better advice to the road users to enable them to optimise journey planning through the availability of more reliable traffic information. Digitalisation will also benefit NRAs in managing their assets as real time information can be collected and used by the NRAs to prioritise maintenance operations.

It is also noted that the collection of the data generated by vehicles is an important benefit from an NRA perspective. Currently, some NRAs are generating all the traffic related data with a significant associated annual cost. Consequently, there is a certain economic relief for the NRAs if the data is being generated and shared by the vehicles themselves. A significant cost to NRAs is the construction and operation of roadside infrastructure, so for example, road signs, could be moved from the roadside ‘’into ‘’ the vehicle. The in-vehicle sign can be visible for as long as it needs to be it and can be presented to driver at a convenient time. Equally, In-vehicle probe data can also support driving functions.

It is expected that cooperation across jurisdictional boundaries, which is becoming increasingly important, will be improved. The cooperation within the organisation and the shift of competences and activities in the sense of Digitalisation will lead to more efficient and transparent processes. However, this can give rise to certain freedom of interpretation, as the future of Digitalisation is partly uncertain and as such may have a negative impact. In the future, road operators need to employ more people skilled in the area of Digitalisation and to conduct more precise maintenance planning.

It is noted that Digitalisation has a big impact on the core areas of operation from an analytics perspective. More precise analysis will be possible on predictive traffic models, on their business models and what business decisions should be made.

It was also noted that Digitalisation will significantly enhance asset management strategies and maintenance strategies.

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 or a shift in the staff demographic (i.e. more software developers will be required).

It is also clear that the existence of both connected and non-connected vehicles, with various Levels of automated functions, could make the traffic conditions very complicated.

4.4.12 Impacts from Automated Driving

Similarly, there are positive as well as negative aspects related to connected and Automated Driving and these could be actor specific depending on their roles.

It is generally agreed that Automated Driving should lead to considerable safety gains. The key gain from self-driving technology is not to have ‘self-driving’ parts but to have ‘*safe*-driving’ parts. It remains to be seen whether every accident can be prevented though it is noted that most accidents are caused by human error (80-90%).

Furthermore, an improvement of traffic efficiency is expected from automated vehicles. However, efficiency effects usually only occur with slightly higher penetration, approximately - 20% fleet penetration or more.

It is also noted that most benefits will possibly come from not only having automated vehicles but from connected and autonomous vehicles rather than just autonomous vehicles. If the vehicles are connected, there is the opportunity to increase the number of vehicles per lane. If connected vehicles are travelling on that road, the vehicle-to-vehicle gap can be decreased potentially leading to an increased capacity without any further investment. Alternatively, connected vehicles could give NRAs the opportunity to effectively build an additional lane and be able to move cars at speed, very close together, safely. The journey will be more informed, quicker and more relaxed because users will not have to put full attention into driving the car. Equally if traffic is more efficient and more harmonious, then the impact on the environment may also be reduced.

Connected and automated vehicles can assist NRAs reduce their costs by removing all or part of their infrastructure elements such as gantries and VMS and provide information on, for example, roadworks, accidents, weather and pavement conditions. So, for example, instead of having inductive loops on the road network, autonomous vehicles can automatically detect if vehicles are stationary or traffic congestion is present. This not only benefits the users but also assist NRAs in managing congestion.

The availability of improved data will enable users to send and receive more reliable information and consequently make better decisions. This is important for users, as well as for automated systems. Ultimately, the aim is to extend the availability of Automated Driving and to introduce automated vehicles where it’s most beneficial from the user’s perspective.

It is also believed that Automated Driving will create more chances in shared mobility services and door-to-door services.

Fully-Automated Driving may also increase the productivity of the users. At present, users are non-productive since they are engaging in the task of driving. Therefore, if road users didn’t have to control the vehicle, then technically, they can use their time to be more productive in other ways.

It is also noted that the most important part of Automated Driving is that there is a broad stream of information to be fed into one human who needs to act and then it goes back into a system. The involvement of humans may lead to errors and as such the processing needs to be automated. In the future, that will be the biggest change that will happen for the NRAs’ data centres. Humans that are working there will no longer operate, but monitor, the system. However, notwithstanding this fact, an automated traffic management system will facilitate for the deployment of a proactive traffic management.

On the other side, the misuse of autonomous vehicles, such as for criminal activity, is highlighted as a concern. From an organisational point of view, there may be a reduction in the number of traffic managers on the road, however this could be offset by the fact that employees with new skills will be required, particularly on the technical side. Equally

Automated Driving could generate a lot of more traffic on the same existing infrastructure which might not be ideal.

4.4.13 Existing and New Business Models from Digitalisation

While there are business opportunities forthcoming from the Digitalisation of the road network the general feeling is that these opportunities are more available to Third parties, such as OEMs, rather than NRAs. It is expected that there will be significant fundamental changes to the way that people drive their cars on the network and as such there is as much an opportunity as there's ever been for the private sector and OEMs to create new products. NRAs, on the other hand, may get involved in small innovations.

It is envisaged that NRAs may move from a very operational business to a more strategic role where part of the traffic management will be privatised. It will engage Third parties, on a more strategic Level to make sure that their public goals are being met. Private traffic management organisations may see significant business opportunities in areas such as collecting the traffic flow information and safety-related traffic information, sharing this information and collecting/providing all kinds of C-ITS information.

At the moment, it appears that Third parties are trying to get the most out of it for themselves i.e. profit maximization. For example, the telecommunications industry is currently trying to find the benefit for itself.

As NRAs are currently responsible for the safety on the road network there is the opportunity to work together with the road users, to create a more customer-focused road network.

Traficom is moving towards data platforms which can bring quite a lot of new opportunities – service providers or OEMs can share traffic information on the cloud networks. This approach is in contrast to the current situation where other actors hold their own data which is not being shared. In contrast, when that data is available new innovative services can be created. Equally, BASt is also trying to grow its database though the Mobility Data Marketplace with the objective to ultimately digitise all transport authority regulations.

4.4.14 Existing and New Business Models from Automated Driving

For NRAs there are relatively few business models/opportunities foreseen from Automated Driving. As for Digitalisation, new business opportunities and models will mainly be seen on the private side.

4.4.15 Current & Future Risks from Digitalisation

At present, it is difficult to draw conclusions about long-term risks, as the development path is still largely unknown.

It is generally agreed that complexity is a risk, and needs to be addressed. In mitigating the complexities, start-up financing may be required to get things moving. This investment should consider the entire process landscape with the hope of becoming more efficient in the future to realise cost savings. However, the funds that must be made available for this also compete with other National budgetary requirements such as users' social expenditure, pension security and education expenditure.

It is also noted that within roles and responsibilities, a different set of skills will be required both for road authorities and operators. Currently there is not the necessary knowledge to manage these risks yet, because Digitalisation is not the NRAs core business. However, as the core business of tomorrow, it is of vital importance to have employees with the relevant skills and knowledge.

Cyber-security is also considered a significant risk - connected vehicles will become susceptible to cyber-attacks and the Digitalisation of the road network itself, has risks associated with data transfer, control issues and data reliability issues. The rights and privacy of users must also be preserved. These are requirements that NRAs see together as a challenge but one that feel they are able to meet.

Along with security issues related to data there are also legal aspects in respect of the data that need to be addressed. Development of the technology is advancing quickly and the European Commission for example is now working on the C-ITS Delegated Act among other regulations. All of these should be included in a legal framework to ensure, among other things that privacy issues are addressed, and bad investments are avoided. In other words, it is not only a case of ''knowing what to do'' but also ''knowing what not to do''

There are also financial risks, i.e. the investment and operational costs are unknown. This may be the main reason for the lack of appropriate investment. Moreover, there are operational concerns, i.e. accumulating the systems without integration and adoption to the needs of the people involved in traffic operation.

Generally, it is agreed that risks are managed through collaboration with other actors through involvement in studies and projects in the ecosystem. One of the first steps to managing risk is to start with a good plan. Therefore, at the high Level, there should be a clear plan led by government. Equally, in making those plans consideration should be given to cooperating with the whole ecosystem including Third parties and OEMs.

4.4.16 Current & Future Risks from Automated Driving

It is noted that social acceptability of technology is a risk. The public does not want to sit in a car that has the possibility of being compromised by external parties. Even if users have the perfect technology, they may reject it. Hence, it is important to involve the public and engage with them in the early stages as much as possible. Equally, society has to see the benefits from connected and automated vehicles and these benefits must be available to society as a whole.

As for Digitalisation, there are also considerable legal risks, such as liability in the event of an incident. For example, what happens when something goes wrong in a situation where the driver still has to technically maintain an overview and awareness of what's going on the road, but the car is very much driving itself.

The transition period, when mixed traffic conditions are present, is identified as a period of significant risk, where there will be non-connected, connected, automated and conventional vehicles existing together on the road. It is not yet known how the transition period risks can be managed.

It is noted that inadequate education and training of the automated vehicle drivers and transport professionals involved in automated processes will not bring the benefit expected from the deployment and operation of automated transport systems. It is necessary to develop training programmes (including lifelong learning programmes) and areas of professional training and regular training designed to acquire, maintain or expand expert qualification and knowledge of the road operator staff. There will also be a need to train staff in cases of emergency when technology fails.

Without confronting this issue in the future, the advances in Automation could result in people simply using and relying on the systems without being able to recognize, due to lack of experience, that a critical situation actually occurred which needs to be understood and handled. Dealing with such critical and dangerous situations can be - particularly in case of professional employees - trained on devices able to simulate emergency situations in the most realistic manner. Adopting this approach would prevent a decline in the ability to deal with critical events as a result of insufficient experience or knowledge.

Automation of transport systems will lead to a change in operational processes resulting in a significant change to the working practices of some professions. This issue must be addressed through the education system. Primary and secondary school pupils and students should also be kept well informed of career possibilities in rapidly-developing modern technologies about which there may not be a sufficient a high Level of awareness at present.

The limited predictability of behaviour is also considered a risk with respect to the reliability of the system and the transfer of control.

Another area of risk for the NRAs is the investment decision. NRAs need guidance on where to spend their money and in which technology. They also need to know the economic benefit for each traffic technology and know where they will see their return on investment.

A lack of clarity on the future roles and responsibilities of both the NRAs and other relevant actors is also a risk. On the one hand, while NRAs need OEMs to develop the technologies, they don't want a situation where one OEM becomes so dominant over the others that it can dictate the technology and standards that are used in ITS rather than the NRAs.

In general, a disruptive showstopper would be when the industry cannot profit from it, such as when there is not enough business interest, or it is simply not feasible. A technologically functioning product may be developed but the legal framework does not allow it to be used appropriately (which requires the proper definition of vehicle's ODD).

The risks envisaged are typically managed in a variety of European ideas and security frameworks or with relevant processes. NRAs are currently managing those risks for Automation mostly though their test admission procedures.

4.4.17 Summary and Conclusions from Interviews

In this section a summary of the main findings from the interviews is presented in respect of Digitalisation and Automated Driving along with some general conclusions and recommendations.

1. All countries represented are currently (or have plans to be) actively involved in research projects (including testing), both nationally and internationally. Ultimately, in order to deploy C-ITS technologies and services and Automated Driving, continuous involvement in these activities will be essential to not only prove the viability of the technologies and services but also to ensure public confidence and trust in the technologies and services provided. A number of NRA's are also developing platforms themselves. It is expected that these type of research initiatives will continue.
2. While it is evident that all countries are actively deploying communication technologies or facilitating this deployment, it is clear that countries are at different stages of deployment. Equally the same can be said in relation to Automated Driving.
3. The interviewees discussed several aspects of Digitalization, distinguishing between;
   - the communication aspects enabled by cellular and ITS-G5 / dedicated short-range technologies;
   - the process of converting physical information to a digital format (i.e. 'Digitisation'), such as physical road information (location in space, physical characteristics, location of signs, location of landmarks)
   - the collection of data using sensors such as traffic speeds, travel times, weather information etc.

   It will be important to distinguish between these various aspects of Digitalisation in the remainder of the project.
4. In terms of Digitalisation Action Plans, some countries identified that they have specific plans in place, though for the most part these are part of overall ITS strategy. However, those countries without a plan, as a standalone document or integrated with a an overall ITS strategy, have indicated their intention to develop the same, whether through their involvement in platforms (e.g. C-Roads) or through Governmental Strategies. Most of these plans extend to 2025 and by this time most countries see full deployment of ITS-G5 technology, with 5G communication technologies coming more to the forefront.
5. In terms of an Automated Driving, Action Plans are typically not in place, though some countries have a general view on how they see the future of Automated Driving. This appears largely due to the fact that, in comparison to Digitalisation Aspects, there are more uncertainties and barriers associated with the development and implementation of Automated Driving.
6. Into the future, views on achievable evels varied, however the general view was that Automated Driving Level 4 could be achievable between 2030 and 2040, with Automated Driving Levels 2 to 3 more likely in the next decade, with certain functions being available (e.g. simple lane keeping, highway pilot etc.). However, it can also be concluded that due to uncertainties and barriers it is difficult to predict, particularly beyond 2030, what Automation driving levels will be achievable.
7. Views on Interoperability for Automated Driving, and the current Levels of cooperation between the relevant actors, differed between interviewees. However, the general view

was that data issues (i.e. data requirements, data exchange/sharing) was critical to realising the full benefits of Automated Driving and cooperation between all actors in this regard is vital.

8. The main barriers or risks to achieving full Digitalisation of the road network and Automated Driving, are for the most part identified as being similar and include; financial barriers; a lack of clarity on roles and responsibilities; legal/regulatory issues; insufficient collaboration between actors; data issues (privacy, cybersecurity, sharing etc.); insufficient interoperability, both at national and European Level; technical issues and public acceptability. Typically, it was acknowledged that the risks can be minimised through participation in research projects, testing, platforms etc. where technologies can be assessed, and collaboration occurs with Third parties.
9. In terms of roles and responsibilities in respect of Digitalisation, though these are identified as unclear at present, the interviewees had some views on where the roles of the NRA's lie. Certain organisations see themselves as enablers of the digitalised ecosystem, while others see themselves as service providers, though their main role is in infrastructure data provision. However, in relation to data, it was generally felt that there should be joint responsibility in providing data and this should be freely available, particularly in relation to safety related data. Equally actors need to work together to agree on the kind of Digitalisation and Connectivity needed on the road network and to develop a joint road map
10. In terms of roles and responsibilities in respect of Automated Driving, the NRA's main role is to ensure that everything is compatible with regulations and legislation, though these should ultimately be set at Government Level. Equally NRA's do not see themselves responsible for ethics, legal, insurance, governance and communication issues. Again, these must be set at Government Level, however, it should be considered that NRA's play a leading role in advising Government of the pertinent issues.
11. Based on the perceived roles and responsibilities outlined in 9. and 10. above, it is clear that collaboration is required between all relevant actors, a point raised by all interviewees. This is particularly important in respect of Automated Driving where traffic safety is concerned – the information provided and or shared to users and vehicles (and between vehicles) must be consistent.
12. 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.
13. Digitalisation is expected to help NRA's with their operations, particularly in relation to traffic management (incidents, maintenance, roadworks etc.) and provide them with the tools to impact traffic safety positively. The latter point was also made in respect of Automated Driving as most accidents are caused by human error.
14. Both Digitalisation and Automated Driving are expected to reduce NRA's costs. Collecting data is a significant cost to NRA's so the ability of vehicles to collect and transmit this data is seen as a potential cost saving benefit. NRA's can also reduce their costs through a reducing or eliminating the need for hard infrastructure (e.g. gantries etc.).
15. In respect of Autonomous vehicles, the general view of the NRA's was that the real

benefit arises from having both connected and autonomous vehicles to leverage the full benefit of the potential improvements in traffic efficiency.

16. While the benefits of Autonomous vehicles are identified, the presence of mixed traffic conditions could make traffic conditions very complicated.
17. In respect of both Digitalisation and Automated Driving the general view is that business opportunities will arise for Third Parties as opposed to NRA’s.
18. How NRA’s operate the road network will also expect to change, from an operational approach to managing the road network at a more strategic Level.

4.5 Areas of core operation affected by Digitalisation and Automated Driving

In this section, as per WP2 objectives, the broad areas operation of NRAs particularly affected by Digitalisation and Automated Driving are presented. These areas of operation were based on the outcomes from the literature review and interview findings in Sections 4.3 and 4.4 respectively. The outcomes are further used for the suggestion of a set of criteria (see *Table 5.1*) that are eventually used for the selection of the Use Cases presented in Section 5.2.

Digitalisation will change the operational processes of NRAs. In effect, less people will be on the road observing if there are incidents or damage to the network infrastructure. The vehicle data or sensor data will be collected and used by NRAs for monitoring the road infrastructure.

Full Digitalisation will also lead to different processes on how to build roads, such as being able to assess which kind of data is needed to finish new road segments. Thus, there could be a need of HD map information which has to be provided with new-build road segments.

Digitalisation of road infrastructure will also see NRAs becoming more active in data analysis such as for example, using the volume of data collected to make business decisions and adopting a proactive approach to traffic management. This will ultimately lead to NRAs having a better understanding of the performance of the network and as a result it will assist in incident management and an enhancement of the traffic efficiency.

All types of sensors, drones, stations, etc will help to undertake more accurate maintenance planning and reduce the number of accidents. In terms of operations having less accidents (or maybe zero accidents) will mean lower costs.

NRAs abilities and knowledge will be expanded. The cooperation within the organisation and the shift of competences and activities in the sense of Digitalisation will lead to more efficient and transparent processes.

Furthermore, more processes will be automated from the deployment of Digitalisation. NRAs will automatically process the data through their traffic management centres and the humans that are working in the centres will see a shift in their roles from ‘operators’ to ‘monitors’ of the system.

Digitalisation will also give NRAs a greater understanding of their assets resulting in improved maintenance strategies. They will be able to proactively maintain the network thus targeting maintenance as part of an overall cost reduction strategy.

NRAs will need to employ more people with skills in the C-ITS sector such as for example software developers.

Automated Driving will improve the traffic safety and efficiency of the road. NRAs will deliver a better service to the customers, i.e. the people who use the road will be more informed about their journey, or whether a quicker journey or a more relaxed journey exists. Safety and customer service seem to be the two main drivers/ main areas of operation particularly affected by Automated Driving. Safety first and then delivering good customer service.

NRAs’ traffic management protocols and procedures will also be influenced by automated vehicles and will have to be brought into this new era of mobility. 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.

With respect to Automated Driving, NRAs will need to work more closely and engage with the automotive industry. 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.

It is also felt that NRAs will not need so many traffic managers on the road. They will change how things are organised internally with more office-based work/staff than on the road work/staff. More people will be needed on the technological side than on the operational side of the organisation and the role of traffic experts and traffic management will be increased.

In summary the deployment of both Digitalisation and Automated Driving in NRAs' road network will first of all change the way they operate. They expect an enhancement of their traffic management where in conjunction with the data produced by vehicle data will facilitate improved traffic safety and traffic flows. Furthermore, 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.

5 Use Cases

5.1 Use Case Selection

Based on the outcomes from the interviews and, partner input, a short list of potential Use Cases was provided that are particularly affected by Digitalisation and Automated Driving as outlined in Appendix B. From the proposed high-level Use Case list, the three final Use Cases were selected following input from the CAD WG at a workshop in Oslo in November 2018. These Use Cases are assessed based on a set of dedicated selection criteria, presented in Table 5.1, along with the scoring ranges. The selection criteria are chosen primarily from the perspective of the NRA's. However, the involvement of external actors is also considered.

Table 5.1 Selection criteria and critical assessment of Use Cases

Selection criteria	***Scoring the Use Cases on the criteria***
Relevance for NRA road networks (not local or cities)	high/medium/low
Supports NRA's core processes (operations/planning & building/ICT)	high/medium/low + area of core process
Scale of impact on NRA	opportunity or threat + high/medium/low
initiator is NRA / Market (OEM, service provider, etc.) / other	indicate actor
NRA can influence development	high/medium/low
Required involvement of external actors	high/medium/low
Benefits: NRA / driver / service provider / other	indicate stakeholder + high/medium/low
Planning horizon: short term (< 8 years), medium term (8 - 12 years); long term (> 12 years)	indicate time frame; long/medium/short
In development (no real-world implementation/ pilot / tested / implemented)	indicate status, + examples if available
Relevant/applicable for different countries	high/medium/low

Based on this assessment the selected Use Cases, within the DIRIZON research project, are;

1. Provision of HD Maps for Automated Mobility
2. Distribution of Digital Traffic Regulation
3. Infrastructure Support Services for CAD

As an effort to further evaluate and validate the importance of the proposed Use Cases, the consortium circulated a dedicated matrix to the CEDR CAD WG members for a critical assessment of these Use Cases. The matrix had the form of Table 5.2 to Table 5.5 *Critical assessment of the proposed Use Cases by Trafikverket, Sweden* and the CAD members had to score each of the selection criteria and for each Use Case. The consortium also provided additional columns for further comments. The consortium managed to gather four responses/ input for the DIRIZON's proposed Use Cases, namely from *ASFINAG*, BASt, Rijkswaterstaat and Trafikverket. Their responses are summarised in Table 5.2 to Table 5.5 *Critical assessment of the proposed Use Cases by Trafikverket, Sweden*.

With regards to the "Provision of HD maps for automated mobility", *ASFINAG*, BASt and Rijkswaterstaat believe that HD maps are highly relevant for NRAs and they can support their future core processes. In comparison, Trafikverket, argues that the deployment of HD maps is not applicable from an NRA perspective and they can be provided by Third parties with some benefits. Moreover, medium scale opportunities are expected for NRAs. *ASFINAG* and BASt state that they can influence HD Maps development while Rijkswaterstaat and Trafikverket argue that they have a medium and low impact on them. These organisations see large involvement of external actors with direct benefits to service providers and drivers. The time frame is anticipated to be short to medium term, i.e. 3 to 7 years, but Trafikverket appears to be more conservative indicating it as a long-term. The Use Case has been studied in pilot and real-world project by major private companies and appears to have a good Level of maturity to be feasible in the future.

On the other hand, these organisations have very similar responses with regards to the "Distribution of digital traffic regulation" Use Case. They do all agree that its development is highly relevant for NRAs providing plenty of opportunities and it can influence their core processes, mainly in the ICT area. Equally, NRAs are the main initiator, but the involvement of external actors is also required for its deployment. The NRAs and drivers seem to be the most beneficial from the digital traffic regulations. The planning horizon is clearly short term with *BASt* trying to get CEF support. These organisations have already implemented pilot tests and also there is the Dutch "Talking Traffic" that provides real time advice to users while driving.

The Third Use Case, "Infrastructure Support Services for CAD" is of medium to high relevancy for the NRAs with medium to high opportunities. In comparison to the previous Use Cases, there are multiple initiators, such as for example, the NRAs, OEMs, freight & logistics and ITS providers. Furthermore, the NRAs can influence its development, but the involvement of external actors is definitely needed. The NRAs, driver and service providers are the direct benefits from that Use Case and the planning horizon is short to medium. Austria and the Netherlands have no real-world implementation of that Use Case while Sweden tested it within the Nordic way project.

The Selected Use Cases are described in more detail in Section 5.2.

Table 5.2 Critical assessment of the proposed Use Cases by ASFINAG, Austria

Selection criteria	*Scoring the Use Cases on the criteria*	**Provision of HD maps for automated mobility**	**Distribution of digital traffic regulation**	**Infrastructure support services for CAD**	**Additional comments**
Relevance for NRA road networks (not local or cities)	high/medium/low	high	high	high	-
Supports NRA's core processes (operations/planning & building/ICT)	high/medium/low + area of core process	high + operations/planning & building	high + operations/ICT	high + operations/ICT	-
Scale of impact on NRA	opportunity or threat + high/medium/low	opportunity + medium	opportunity + high	opportunity + medium	-
initiator is: NRA / Market (OEM, service provider, etc.) / other	indicate stakeholder	Market (OEM, service provider)	NRA	NRA / freight & logistics companies, ITS provider	-
NRA can influence development	high/medium/low	high	high	high	-
Required involvement of external stakeholders	high/medium/low	high	high	high	-
Benefits: NRA / driver / service provider / other	indicate stakeholder + high/medium/low	NRA, driver, service providers / high	NRA & Driver / high	NRA, driver, service providers / high	-
Planning horizon: short term (< 3 years), medium term (3 - 7 years); long term (> 7 years)	indicate time frame; long/medium/short	short	short	short	-
In development (no real-world implementation/ pilot / tested / implemented)	indicate status, + examples if available	pilot + HERE, TOMTOM, Google, INRIX, ASFINAG JR UHD Platform	pilot + ITSM 24/7 Service Traffic signs, unplanned events running in service provider testbeds	no real-world implementations + connecting Austria	-
Relevant/applicable for different countries	high/medium/low	high	high	high	-
	Additional questions for Use Case clarification	Please provide a short description of how HD maps are used in 2-3 examples of automated mobility applications	Please provide 2-3 examples of the type of regulation to be distributed; digital traffic regulation covers static information first, followed by dynamic information. There is the liability issue within communication between roadside and vehicle or via the maps in the vehicle. Does this indeed mean the mechanism for distribution including the roles of the different stakeholders?	Please provide 2-3 examples of specific infrastructure support (services) for a specific CAD application (e.g., highway chauffeur or Driverless maintenance and roadworks warning). What kind of infrastructure are we talking about? Functional --> assurance	-
	Answers provided	Prerequisite for Automated Driving.	Static & dynamic information: traffic signs, planned events, unplanned events.	Extended horizon and merging assistant, traffic management for platoons, SAE Level clearance.	-

Table 5.3 Critical assessment of the proposed Use Cases by BASt, Austria

Selection criteria	*Scoring the Use Cases on the criteria*	**Provision of HD maps for automated mobility**	**Distribution of digital traffic regulation**	**Infrastructure support services for CAD**	**Additional comments**
Relevance for NRA road networks (not local or cities)	high/medium/low	high	high	high	-
Supports NRA's core processes (operations/planning & building/ICT)	high/medium/low + area of core process	high + operations/planning & building	high + operations/ICT	high + operations/ICT	-
Scale of impact on NRA	opportunity or threat + high/medium/low	opportunity + medium/high	opportunity + high	opportunity + high	-
initiator is: NRA / Market (OEM, service provider, etc.) / other	indicate stakeholder	Market (OEM, service provider)	NRA	NRA / OEMs, freight & logistics companies, ITS provider	Chicken and egg situation. It is a collaborative effort. The MANTRA project brings this forward, makes issues explicit.
NRA can influence development	high/medium/low	high	high	high	NRA ambition is to influence Use Case. these topics are all relevant. Nuance: it makes a difference whether the stakeholder is the initiator or not, as this affect the Level of influence. digital traffic regulation is initiated by NRAs, then NRAs have more control if you take the position (influence).
Required involvement of external stakeholders	high/medium/low	high	high	high	high with different meanings. On the one hand, as initiator, exchange the plans of NRAs with stakeholders to check feasibility. For the other ones in which the initiator is not the NRA, the NRAs need to take the initiative.
Benefits: NRA / driver / service provider / other	indicate stakeholder + high/medium/low	NRA, driver, service providers / high	NRA & Driver / high	NRA, driver, service providers / high	initiator has benefits, otherwise odd that they would initiate. NRAs must have benefits, otherwise strange to choose the Use Case.
Planning horizon: short term (< 3 years), medium term (3 - 7 years); long term (> 7 years)	indicate time frame; long/medium/short	short (if you take OEM marketing plans)	short (try to get CEF support)	short, but depends on the Use Cases. Platooning more medium. (AUWE). Awareness is present. Understanding is needed from NRA perspective, requiring the planning for investments.	NAP required, being worked on in Germany. National body to check quality of the self-declarations of the data providers. This is a permanent task, required by law. Alignment over all road directors required.
In development (no real-world implementation/ pilot / tested / implemented)	indicate status, + examples if available	pilots + Here, TomTom, INRIX, Google - dynamic event layer public role	intended pilot, capabilities of NAP (Mobility Data Marketplace)	high	BASt role different from that of ASFINAG. Constitution changed to bring back operations to federal (German) Level, body was established in Sept 2018. What it will look like exactly for items such as traffic management and CAD is currently yet unknown. Goal for operation in 2021.
Relevant/applicable for different countries	high/medium/low	high	high	high	-
	Additional questions for Use Case clarification	Please provide a short description of how HD maps are used in 2-3 examples of automated mobility applications	Please provide 2-3 examples of the type of regulation to be distributed; digital traffic regulation covers static information first, followed by dynamic information. There is the liability issue within communication between roadside and vehicle or via the maps in the vehicle. Does this indeed mean the mechanism for distribution including the roles of the different stakeholders?	Please provide 2-3 examples of specific infrastructure support (services) for a specific CAD application (e.g., highway chauffeur or Driverless maintenance and roadworks warning). What kind of infrastructure are we talking about? Functional --> assurance	-
	Answers provided	Lateral control of vehicles in e.g. highway chauffeur, managing bridge loads in presence of truck platoons (e.g. 50 m distance even in case of congestion)	Static & dynamic information: traffic signs, planned events, unplanned events, tend to state yes (when the last question was purposed to ensure the scope of the Use Case)	see ASFINAG examples	-

Table 5.4 Critical assessment of the proposed Use Cases by Rijkswaterstaat, the Netherlands

Selection criteria	***Scoring the Use Cases on the criteria***	**Provision of HD maps for automated mobility**	**Distribution of digital traffic regulation**	**Infrastructure support services for CAD**	**Additional comments**
Relevance for NRA road networks (not local or cities)	high/medium/low	high	high	high	-
Supports NRA's core processes (operations/planning & building/ICT)	high/medium/low + area of core process	high + operations/planning & building	high + operations/ICT	high + operations/ICT	-
Scale of impact on NRA	opportunity or threat + high/medium/low	opportunity + medium	opportunity + high	opportunity + medium	-
initiator is: NRA / Market (OEM, service provider, etc.) / other	indicate stakeholder	Market (OEM, service provider, map maker) + public authorities	NRA	NRA / freight & logistics companies, ITS provider	TN-ITS platform (TN-ITS.eu)
NRA can influence development	high/medium/low	medium	high	high	-
Required involvement of external stakeholders	high/medium/low	high	high	high	-
Benefits: NRA / driver / service provider / other	indicate stakeholder + high/medium/low	NRA, driver, service providers / high	NRA & Driver / high	NRA, driver, service providers / high	-
Planning horizon: short term (< 3 years), medium term (3 - 7 years); long term (> 7 years)	indicate time frame; long/medium/short	short/medium	short/medium	short/ medium	-
In development (no real-world implementation/ pilot / tested / implemented)	indicate status, + examples if available	pilot + HERE, TOMTOM, Google, INRIX, Talking Maps	pilot + Talking Traffic	no real-world implementations	-
Relevant/applicable for different countries	high/medium/low	high	high	high	-
	Additional questions for Use Case clarification	Please provide a short description of how HD maps are used in 2-3 examples of automated mobility applications	Please provide 2-3 examples of the type of regulation to be distributed; digital traffic regulation covers static information first, followed by dynamic information. There is the liability issue within communication between roadside and vehicle or via the maps in the vehicle. Does this indeed mean the mechanism for distribution including the roles of the different stakeholders?	Please provide 2-3 examples of specific infrastructure support (services) for a specific CAD application (e.g., highway chauffeur or Driverless maintenance and roadworks warning). What kind of infrastructure are we talking about? Functional --> assurance	-
	Answers provided	-	-	-	-

Table 5.5 Critical assessment of the proposed Use Cases by Trafikverket, Sweden

Selection criteria	*Scoring the Use Cases on the criteria*	Provision of HD maps for automated mobility	Distribution of digital traffic regulation	Infrastructure support services for CAD	Additional comments
Relevance for NRA road networks (not local or cities)	high/medium/low	Not applicable from a NRA perspective	High	Medium	-
Supports NRA's core processes (operations/planning & building/ICT)	high/medium/low + area of core process	In case the HD map would be provided by a Third party, NRA could have some benefits from some processes but not the core processes	Medium- our core processes shall function properly even without digitalized regulations in order to guarantee robustness in our core processes	Low, its core processes need to serve more than only CAD	-
Scale of impact on NRA	opportunity or threat + high/medium/low	Opportunity - medium	Opportunity – high	Opportunity - high	
initiator is: NRA / Market (OEM, service provider, etc.) / other	indicate stakeholder	Third party/ service provider	NRA	A combination of NRA, service provider and similar	-
NRA can influence development	high/medium/low	Low	High	Medium	-
Required involvement of external stakeholders	high/medium/low	High	Medium	High	-
Benefits: NRA / driver / service provider / other	indicate stakeholder + high/medium/low	NRA – medium but for driver / service provider high	NRA and driver - high	Driver / service provider / NRA – high	-
Planning horizon: short term (< 3 years), medium term (3 - 7 years); long term (> 7 years)	indicate time frame; long/medium/short	Not applicable from a NRA perspective but medium to long term horizon for service providers	Short term horizon	Medium	-
In development (no real-world implementation/ pilot / tested / implemented)	indicate status, + examples if available	Pilot/ on real world, Google, TomTom, INRIX	Partly implemented on real world, Sweden	Tested within the Nordic way project	-
Relevant/applicable for different countries	high/medium/low	Low	High	Medium-High	-
	Additional questions for Use Case clarification	Please provide a short description of how HD maps are used in 2-3 examples of automated mobility applications	Please provide 2-3 examples of the type of regulation to be distributed; digital traffic regulation covers static information first, followed by dynamic information. There is the liability issue within communication between roadside and vehicle or via the maps in the vehicle. Does this indeed mean the mechanism for distribution including the roles of the different stakeholders?	Please provide 2-3 examples of specific infrastructure support (services) for a specific CAD application (e.g., highway chauffeur or Driverless maintenance and roadworks warning). What kind of infrastructure are we talking about? Functional --> assurance	-
	Answers provided	-	-	-	-

5.2 Use Case Description

Taking the CAD WG inputs into account together with the literature review and interview outcomes the following sections provide a short description for each Use Case, i.e. what its subject is and why there is the need to implement it. Next, the Use Case scenario is discussed where 2-3 real-world applications and their impacts are discussed. Then, the boundaries and objectives of the Use Cases are well-defined within the scope.

To demonstrate the impacts of the Use Cases, with respect to Digitalisation and Automated Driving, all the relevant actors are listed where their roles and responsibilities are briefly presented. The relevant actors are distinguished between *Primary* and *Secondary* actors. A primary actor is considered an actor that is necessary for the deployment of the Use Case and has a primary interest in it. In contrast, secondary actor is a Third-party actor from which the system needs assistance to achieve the primary actor's goal.

Certain organisations relevant to the Use Case are listed as the stakeholders. Finally, the assumptions made for each Use Case are summarised. That Use Case description will be the basis their further expansion in WP3 and WP4 where their implications, data needs, evolution, uncertainties and recommended actions will be addressed.

5.2.1 Provision of HD maps for Automated Mobility

DIRIZON USE CASE 1	
Use Case Name	**Provision of HD Maps for Automated Mobility**
Use case reference /id	**DIRIZON-UC-1**
Description	The provision of detailed mapping in a machine-readable format supports a connected automated vehicle's (CAV) ability to understand its precise positioning, plan beyond sensor visibility, possess contextual awareness of the environment and local knowledge of the road rules. Hence, HD Maps can assist automated vehicles to optimize: 1. Their precise positioning and control on the road surface; 2. Their accurate planning and control maneuvers beyond sensor capability. HD maps can effectively extend (automated) vehicle's ODD in complex traffic situations.
Scenario	An autonomous vehicle needs more than sensor data to know exactly where it is on the road. A self-driving vehicle needs multiple information sources to see and understand its surroundings, know where it is going, and make safe, efficient, and legal driving decisions while getting to its programmed destination. A scenario for High Definition Maps to support CAD is the extension of the CAVs horizon, beyond sensor visibility. To make safe, efficient and legal driving decisions beyond sensor range, an automated vehicle would need precise information on static and dynamic elements of the road infrastructure and conditions. Assuming Level 4 CAVs are allowed on motorways in Europe, they can operate fully automated entering the motorways, driving through interchanges and leaving the motorway at exits. The CAV needs information to plan the route and make dynamic driving decisions based on information matched on HD Maps, such as in the examples below; *Example1:* The CAV enters the motorway and the vehicle switches to Automation mode at the entry point where fully Automation is legally allowed. The HD Map and the precise mapping of localization objects allows the CAV to position itself with the help of sensors exactly on lane Level and give the driver information where to go in autonomous mode. *Example 2:* The CAV gets the information of a lane closure and reduced speed because of construction/maintenance works on a section of its route. Based on the information about lanes, lane markings and legal restrictions mapped in the HD Map, the CAV knows in advance where it is legal to change lanes and can make the correct decision to reduce speed and move into to the remaining open lanes. *Example 3:* A traffic jam develops on the route before it becomes visible to the driver and sensors, which can lead to rear-end incidents or collisions (minor and major vehicle collisions). Through combining precise static information from the HD Map and dynamic information from traffic management centres, the CAV is able to slow down in anticipation of an upcoming and developing traffic jam.

DIRIZON USE CASE 1	
Scope	Automated vehicles may be equipped with HD digital maps. These digital maps will exploit and digest the appropriate data from relevant sources, and they will provide input to decision-making for the (automated) vehicle users. HD maps will be equipped with both static and dynamic data. They will provide information to (automated) vehicles pertinent to: Static and dynamic (real-time) data: • Road infrastructure (e.g. road design, geometry, travel routes, traffic regulations etc.); • Traffic conditions (e.g. volume, delays, remaining travel time, safety); • Roadworks and emergency situations. • Weather conditions.
Actors Involved, and their roles	*Primary actors:* • Digital map providers: Development/ maintenance of digital maps. • National Road Authorities (and private operators): (i) Provision of physical infrastructure data e.g. road geometry. Provision of digital infrastructure data: digital traffic regulations (i.e. digital messages (VMS on vehicles), speed limits), roadworks, weather and road surface conditions etc. (ii) provision of positioning support (provision of differential GNSS-information, indoor-routing support) • Road operators: Provision of traffic volume, travel time, road surface conditions, cost of tolls etc. • OEMs (automotive industry): Adoption of HD maps in (automated) vehicles. Regular upgrades to vehicles to support HD mapping. • (Automated) vehicles: Provision of their produced data for exploitation through V2V and V2I communication. • Vehicle driver/ passenger receives information from the HD map and makes decisions on his/her actions in the infrastructure. • Meteorological service providers: Provision of data related to weather conditions. • Roadworks service providers: Provision of roadworks details e.g. location, duration, kind of roadworks, Level of obstruction etc. • Third party data providers (e.g. probe vehicle data, traffic information etc.). *Secondary actors:* • Ministries/Departments for Transport: Provision of traffic regulations for road infrastructure, including regular updates when needed. • Communication network providers: Provision of network coverage e.g. ITS-G5 or 3G/4G/5G including regular upgrades to the network to support HD mapping. • Logistics service providers: Provision of scheduled travel routes

DIRIZON USE CASE 1	
	to HD maps for planning/ optimising the travel journey. • Transport service providers: Provision of transport related data i.e. location of stop/schedules, real-time location of busses etc.
Stakeholders	• PIARC (World Road Association) • EARPA (European Automotive Research Partners Association) • ACEA (European Automobile Manufacturers Association) • TISA (Traveller Information Services Association) • NDS (Navigation Data Standards) • CEDR (Conference of European Directorate of Roads) • Standardisation bodies. • C-Roads • EU-EIP (EU ITS Platform) • TN-ITS • CLEPA (European Association of Automotive Suppliers)
Assumptions	• Most of the physical infrastructure elements are digitised. In the medium term, the Level of detail is enhanced. • The digital infrastructure elements are gradually digitised in the short, medium and long term. • There are mixed traffic conditions in the short, medium and long term. • The HD map has both static and dynamic data. • The accurate vehicle position (localisation) is determined by the vehicle's sensors, GNSS navigators and HD maps. • That Use Case is primarily for motorways. However, an extension of that into urban and rural regions can be implemented in the future.

5.2.2 Distribution of Digital Traffic Regulation

DIRIZON USE CASE 2	
Use Case Name	**Distribution of Digital Traffic Regulation**
Use case reference /id	**DIRIZON-UC-2**
Description	Distribution of digital traffic regulation becomes more and more relevant for CAM (Connected and Automated Mobility as well as for other areas such as smart cities, and is currently being addressed in more detail within CEN/TC 278 WG17. It has been found that, currently legal responsibilities and authorisation schemes vary a lot between countries, states and cities. Rules are time-and-place referenced similar to a digital map. This means that for connected automated mobility (CAM) there will be a need to maintain and encode traffic regulations electronically to be machine readable, processed and correctly interpreted by a receiver (e.g. a connected automated vehicle).
Scenario	A currently discussed scenario for digital regulations with regard to diesel driving bans could be the central management of traffic flows in a "Controlled Zone" (e.g. emission zone in a city). The subject is complex, and to date has proven difficult, and may technically depending on the Level of Automation, downloading data to an "In-Vehicle System", e.g. an ITS station (ITS-S) or a navigation device. A Controlled Zone is a physical location which has restricted access defined by access conditions including information on timely validity. Appropriate data has to be provided to a vehicle as Controlled Zone user. The location of a Controlled Zone may be defined quite differently, e.g. being a linear location (e.g. a street), a two-dimensional area (e.g. up to a complete city) or any other reasonable definition. Access conditions could be binary options of "allowed" or "prohibited", combined with an indication of one or several reasons why access to a Controlled Zone is restricted. This approach enables conditional access, dependent on the access conditions and the properties of a vehicle. Examples of this particular scenario are provided below; <u>Example 1:</u> The Controlled Zone access condition "prohibited for vehicles with given properties" can contain a restriction concerning vehicle emissions and a restriction for vehicles with a total weight exceeding a defined limit. Operation in the Controlled Zone, thus, is only allowed if neither the emissions of the vehicle are above the given limit, nor the total weight exceeds the given limit. A special case could be the "diesel engine control zone", where there is a ban on the use of diesels prior to Euro Class 5, and time-of-day limitations on the use of any diesel. <u>Example 2:</u> Powertrain management is a special case of air quality management. In the case of hybrid vehicles, the Controlled Zone regulation can set up an access condition that hybrid vehicles can enter and operate within the Controlled Zone, but only in a tail-pipe emission free mode (i.e. electric). <u>Example 3:</u> A Controlled Zone may be generally closed due to a spatially and temporally limited event. Although Controlled Zones are currently specified within CEN/TC278

DIRIZON USE CASE 2	
	WG17 for an urban context, these examples show the various possible applications which seem to be not only limited to urban scenarios.
Scope	• The traffic regulation and relevant infrastructure elements (e.g. traffic signs and related additional information) will be gradually digitised (short-medium-long term) in a computer-readable format. There are mixed traffic conditions operating on the infrastructure However, most of the vehicles are expected to be connected and automated in long term. • This Use Case will be an additional layer for the HD maps (see DIRIZON Use Case 1). Traffic regulation data produced by this Use Case will equip the HD maps of Use Case 1.
Actors Involved, and their roles	*Primary actors:* • National Road Authorities: Provision of traffic regulations to the digital map providers or directly into vehicles (e.g. via vehicles' VMS). They control the traffic regulations and are able to update them. Each NRA has to define processes for the management of electronic traffic regulations according to a standardised METR architecture. NRAs will collect data from actors and will assign roles and responsibilities to them (NRAs will control and share the data). Sub-Roles include traffic managers, parking managers, asset managers, traffic regulation officer (Planning). • Digital map providers: Development/maintenance of digital maps layers for NRAs enriched with up to date traffic regulations. Further development of automated traffic management plans during e.g. roadworks and emergency situations. • Road maintenance service providers: Provision of roadworks information i.e. location, duration etc. to NRAs in order to automatically adjust the traffic regulations in the corresponding part of the infrastructure. • Traffic incident support units: Provision of real-time traffic incident data to NRAs. Thus, NRAs can automatically produce a traffic incident plan and update the traffic constraints, within the boundaries of relevant regulations. For instance, NRAs can implement lane closures at specific parts of the infrastructure, though LCS, to enhance traffic safety. • Police and emergency responders. *Secondary actors:* • (Automated) vehicles/vehicle users: They are automatically informed about the current measures based on traffic regulations e.g. through a vehicle VMS and act accordingly. • European Commission (EC): To achieve agreement at EU Level. • SDOs (Standards Developing Organizations): Provision of a standardised framework for electronic traffic regulations including appropriate data exchange formats. Development of commonly agreed map matching procedures (based on Open-LR and Agora-C) • Enforcement bodies: Verification that connected automated vehicles operate within the framework of the electronic traffic

DIRIZON USE CASE 2	
	regulations. • OEMs (automotive industry): Cooperation with NRAs and ensure compatibility and usage. • Ministries/Department for Transport. • Service aggregators (as defined in the METR architecture of CEN TC278/WG 17). • Regional and local transport authorities/administrations.
Stakeholders	• RNO-ITS (Road Network Operations) • FEHRL (Forum of European National Highway Research Laboratories) • DATEX II community • EC (European Commission) • TN-ITS • ACEA (European Automobile Manufacturers Association) • TM2.0 (Traffic Management 2.0)
Assumptions	• Each NRA will collect data from the actors and will assign roles and responsibilities to them (NRAs will control and share the data). • Appropriate standards pertinent to data quality, data format and security will be developed (where needed) and adapted for traffic regulations. • The traffic regulations are gradually digitized in line with the Use Case evolution (short-medium-long term). Mixed traffic conditions take place in the short, medium and long term. However, many of the vehicles are expected to be fully automated in the long term. There are also mixed Automation Levels in all terms. Both static and dynamic traffic regulations are available in the short and the medium term. In the long term, all of them are provided in real-time. • This Use Case is referred to motorways. However, the implementation of this Use Case can help towards digital traffic regulations on rural and urban networks. • Relevant traffic regulations are digitised and used by automated vehicles for decision making. • Legislation facilitates the publication and application of digital traffic regulations.

5.2.3 Infrastructure Support Services for CAD

DIRIZON USE CASE 3	
Use Case Name	**Infrastructure Support Services for CAD**
Use case reference /id	**DIRIZON-UC-3**
Description	Infrastructure support for Connected and Cooperative Automated Driving (ISAD) is digitized information, including representations of the physical environment, to support CAD functioning. Map data could be complemented by physical reference points (landmarks, signs, beacons). This Use Case provides digital and physical infrastructure support (including traffic management measures) of vehicles in a mixed environment, supporting CAVs by extending their ODD's and improving safety, traffic flow and environmental impacts.
Scenario	A scenario for Infrastructure support services for CAD is the extension of the ODD of Cooperative Automated Vehicles (CAVs). The ability to have access to information that complements the capability of the sensors can extend the ODD for CAVs. Assuming a Level 4 CAV can operate using full Automation on the motorways between Enschede and Rotterdam, the Netherlands, the vehicle can drive autonomously from the highway entrance, via interchanges, to the exit in Rotterdam. The CAV uses it sensors to carry out its interactions with other vehicles in its immediate vicinity. The vehicle has information about the maximum speed limit (UC-1 and UC-2). Examples of this particular scenario are provided below; Example 1: The rain radar of the Royal Netherlands Meteorological Institute detects heavy rain showers in the central part of the Netherlands. The Traffic Management Centre (TMC) in the area of Apeldoorn receives information that drivers have called to warn about the heavy rain and the dangerous driving situation. The TMC decides to dynamically reduce the maximum speed to 100 km/hour. Tom-Tom retrieves this information from the official TMC data feed, and sends this certified information to the CAV. The CAV reduces its speed, considering the surrounding vehicles and its lane, avoiding sudden braking. Example 2: A traffic jam is detected by the traffic management centre in the area of Gouda. This traffic jam increases the travel time on the original route. As the CAV is in the area of Utrecht, it has the option of choosing an alternative route, circumventing the traffic jam. Tom-Tom uses data from its fleet of Tom-Tom clients and the TMC feed to determine that there is an alternative route that has a shorter travel time to the destination. The decision to choose the alternative route is made by the vehicle, because the driver has accepted the option to dynamically change the route in case of large travel time savings.
Scope	The operation of Automated vehicles on road infrastructure is expected to cause substantial impacts to traffic flows. However, there are a number of issues yet to be addressed, as follows: • how can road infrastructure support connected and Automated Driving in the future? • what infrastructure services should be introduced and by who?

DIRIZON USE CASE 3	

	• where should they be introduced (which locations)?
	• when should they be introduced?
	• at which Level of technology should they become available?
	• what are the traffic/safety concerns from the mixed traffic conditions, i.e. automated vehicles and conventional traffic?
	This Use Case considers the dynamic development of both vehicles' ODD and infrastructure services over the short, medium and long term. During this transition period, automated and conventional vehicles coexist at different Levels of (Automation) technology.
	Infrastructure support services and vehicle equipment can be for example;
	• Infrastructure services:
	  ○ Roadside units, I2V and V2V communication technologies e.g. cellular;
	  ○ Road weather stations;
	  ○ Hazardous warnings, messages though VMS (e.g. tunnel ventilation out of order, debris on the road;
	  ○ Gantries, lane guidance and VMS on infrastructure;
	  ○ Video (CCTV cameras);
	  ○ Ground-based radars;
	  ○ Obstacle detection;
	  ○ Digital traffic regulations (UC-2);
	  ○ Roadworks and traffic incident support units;
	  ○ Traffic management centres;
	  ○ Cloud services.
	• Vehicle equipment:
	  ○ HD maps (UC-1);
	  ○ Vehicle sensors e.g. obstacle detection, weather and road surface conditions;
	  ○ Probe vehicle data
	  ○ V2V communication.

Actors Involved, and their roles	*Primary actors:* • National Road Authorities: They should dynamically provide infrastructure services to support both automated, when their ODD is inadequate, and conventional vehicles in order to avoid traffic degradation due to mixed traffic flows. They are responsible for planning and organising future infrastructure investments. • Local authorities: Provision of compatible infrastructure services. • OEMs (automotive industry): Technological adaption of infrastructure services with vehicles (I2V communication). They should also enable V2V communication with vehicles of different brand and technology.

DIRIZON USE CASE 3	
	• Digital map providers (see UC-1). • Automated vehicle users/customers: Communication with infrastructure services and other vehicles to increase traffic reliability. • Roadworks, weather and incident service providers: Provision of their relevant data either to NRAs/Road operators or directly to automated vehicles when available. Gantries and VMS on road infrastructure will support conventional vehicles. • Road operators: They operate and continuously observe the infrastructure services and traffic flows. They collaborate with NRAs and OEMs to address possible traffic issues. • Third party data providers (e.g. probe vehicle data, traffic information etc.). Standardisation bodies/organisations. *Secondary actors:* • Ministries/Department for Transport: Provision of traffic regulations (see UC-2). Introduction of regulations for mixed traffic conditions e.g. Can there be mixed traffic conditions in the same lane? Should the lane width, geometry and marking change due to automated vehicles? • Fleet operators. • Infrastructure suppliers (e.g. ITS roadside stations).
Stakeholders	• ACEA (European Automobile Manufacturers association) • FIA (Federation Internationale de l'Automobile) • Amsterdam Group • TM2.0 (Traffic Management 2.0) • EC (European Commission) • EU-EIP (EU ITS Platform) • EuroRAP (European Road Assessment Programme) • ENISA (European Union Agency for Network and Information Security) • CLEPA (European Association of Automotive Suppliers) • ETSC (European Transport Safety Council) • C-Roads • DATEX II community • ERTRAC (European Road Transport Research Advisory Council) • IRU (International Road Union)
Assumptions	• Mixed traffic conditions are assumed in the short, medium and long term. The maximum Automation Level that is expected by the end of long term is Level 4. There is not much V2V communication in short term (compatibility issues) while most of the vehicles can communicate in long term.

DIRIZON USE CASE 3	
	• The physical infrastructure elements are gradually digitised in short term, medium and long term. • There is not the same Level of technology deployed on motorways in terms of infrastructure services (even between motorways in same country). Furthermore, the technological Level may change across motorways. • Local roads may also have different technological Levels from the motorways.

6 Conclusions and Outlook

The primary aim of this report is to identify and understand the current and expected Level of Digitalisation and Automated Driving across various European countries and the impact this has and will have on NRA's current and future operations.

To this end, a three stage methodology is considered; A literature review, a series of interviews with both NRA and non-NRA representatives and the selection of three uses cases, the latter which will be assessed in subsequent work streams within the DIRIZON project.

In the first stage, a detailed literature review is carried out where significant past and ongoing EU platforms and projects are briefly described together with the services covered or standards/ regulations introduced. The literature review key findings not only assist the consortium in understanding the current state of the art in respect of Digitalisation and Automated Driving but also informs the interview questions formulated. The purpose of these interviews is to obtain general information regarding issues such as the current & future status of Digitalisation & Automation, their policies, and their views on benefits and barriers. The output of both these stages is subsequently used, in conjunction with input from the CEDR CAD WG, to select three Use Cases specific to the areas of Digitalisation and Automated Driving.

From the findings of both the literature review and interviews a number of conclusions can be drawn.

A number of barriers to achieving full Digitalisation of the road network and Automated Driving are identified, from both the literature review and interviews, including financial barriers; roles and responsibilities; legal/regulatory issues; insufficient collaboration between actors; public acceptability and data issues (privacy, cybersecurity, sharing etc.). Eliminating the barriers and mitigating the risks is not the sole responsibility of the NRA's and it is clear that a holistic approach is required which requires the involvement of all actors, including but not limited to NRA's, Governments, Third parties, road operators and other stakeholders.

From the interview findings, testing is seen as a significant prerequisite for the implementation of C-ITS and even more so for Automated Driving (e.g. testing mixed traffic conditions). There are a number of both Digitalisation and Automated Driving focused projects ongoing and planned, testing various technologies and services, although it is apparent that the there is more activity in the area of Digitalisation (through C-ITS deployment projects) than in the area of Automated Driving. This is not unexpected as Digitalisation and C-ITS deployment is a prerequisite to implementing Automated Driving, however participation in both are key for the NRA's as they allow them to validate the technologies and services being developed and address some of the risks and barriers to implementation. Equally, these projects enable NRA's to work alongside Third Parties, who they primarily see as the 'innovators' of the technologies. Furthermore, collaboration among the various actors is seen as a significant barrier which can only be improved through the NRA's direct involvement in projects with other relevant actors. However, in this regard, all actors must show a willingness to collaborate and share information. In doing so, 'trust' will be built between the actors, an issue identified in the interviews, particularly in relation to data. Without this trust, realising the full benefits of Automated Driving may not be realised. In this regard a trusted Third party that evaluates data and quality in a neutral environment could be of benefit.

It is clear from the interviews that different NRA's are at various levels of C-ITS deployment and Automated Driving implementation as evident from their participation in the various projects and the Digitalisation and action plans in place. In terms of Digitalisation Action Plans, some countries identified that they have specific plans in place, though for the most part these are part of overall ITS strategy. In terms of an Automated Driving, Action Plans are typically not in place, though some countries have a general view on how they see the future of Automated Driving. This appears to be as a result of some countries, at a National Level, adopting a more proactive approach to implementing the various technologies and services. However, in order to achieve a harmonised European approach to Digitalisation and Automated Driving, , in a connected Europe, participation of all countries in these areas is recommend. However, the outlook in this area is positive as of the interviewed countries, all have indicated their intention to develop plans and get involved in projects, whether through their involvement in platforms (e.g. C-Roads) or through Governmental Strategies.

In respect of roles and responsibilities of both NRA's and Third parties, the findings were consistent in that these are not clearly defined. However, the interviews did give an insight into what the NRA's view as their primary roles and responsibilities. Typically, the NRA's see themselves as enablers and/or facilitators of both the digitalised ecosystem and the use of autonomous vehicles on their road networks. Equally the responsibility for data (who collects it, who owns it etc.) is identified as an issue, however the NRA's believe that there should be joint responsibility in providing data and this should be freely available, particularly in relation to safety related data. However, it was noted that ultimately the responsibility for developing action plans, legislation, ethical issues etc. is the responsibility of Government. Not only is legislation required for implementing pilot tests, but issues such as liability, data privacy and access to data need to be addressed as part of a legal framework. Initially these frameworks should eb implemented at National Level and ultimately at EU Level (though Guidance at a national Level is typically sought through EU Level standards and directives).

Notwithstanding the above, the NRA's can play a key role in this area, advising the Government of how Digitalisation and Automated Driving can improve the efficiency and safety of their road networks. Irrespective of the presumed roles and responsibilities of the various actors, it is however clear that formalising the roles and responsibilities among the various actors will be critical for implementation of the technologies and services which can be delivered.

While investment is essential in both digital infrastructure and Automation technologies, at the present time, there is no clear understanding of the investment costs or the operational costs of implementing them. The general view from the interview is that Digitalisation and Automated Driving can reduce NRA's expenditure as significant cost savings can be realised if the vehicles are collecting the data and if there is no longer requirement to install hard infrastructure.

A number of standards, guidelines and regulations have been published in respect of Digitalisation, however there is not the same Level of documentation available related to Automated Driving. This is particularly the case for digital traffic regulations. However, notwithstanding this fact, there is a need to harmonise the current standards, guidelines and regulations at an EU Level. Equally, it is important that these form part of a legislative framework.

Irrespective of the barriers and risks associated with Digitalisation and Automated Driving, it is expected that they will to help NRA's with their operations, particularly in relation to traffic management (incidents, maintenance, roadworks etc.) and provide them with the tools to impact traffic safety positively.

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Appendix A – Interview Questions

1. What is your (or your organisation's) involvement in road infrastructure?
2. What are your organisations current areas of operation in respect of road infrastructure?
3. What is your background in respect of Digitalisation & Connectivity?
4. What is your background in respect of Automated Driving?
5. What infrastructure elements are currently digitised on your road network? To what end are they digitised?
6. Does your organisation have a Digitalisation action plan and if so, what time frame does it cover?
7. Does your organisation have an action plan for Automated Driving and if so, what time frame does it cover?
8. What systems/processes are currently in place to facilitate the use of automated vehicles on the road network?
9. What is the current Level of interoperability (for Automated Driving) between your department and Third parties?
10. If there is a lack of interoperability (for Automated Driving), what sort of problems does this create and what are the main organisational changes that need to happen to overcome these problems?
11. What do you see currently as the most important benefits from the Digitalisation of the road network?
12. What do you see currently as the most important benefits of Automated Driving on the road network?
13. What are the current barriers faced in achieving the full Digitalisation of road Infrastructure?
14. What are the current barriers faced in Automated Driving?
15. Where do you currently see the main division of roles and responsibilities between the NRA's and Third parties in the area of Digitalisation and service provision (data/service exchange between infrastructure and vehicles)? Is there a difference between your view on this topic and that of other NRAs?
16. Where do you currently see the main division of roles and responsibilities between the NRA's and Third parties in the area of Automated Driving? Is there a difference between your view on this topic and that of other NRAs?
17. Where do you currently see the role of Third parties in the implementation of Digitalisation & Connectivity on the road network?

18. Where do you currently see the role of Third parties in the implementation of Automated Driving?

19. Do your current business models/operational models show business opportunities for these Third parties / private sector?

20. What are the current risks associated with Digitalisation of the road network? (e.g. legal, financial, operational, security, privacy, roles, tasks, responsibilities, complexity)?

21. What are the current risks associated with Automated Driving (e.g. legal, financial, operational, security, privacy, roles, tasks, responsibilities, complexity)?

22. How are those risks being managed?

23. What do you believe is the future of Digitalisation of road infrastructure up to up to 2025 and beyond to 2040?

24. What do you believe is the future of Automated Driving up to up to 2025 and beyond to 2040?

25. How will full Digitalisation affect the core activities/areas of operation of your organisation?

26. How will Automated Driving affect the core activities/areas of operation of your organisation?

27. What do you see as the new business opportunities from full Digitalisation of the road network primarily for your organisation but also for other parties involved?

28. What do you see as the new business opportunities from full Automated Driving on the road network primarily for your organisation but also for other parties involved?

29. What are the future risks you envisage as a result of full Digitalisation on the road network (e.g. legal, financial, operational, security, privacy, roles, tasks, responsibilities, complexity)?

30. What are the future risks you envisage as a result of Automated Driving (e.g. legal, financial, operational, security, privacy, roles, tasks, responsibilities, complexity)?

31. Have you been involved in any trials/implementation/research related to Automated Driving (e.g. C-ITS / CAV or other types) and what lessons have you learned? What services or technologies have you tested?

32. Are any of the plans/documents mentioned in this interview available to the DIRIZON Consortium?

33. Could you suggest any relevant literature or sources of information which may be beneficial to our research?

34. Do you have any additions to the questions asked or other remarks for DIRIZON to consider?

Appendix B – Proposed High Level Use Cases

Use case	***Description***
Driverless maintenance and roadworks warning, including roadworks warning and other (C-ITS) services.	Mobile road works on the hard shoulder of motorways bear an increased accident risk for the crew of the protective vehicle which safeguards road works against moving traffic. The operation of a connected automated protective vehicle, which follows the maintenance vehicle, will reduce this risk. The Use Case of unmanned protective vehicles for motorway hard shoulders implies a structured operational environment, and the number of situations which have to be perceived and considered for driving decisions is limited. The operating speed of the unmanned vehicle depends on the speed of the road works, which is at most <12km/h. This results in lower functional requirements compared to Use Cases on driving lanes or with higher speeds. (Example: www.aFAS-online.de) An advanced version of the Use Case is mobile roadworks on the driving lane with a higher speed.
Automated traffic management services.	Automated traffic management services manage the road traffic automatically by combination of algorithms, equipment's and communication networks without involvement of human personnel in decision making according to various kinds of situations of road traffic that could arise.
Provision of HD maps for automated mobility.	The provision of detailed mapping in a machine-readable format supports a connected automated vehicle's ability to understand its precise positioning, plan beyond sensor visibility, possess contextual awareness of the environment and local knowledge of the road rules.
Management of digital traffic regulation (METR).	Management for Electronic Traffic Regulations (METR) becomes more and more relevant and is currently being addressed in more detail within CEN/TC 278 WG17. It has been found that currently legal responsibilities and authorization schemes vary a lot between countries, states and cities. Rules are time-and-place referenced similar to a digital map. This means that for connected automated driving there will be a need to digitalize and maintain regulation and make it available in a machine-readable format.
Fully automated private vehicle (Level 5)	Fully automated driving from point A to B. The driver does not need to monitor the system and no input is given by him/her to the system. Random traffic conditions exist e.g. traffic jams, accidents, road closure etc. The system also estimates the remaining travel time and can optimize its route if any traffic issues exist. The system can have an adaptive traffic control when needed e.g. control the traffic lights, speed limits.
Automated driving across borders (Level 5)	Fully automated driving from point A to B across borders. The driver does not need to monitor the system, and none input is given by him/her to the system. Random traffic conditions exist e.g. traffic jams, accidents, road closure etc. The system also estimates the remaining travel time. The digital cross-border corridors are tested. The automated vehicle collects real time traffic data though a single point of access and makes decisions for any possible traffic problems.

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