DIRIZON

Digitalisation and Automation: Implications for use cases, Identification of Stakeholders and Data Needs and Requirements

Deliverable 3.1

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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 carry out and provide them with new and more efficient ways to achieve their goals for road safety, traffic efficiency, the environment and customer service. In this context, digitalised 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 crucial prerequisites to enable connected and cooperative automated driving. Digitalisation of road assets can provide a number of benefits to road authorities including new (business) opportunities resulting from data sharing, the improvement of enhanced traffic management with Intelligent Transport System (ITS) equipment, improved asset management thus allowing for more reliable performance monitoring of assets and more efficient maintenance processes. Road Operator business practices will need to adapt to exploit these opportunities

To support road authorities in their digital transition and in their interaction with other actors in cooperative automated driving, the Conference of European Directors of Roads (CEDR) commissioned and funded the “advanced options for authorities in light of automation and DIgitalisation hoRIZON 2040”, (DIRIZON) project in the Transnational Research Programme Call 2017 on “Automation”. The DIRIZON project’s goal is to assist the aforementioned road authorities in identifying how these developments will affect their operations and their interaction with others. In this respect, DIRIZON will determine the implications of digitalisation and automated driving on specific core topics and their consequences on data needs and requirements for data-exchange.

Work Package 3 (WP3), “Digitalisation and Automation: Implications for use cases, Relationships with Stakeholders and Data needs and requirements”, extends the use cases selected in this project, as presented in DIRIZON Deliverable D2.1 (Tucker *et. al*, 2019) by developing a future view of the process flow in each use case, and identifying a first draft of the data requirements and data quality criteria in providing the use cases. This project takes a bird’s-eye view of data, looking at the whole eco-system where other actors can provide data, thus, beyond the data that can be supplied by Road Operators. This involves exploring the use cases of the future in which vehicles of different levels of driving automation use the road, and the activities of the process flow.

The process flow, data requirements and data quality criteria are used by WP4 in interaction with non-National Road Authority/Road Operator actors to check their views on the different roles of the involved actors and their interaction. The results of WP3 and WP4 together will be the very basis for the data exchange concept provided by DIRIZON in WP5, the business models in WP6, and the formulated recommendations towards the next steps in WP7. They also form input to CEDR to lay the groundwork for new ways of cooperation with other actors in the future.

Together with the CEDR/CAD working group in Oslo on November 6-7, 2018, the following use cases were selected for DIRIZON and presented in DIRIZON Deliverable D2.1 (Tucker et. al, 2019):

1. Provision of High-Definition (HD) maps for automated mobility
2. Distribution of digital traffic regulations
3. Infrastructure support services for cooperative automated driving

In order to identify the data needed, identification of data quality criteria, and a proposal of the data quality criteria for the data categories, this work package started with understanding how the service is provided in each use case. The process flow diagrams are generic and not country-specific. They are target situations, that is, they do not sketch what the situation is today but how it could be in the future. Finally, the process flow diagrams indicate the roles or

activities that need to be carried out.

Data categories were identified while researching the use cases. Sources include those developed for ITS and C-ITS. Projects and programs in the area of automated driving were also consulted, although there is limited information available from automated driving projects at this point in time. The data categories are distinguished according to how static or dynamic the data are. The project has divided the identified data into the following categories:

- Static data include the digitized information about the road and traffic regulations.
- Traffic data include for example traffic volume, speed, occupancy, and travel times per lane, plus vehicle types and the SAE level of vehicles.
- Events or conditions are primarily safety-related and are covered by the Safety-related Traffic Information (SRTI).
- Dynamic regulations

DIRIZON proposes the following data quality criteria for connected and cooperative automated vehicles.

- Geographical coverage: Road types in the road network covered by the service.
- Refreshment rate: The rate at which the data are updated in the vehicle, regardless if there has been a change in the data provided or not. This criterion is expressed in refreshments per unit of time
- Availability: Percentage of the time that the service is available with fresh data. Expressed as a percentage of the time. It can be interpreted as “up time” of the system.
- Timeliness/ Latency: the total time between the detection of an event or a change, and the delivery to the user.
- Location accuracy: Accuracy to within a specific distance
- Classification correctness: Correct identification of, e.g., a static road element, a vehicle type, event or condition, or a dynamic regulation.
- Event coverage: Percentage of the actually occurring events which are known to be correctly detected and published by type / class, time and location
- Variance: for many or all of the criteria, a variance should be provided. This provides the connected and cooperative automated vehicle extra information to judge the reliability of the provided information, for the vehicle to decide how to use the information.
- Predictability: this criterion results from the experience of Service Providers with data provided for Green Light Optimal Speed Advisory (GLOSA). In countries with traffic lights with dynamic cycles, the predictability (or reliability) of the advice is adversely affected by the possibility by a jump in the cycle length (shorter or longer), and thus the (implicit or explicit) prediction of the Time-to-Green or Time-to-Red. This requirement is specific to GLOSA, but may be extended.

Using the level concept from existing analyses (EU-EIP and Calvert et. al, [EU-EIP, 2018; Calvert, 2016]), a proposal for the required data quality levels is made for each data category. These data quality levels pertain to Infrastructure-to-Vehicle (I2V) communication. These data quality levels were developed using the three use cases. The data quality levels will be different from those developed for Vehicle-to-Vehicle (V2V) services. The concept of data quality levels (Low (L), Medium (M) and High (H)) needs to be seen as a proposal, to be discussed among Road Operators and with other actors for usefulness, feasibility, and desirability. Furthermore, the quantification of the criteria suggested need to be addressed as well.

For each suggested quantification level, existing quantifications were used as a basis, when available. The quantification distinguishes between the data categories.

The consortium has not provided levels for variance and predictability, as no existing sources were available.

Finally, after having estimated the quality levels for each level in the data categories, the project suggests the data quality level required. Table 1 summarizes the proposed data quality levels by data category.

Table 1: Overview of proposed data quality levels by data category

Data type	**Data quality criteria level**					
	Refresh-ment	**Avai-lability**	**Location accuracy**	**Classification correctness**	**Event coverage**	**Geographic coverage**
Static data	M/H	H	H	H	H	H
traffic data	H*	L	H*	H	L	L
safety-related events or conditions	H	H	H	H	H	L**
Dynamic traffic regulations	H	H	H	H	H	L**

* To support Infrastructure Support for Automated Driving, level A (highest level)

** from the view of a National Road Operator

To take the quantification data quality levels and realization of the process flow, actions in several areas are recommended:

- Learn from the Proof-of-Concept of the Data Task Force and other pilots: determine additional standards for data exchange, agree on standards for access, and explore where the quality checks need to take place and by which actors.
- Use pilots to refine data needed, data quality standards, implementations and profiles: implementations should be correct, taking into account the coverage and range of communication. For example, if ITS-G5 coverage is incomplete, the revocation of a message can fail due to a vehicle being out of range. Uniform profiles are required: the data need to have clear definitions and explanations so that they can be used regardless of the data source.

- Engage with OEMs to achieve Operational Design Domain extension of connected and cooperative automated vehicles. For example, work with OEMs to determine under what conditions will OEMs use data from outside the vehicle, that is, data not generated by the CAV's own sensors.
- Consider the use cases in a pan-European context. Does the service work in two different countries with possibly different implementations?

In the future, the amount of data stored and exchange can grow enormously. Traditional monitoring means collect traffic data each minute-kilometre level while C-ITS does at millisecond-meter level, which is a factor of 10^3 to 10^5 more data. To keep the service provision manageable the implications of the amount of data need to be investigated. Intelligence needs to be built into the system to reduce storage needs and the amount of data that is transferred. This has implications for individual vehicles, personal electronic devices such as mobile phones, and roadside units.

Synergies can be realised. Digitalisation efforts at lower levels of government (e.g., provincial, regional , and city-levels) can provide a synergy with the work at the national and European levels.

Realization of Mobility as a Service (MaaS) can benefit from the data-exchange platforms established for CAVs. MaaS analyses of data required goes beyond the data needs for road-based traffic, examined in this study. MaaS data needs include data on other modes such as public transport and other innovative forms of transport, including schedules and real-time (availability) data, data on pricing and stipulations, and transaction data. Enabling MaaS means enabling parts of road-based data as described here.

Project information

Project title	advanced options for authorities in light of automation and **DI**gitalisation ho**RIZON** 2040.		
Acronym - Logo	DIRIZON		
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.		
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Start date **End date**	01/09/2018 31/08/2020	**Duration (in months)**	24
Project Website	https://www.dirizon-cedr.com/		

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Abbreviations

Abbreviation	Full Title
ASIL	**A**utomotive **S**afety **I**ntegrity **L**evel
CAD	**C**onnected and **A**utomated **D**riving
CAM	**C**ooperative **A**wareness **M**essage
CAV	**C**onnected and Cooperative **A**utomated **V**ehicle
CCAM	**C**onnected and **C**ooperative **A**utomated **M**obility
C-ITS	**C**ooperative **I**ntelligent **T**ransport **S**ystems
CEN/TC	**E**uropean **C**ommittee for **S**tandardization/ **T**echnical **C**ommittee
C-Roads	**C**ooperative **R**oads
DAB	**D**igital **A**udio **B**roadcasting
DENM	**D**ecentralized **E**nvironmental **N**otification **M**essage
DoS	**D**enial of **S**ervice
DSRC	**D**edicated **S**hort **R**ange **C**ommunications message set dictionary
DTR	**D**igital **T**raffic **R**egulations
HD	**H**igh-**D**efinition
GDPR	**G**eneral **D**ata **P**rotection **R**egulation
ICT	**I**nformation and **C**ommunications **T**echnology
INFRAMIX	Preparing road infrastructure for mixed vehicle traffic flows
ISAD	**I**nfrastructure **S**upport for **A**utomated **D**riving
ITS	**I**ntelligent **T**ransportation **S**ystem
MaaS	**M**obility **as a S**ervice
METR	**M**anagement for **E**lectronic **T**raffic **R**egulations
NIS	**N**etwork and **I**nformation **S**ecurity regulation
NRA	**N**ational **R**oad **A**uthority
ODD	**O**perational **D**esign **D**omain
OEMs	**O**riginal **E**quipment **M**anufacturer**s**
PKI	**P**ublic **K**ey **I**nfrastructures
RDF	**R**esource **D**escription **F**ramework
RO	**R**oad **O**perator
RTTI	**R**eal-**t**ime **T**raffic **I**nformation
SAE	**S**ociety of **A**utomotive **E**ngineers
SPARQL	SPARQL **P**rotocol **A**nd RDF **Q**uery **L**anguage
SRTI	**S**afety-**R**elated **T**raffic **I**nformation

Abbreviation	Full Title
RDS	**R**adio **D**ata **S**ystem
TDRAP	**T**rusted **D**igital **R**egulations **A**ccess **P**oint
TMC	**T**raffic **M**essage **C**hannel
TPEG	**T**ransport **P**rotocol **E**xperts **G**roup
VMS	**V**ariable **M**essage **S**igns
V2P	**V**ehicle **to P**erson
V2I	**V**ehicle **to I**nfrastructure
V2V	**V**ehicle **to V**ehicle
WG	**W**orking **G**roup
WP	**W**ork **P**ackage

Definitions

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

Term	Definition
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.
PUBLIC KEY INFRASTRUCTURE (PKI)	A set of dedicated policies, procedures and technology that are needed to deal with digital certificates in a public key cryptography scheme. This includes Certificate Authorities (CA) communication for initial enrolment of ITS stations, certificate requests and re-keying and certificate renewal (ENISA, 2019 & C-Roads, 2018c)
SYSTEM	It comprises a set of sequences of actions and variants that are performed within it and lead to value of an actor. It can be a complex combination of various components that interact each other to satisfy individual objectives.
SYSTEM SECURITY	It consists of all functions required for a secured message generation, i.e. signature generation, key and certificate handling, as well as authentication (verification) of received messages (C-Roads, 2018c).
USE CASE	A function of the system, the desired behaviour (of the system and actors), specification of system boundaries and definition of one or more usage scenarios. It combines all possible scenarios that can occur when an actor tries to achieve a certain technical objective (business goal) with the help of the system under consideration.

1 Introduction

1.1 Background

The CEDR Transnational Research Programme was launched by the Conference of European Directors of Roads (CEDR). CEDR is the Road Directors' platform for cooperation and promotion of improvements to the road system and its infrastructure, as an integral part of a sustainable transport system in Europe. Its members represent their respective National Road Authorities (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.

The digitalisation of road networks and the rapid developments in automated driving will affect the core activities that (national) road authorities carry out and provide them with new and more efficient ways to achieve their goals for road safety, traffic efficiency, the environment and customer service. In this context, digitalised 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 crucial prerequisites to enable automated driving. Digitalisation of road assets can provide a number of benefits to road authorities including new (business) opportunities resulting from data sharing, the improvement of enhanced traffic management with Intelligent Transport System (ITS) equipment, improved asset management thus allowing for more reliable performance monitoring of assets and more efficient maintenance processes. Road Operator (RO) business practices will need to adapt to exploit these opportunities

To support road authorities in their digital transition and in their interaction with other actors in cooperative automated driving, the Conference of European Directors of Roads (CEDR) commissioned and funded the "advanced options for authorities in light of automation and DIgitalisation hoRIZON 2040", (DIRIZON) project in the Transnational Research Programme Call 2017 on "Automation". The DIRIZON project's goal is to assist the aforementioned road authorities and Road Operators in identifying how these developments will affect their operations and their interaction with others. In this respect, DIRIZON will determine the implications of digitalisation and automated driving on specific core topics and their consequences on data needs and requirements for data-exchange.

1.2 WP3 in DIRIZON, including scoping

Work Package 3 (WP3), "Digitalisation and Automation: Implications for use cases, Relationships with Stakeholders and Data needs and requirements", extends the use cases selected in this project, as presented in DIRIZON Deliverable D2.1 (Tucker *et. al*, 2019) by developing a future view of the process flow in each use case, and identifying a first draft of the data requirements and data quality criteria in providing each use case. This project takes a bird's-eye view of data, looking at the whole eco-system where other actors can provide data, thus, beyond the data that can be supplied by Road Operators (ROs). This involves exploring the use cases of the future in which different Society of Automotive Engineers (SAE) levels of vehicles use the road, and the roles involved in the process flow.

The process flow, data requirements and data quality criteria are used by WP4 in interaction with non-NRA/RO actors to check their views on the different roles of the involved actors and their interaction. The results of WP3 and WP4 together will be the very basis for the data exchange concept provided by DIRIZON in WP5, the business models in WP6, and the formulated recommendations towards the next steps in WP7. They also form input to CEDR to lay the groundwork for new ways of cooperation with other actors in the future.

Connected and cooperative automated driving is a field of great research and industrial interest. The field is in flux. A lot of activities and research take place in parallel. Simultaneously, there are few aspects that have been made definite in terms of responsibilities, agreements, etc., resulting in a greenfield situation. This report presents the state of knowledge accessible by the project at the time of its writing.

1.3 Structure of the Report

The report is structured as follows. Chapter 2 explains the methodology used to achieve the results of WP3. Chapters 3, 4, and 5 extend the use cases “Provision of HD maps for automated mobility”, “ Distribution of digital traffic regulations”, and Infrastructure support services for connected and cooperative automated driving”, respectively. Chapter 6 creates data categories and reviews existing knowledge form the literature, projects, and programmes on data quality criteria, while Chapter 7 proposes data quality criteria for connected and cooperative automated driving. The summary and conclusions are presented in Chapter 8.

2 Methodology

2.1 Introduction

DIRIZON looks to the future in which connected and cooperative automated driving (CAD) is supported by both digitalisation and connectivity which are crucial prerequisites to enable automated driving. The timeframe of the project – until 2040 -- means that vehicles of different levels of automation will use the road at the same time. Vehicles that are not connected and without automation will also use the road network. DIRIZON looks specifically to the requirements that automated vehicles will place on data needs and data quality requirements. It is assumed that the data provision for automated vehicles is adequate for the human driver (assuming it is provided in a correct and usable form) and thus the latter will not be addressed. For automated vehicles, the information will be provided in an appropriate digitized and machine-readable form.

2.2 Approach

DIRIZON approached the broad topic of digitalization by identifying three use cases. The use cases provided the specificity needed to answer the questions posed within the project. Together with the CEDR/CAD working group in Oslo on November 6-7, 2018, the following use cases were selected and presented in DIRIZON Deliverable D2.1 (Tucker et. al, 2019):

1. Provision of High-Definition (HD) maps for automated mobility
2. Distribution of digital traffic regulations
3. Infrastructure support services for cooperative automated driving

The three use cases cover many but not all the possible aspects of data related to digitalisation and automation, for example, the use case of road infrastructure maintenance using digitalized information. The results of the project and specifically this work package 3 aim to provide value to the National Road Authorities and to the work packages of DIRIZON that follow.

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

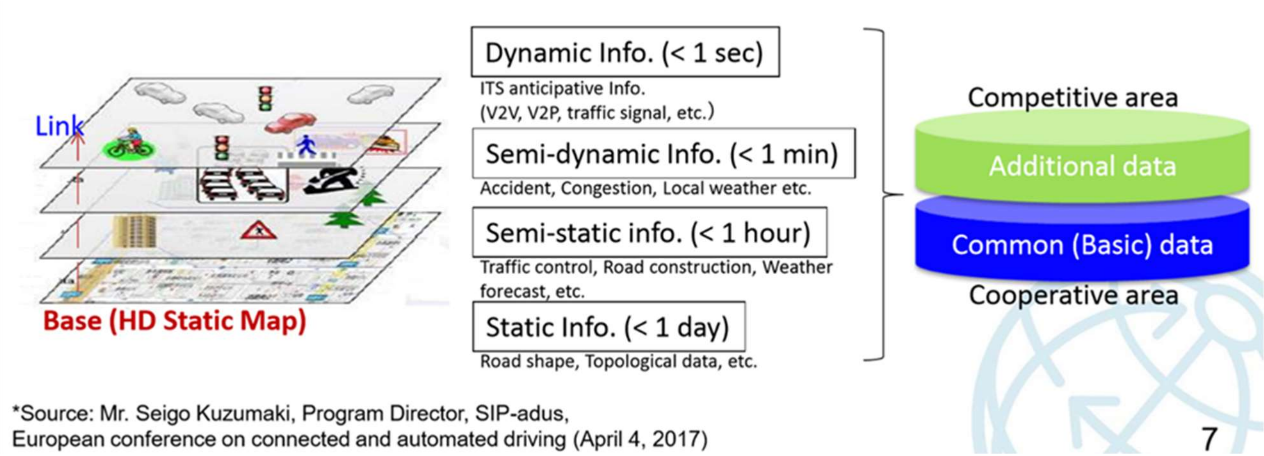

Figure 1: Visualization of the layers and data types for a High-Definition (HD) map. Source: presentation of Jun Shibata at the SIS 37, 12th ITS European Congress Strasbourg, June 21, 2017 [Shibata, 2017]

The DIRIZON project sees the use cases as building on atop the other, all within a High-Definition (HD) map. The basis or base layer is the static data in the HD map. The distribution of digital traffic regulations adds traffic regulations in digital and machine-readable form. Infrastructure support for connected and cooperative automated driving (ISAD) is digitized information, on top of the HD map and the digitized traffic regulations, to support CAD functioning. Use case 3 covers vehicles in a mixed environment, supporting connected automated vehicles (CAVs) by extending their Operational Design Domain (ODD), and improving safety, traffic flow and environmental impacts. The Society of Automotive Engineers (SAE) defines the ODD as, “Operating conditions under which a given driving automation system or feature thereof is specifically designed to function, including, but not limited to, environmental, geographical, and time-of-day restrictions, and/or the requisite presence or absence of certain traffic or roadway characteristics” [SAE J3016]. Figure 1 illustrates the layers of a HD map. Figure 1 shows layers that differ according to how static or dynamic these data are. Conceptually, the HD map integrates layers of different types of data, which can come from different use cases.

In order to identify the data needed, identification of data quality criteria, and a proposal of the data quality criteria for the data types and issues, this work package started with understanding how the service is provided in each use case. This process began with the CEDR-CAD workshop in Tallinn (see the Appendix in Section 10) and its preparation. Based on the Tallinn workshop results, and subsequent work by the consortium, the consortium developed a process flow diagram for each use case in Chapters 3, 4, and 5 to convey what the activities are to deliver the use case, which types of data are exchanged, and which roles are involved to deliver the service. The process flow diagrams are generic and not country-specific. They are target situations, that is, they do not sketch what the situation is today but how it could be in the future. Finally, the process flow diagrams indicate the roles or activities that need to be carried out. The roles and activities are distinguished, but an actor could carry out more than one role in the process. This means that actors fulfilling single roles and integrated roles can exist in parallel. The use cases were individually refined, and the relationships among the use cases were better defined. Allocation of roles to specific parties, e.g. market or government, is an important part of the studies carried out by WP6.

Data categories and data quality criteria were identified while researching the use cases. Sources include those developed for ITS and C-ITS, such as work done by the EU-EIP platform [EU-EIP, 2018], which is focused on the Road Operator (RO), and is based on the ITS directive and more detailed information provided, for example, in the delegated regulations for Real-time Traffic Information (RTTI) [RTTI, 2014] and Safety-related Traffic Information (SRTI) [SRTI, 2013], data quality requirements for C-ITS services [Calvert, 2016], the proof-of-concept of the Data Task Force [Felici, 2019], and projects on the digitalization of mobility in the Netherlands.

Projects and programs in the area of automated driving were also consulted, although there is limited information available from automated driving projects at this point in time: INFRAMIX [INFRAMIX, 2018], which investigates infrastructure support for automated driving, the Dutch TKI project on automated driving, and with the L3 Pilot project (https://www.l3pilot.eu/).

The data discussed in Chapter 6 cover all three use cases. The project is aware that the data needed for all possible use cases beyond the three analysed in this report related to digitalization and automation are not exhaustively enumerated, thus could not be considered a complete list of data to enable the use cases.

To understand the data quality criteria, the data are categorized similarly but not the same as the layers in the conceptual model as presented Figure 1. The layers of the map distinguish between how static or dynamic the data are. The EU-EIP platform [EU-EIP, 2018] also identifies criteria for the data required for RTTI and SRTI, from a road operator's perspective in order to meet the requirements outlined in RTTI [RTTI, 2014] and SRTI [SRTI, 2013]. The work in DIRIZON looks beyond these requirements, which assume existing traffic management systems, to the provision of such data and more (when the distribution of digital traffic regulations are included) to connected and cooperative automated vehicles. INFRAMIX [INFRAMIX, 2018] also indicates some data quality criteria for automated driving.

The project has divided the identified data in RTTI [RTTI, 2014] and SRTI [SRTI, 2013] into static road data, traffic data, and events or conditions. On the basis of use case 2, distribution of digital traffic regulations, the project added another category, dynamic regulations, which are binding traffic regulations that are dynamic. This category covers for example dynamic speed limits and road closures.

2.3 Thoughts on the relationship between data requirements and data quality criteria for C-ITS and CAD

Most of the data requirements and data quality criteria come from work carried out in the C-ITS domain. High-level conceptual information is available for automated driving. Moreover, automated driving presents dilemmas that do not exist or exist to a much lesser extent, when a driver is present in a vehicle using C-ITS. If a vehicle is operating at SAE level 4 or 5, meaning that the vehicle operates in an ODD that fully supports automated driving, data and information need to be clear and unambiguous, that is, the information can be interpreted in only one way, if it is to be used correctly by the automated vehicle. Also, the same information provided via different channels (shown on Virtual Message Signs (VMSs) and transmitted to the vehicle) should not conflict. A driver actively driving could most likely resolve the situation in which conflicting information is provided. An automated vehicle could as well, it if has been developed to deal with resolving these types of situations. However, the project hypothesizes that it is preferable to take preventive measures to avoid such situations in which conflicting information is provided. Thus, automated vehicles appear to place at least as strict standards, if not stricter, on the criteria than C-ITS services do, and most likely other quality criteria and the introduction of Safety Integrity Levels (like the Automotive Safety Integrity Levels) are necessary, compared to what is needed for (recommendation-based) C-ITS services.

3 Use Case 1: Provision of HD maps for automated mobility

3.1 Description

High-Definition (HD) maps are defined here to be the provision of detailed mapping in a machine-readable format to support a CAV's ability to understand its precise positioning, plan beyond sensor range, possess contextual awareness of the environment and local knowledge of the road rules. Hence, HD Maps can assist automated vehicles to optimize their precise positioning and control on the road surface and potentially extend their ODD.

HD maps are required for automated driving. 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 built up in layers, depending on the type of data (from static to dynamic). The base layer of HD maps will be populated with static data[1]. They will provide to (automated) vehicles information on pertinent road infrastructure (e.g. road design, road geometry, and lane information.)

Figure *2* shows the process flow of the provision of high-definition maps for automated vehicles, for a future, generic implementation. Road operators or authorized parties provide road model, lane model and localization data to a National Access Point. Road operators or authorized parties provide data needed for an HD map via a National Access Point (option 1) and / or to the map providers (option 2). These data include road model data (road geometry, width, gradients, and junctions), lane model data (number of lanes, widths, and attributes), localization model data (beacons, signs, and landmarks) or other relevant road-related information (e.g. public parking information, etc). Road operators provide certified / signed Digital Traffic Regulations (DTR) data relevant to the HD map either to the Trusted Digital Regulation Access Point (option 3), or directly to HD map providers via a trusted party / secure connection (option 2). Figure *2* shows the National Access Point and the Trusted Digital Regulation Access Point are functionally different, with the Trusted Digital Access Point requiring an extra level of certification and security, as its data have binding power. However, they do not need to be completely separate entities. For example, the Trusted Digital Regulation Access Point could be a secure section within a National Access Point. The exact configuration is up to the responsible authority. WP5 of DIRIZON will investigate the blueprint for the data sharing platform, and will consider the repercussions of requirements on the Trusted Digital Access Point for the blueprint of the platform.

[1] Currently discussions on HD maps do not focus on the differences between static and dynamic, but focus on the process side, e. g. what is part of the base layer and what will be provided in a service on top.

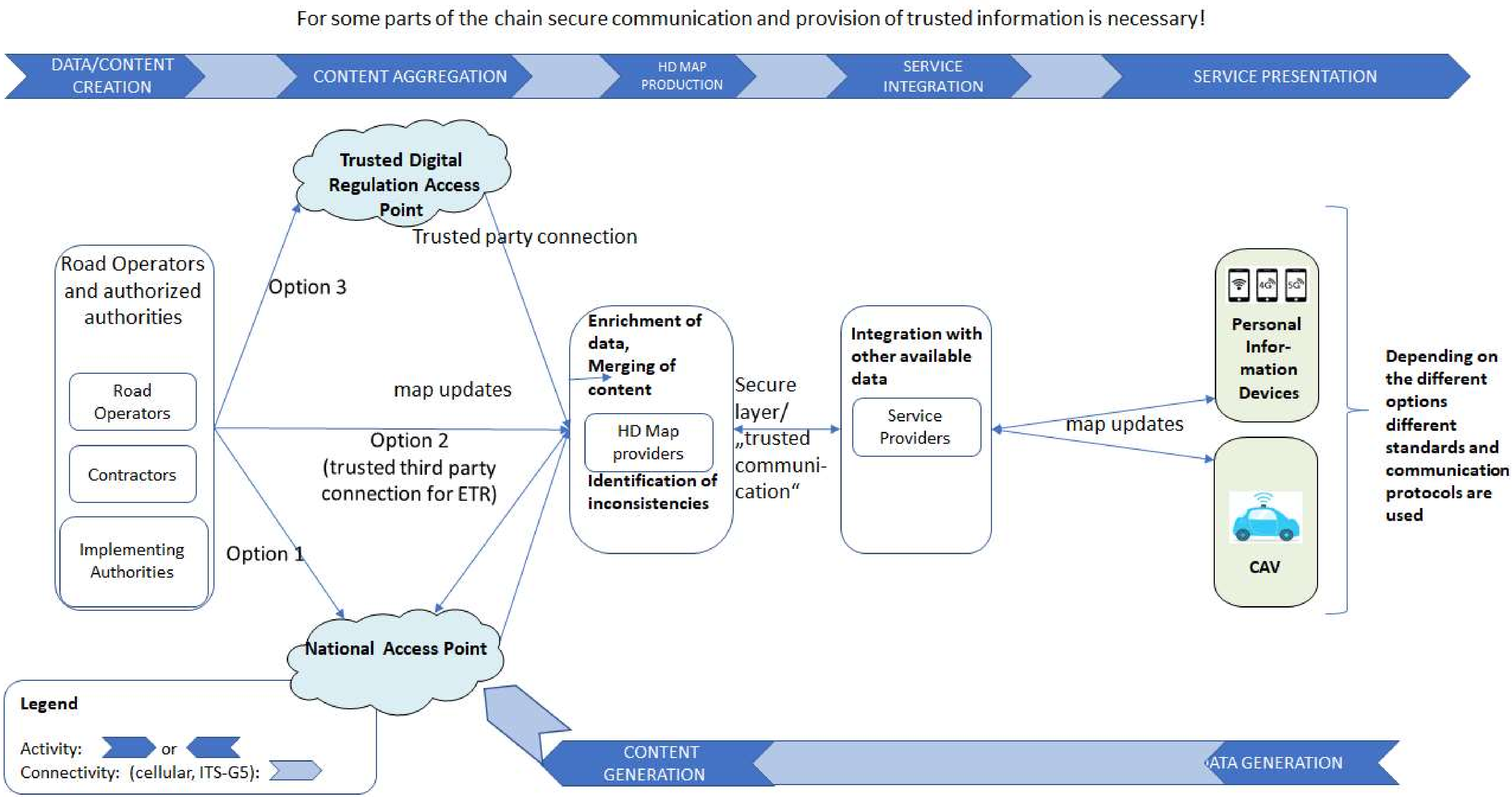

Figure 2: Process Flow diagram for Provision of High-Definition maps for automated mobility

If they have not received it directly, the HD map providers can pick up DTR from the Trusted Digital Regulation Access Point, and digitized road and lane models and localization data from the National Access Point. This information is integrated into its HD map, along with the certificate for the regulations.

The HD map provider provides its map to the service provider. The service provider uses the HD map in its service such as navigation, providing it to CAVs and to (portable) electronic devices to be used by human drivers. The information provided to the CAVs and to the (portable) electronic devices is then “visualized” for use.

The CAVs and (portable) electronic devices also provide feedback to Service providers when inconsistencies are found between the information provided in the services and the environment sensed by the vehicle sensors or the (portable) electronic devices mounted on the windshield or perceived by the human driver.

The Service Provider passes on relevant feedback to the HD Map providers. Although presented here in the process flow diagram, the actors involved in providing feedback need to agree on the sharing of these data.

HD Map providers provide automated feedback to road authorities via the National Access Point and Trusted Digital Regulation Access Point. The feedback concerns how and whether the data provided are used and feedback on the quality of the data provided. This allows the Road Operators to better optimize their process.

The topic of enforcement, e.g. to verify if the car follows the distributed regulations, is not covered in this core topic.

3.2 Use Case Evolution

The paragraphs below sketch the evolution of the use case, for the short (1-3 years), medium (3-7 years) and long (>7 years to the year 2040) terms.

Short term:

- Basic Process flow is established: Establishment of NAPs or processes for data provision; profiles, formats, structures and procedures needed to handle data streams; testing.
- Agreements and digitalisation of road, lane and establishment of localization
- Mixed traffic conditions exist in the infrastructure and not all the vehicles have the capabilities to fully use an HD map and all its layers.
- The HD maps comprise validated data from various sources/domains that are in standardised computer-readable formats and are queried and linked via suitable web technologies, e.g. SPARQL and RDF.
- Data can be public and/or private data. Relevant physical infrastructure elements (e.g. road, lane and localization landmarks) have been digitised and are available to HD maps.
- The HD map does not act as a decision-making tool for the vehicle. However, it supports the driver or vehicle actions.

- There is not much V2V communication, i.e. data sharing amongst vehicles. Furthermore, there is not an extra validation of the HD map data with vehicle produced data from sensors. It is not expected that different OEMs will share fleet-generated data with the exception of pilots.

Medium term:

- Feedback loops established
- discussion of TDRAP structure starts, discussion of certificates, secure connections, access, standards establishment for TDRAP
- HD maps localization quality reached
- Mixed traffic conditions exist on the infrastructure and almost all the vehicles are equipped with a HD map.
- Most of the physical and digital infrastructure elements have been digitised and are available to HD maps. Digital infrastructure refers to static speed limits, access restrictions, and other traffic regulations.
- HD digital map achieves the data quality levels required for the decision-making process in a CAV.

Long term:

- Mixed traffic conditions exist. HD digital map supports, but does not control, decision making (through suitable algorithms developed by OEMs). Decision-making by the CAV remains within the automated vehicle.

3.3 Data needs for provision of HD maps

At this point in time, there are no publicly available explicit data quality requirements for data to be used by automated vehicles. Therefore, this work focuses on providing a framework for thinking about which data quality criteria are appropriate, the identification of classes of data, and making initial suggestions for the data criteria. The initial suggestions are based on the EU-EIP [EU-EIP, 2018] as a starting point. These criteria need to be checked with the actors involved. The actors would also need to establish the responsibilities for checking of the data.

The paragraphs below provide examples in the categories, again, not an exhaustive list.

Static data means the digitized information about the road and traffic regulations. These include the

- road model
  - geometry, road width, gradients, and junctions,
- road classification,
- lane model
  - number of lanes
  - link attributes, including speed limits, access conditions for tunnels and bridges and permanent access restrictions, other traffic regulations, freight delivery regulations such as for dangerous goods, and the direction of travel on reversible lanes, with time windows

- HD localization model (beacons, landmarks), locations of, for example, tolling stations, parking spaces and service areas, charging points, public transport stop, and the location of delivery areas. Note that HD map providers may provide parts of this information in a basic map or in a premium version, depending on the specific client group.

3.4 Standards and gaps in standardisation

Standards for data and data exchange are required for all of the data listed in Section 3.3. There are existing standards for data.

- OSM XML is an open standard for HD maps
- The INSPIRE Directive aims (among other things) to create a European Union spatial data infrastructure which will enable the sharing of environmental spatial information among public sector organizations. Common data models, code lists, map layers and additional metadata are described in the INSPIRE Implementing Rules on interoperability of spatial data sets and services [EU, 2013] and Technical Guidelines (Data Specifications) [INSPIRE, 2019].
- TN-ITS (CEN TS278). The TN-ITS specifications are published under CEN TS 17268 and are maintained in the CEN TC 278/WG3. CEN TS 17268 describes the specification for standardized map layer data exchange between NRA and data users, such as map providers. This document defines the content specification for the exchange of road-related spatial data, and especially updates thereof. Based on the content specification, this document defines also a physical exchange format (structure and encoding) for the actual data exchange. In addition, it defines web services that are needed to make the coded data on updates available. Exchange of dynamic information is not in the scope of this document. Although the focus of this document is on providing information on updates, the technology described in this document in principle also enables the exchange of full data sets, either concerning the whole road network in a coverage area, including all geometry and all attributes, or a subset, concerning for instance all instances of one or more specific attributes [CEN TS 17268, 2019].
- Navigation Data Standard (NDS) is a standardized format for automotive navigation databases, jointly developed by automobile manufacturers and suppliers. The standardized database format allows the exchange of navigation data between different systems [NDS, 2019].

Data standards for the HD lane model and the HD localisation model are in progress. Different organisations are trying to build a standard: the OneMap Alliance (association with HERE), TomTom Road DNA, the Japanese initiative on SIP ADUS, a cross-ministerial Strategic Innovation Promotion Program (SIP) on automated driving for universal services (ADUS): http://en.sip-adus.go.jp/ and The Navigation Data Standard (NDS), an industry-driven organisation including OEMs and service providers.

Standards related to the Trusted Digital Regulations Access Point and the development of the secure connection and access to it need to established.

The data exchange mechanisms between all the stakeholders need to be realized.

The Elektrobit White Paper [Elektrobit, 2019] discussed aspects of maps that can affect the safety of applications that use them, and identified remaining challenges. The actors identified to work together to find solutions to the challenges below include map providers, providers of highly automated driving functions, automated vehicle producers, and road authorities need to work together to find the solutions.

- Human error prevention guidelines must be developed for map making.

- Effective analysis methods for safety in use and “safety of the intended functionality” (relating to functions in the car and the “nominal performance” necessary for safe operation) must be identified or developed.
- Communication between road building authorities and map makers must be established.
- Safety mechanisms to detect map data collection or map production interruptions must be specified and implemented.
- The different Automotive Safety Integrity Levels (ASIL) for qualitative safety measures need to be distinguished.

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4 Use case 2: Distribution of digital traffic regulations

4.1 Description

Distribution of digital traffic regulation becomes more and more relevant for Connected and Automated Mobility (as well as for other areas e.g. smart cities) and is currently being standardized within CEN/TC 278 WG17. It has been found that current 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 there will be a need to maintain and encode traffic regulations electronically to be machine readable, processed and correctly interpreted by a receiver, in the context of this report, a CAV.

The process of creating legislation at different governmental levels (national, regional and local), creating a harmonized digital equivalent for traffic regulations (e.g. normally represented thought physical signs) across Europe, and the enactment of these regulations are prerequisites but not part of the operations of distribution of digital traffic regulations. This use case focuses on how the static and dynamic regulations are distributed to the users (map providers, etc.)

Figure 3 shows the process flow diagram for the distribution of digital traffic regulations. Traffic regulations comprise static and temporary (dynamic) regulations. These can be triggered by different sources:

- European legislation
- New national and regional framework conditions
- Current (pre-defined) situations to react on (e.g. weather-related, traffic condition related, environmental conditions (e.g. within low emission zones))

A traffic regulation can be the effectuation of a traffic ban, traffic restriction or a traffic facilitation (either route/section-related, vehicles category-related or time-related or a combination of these). The traffic regulation authorities define the regulation within their area of competence, whether it be long-term static regulations or temporary traffic regulations. The enacted regulations are implemented by the implementing authorities (Road Operators, administrative bodies, police, etc.). The implementing authorities notify the traffic regulation authorities of the implementation.

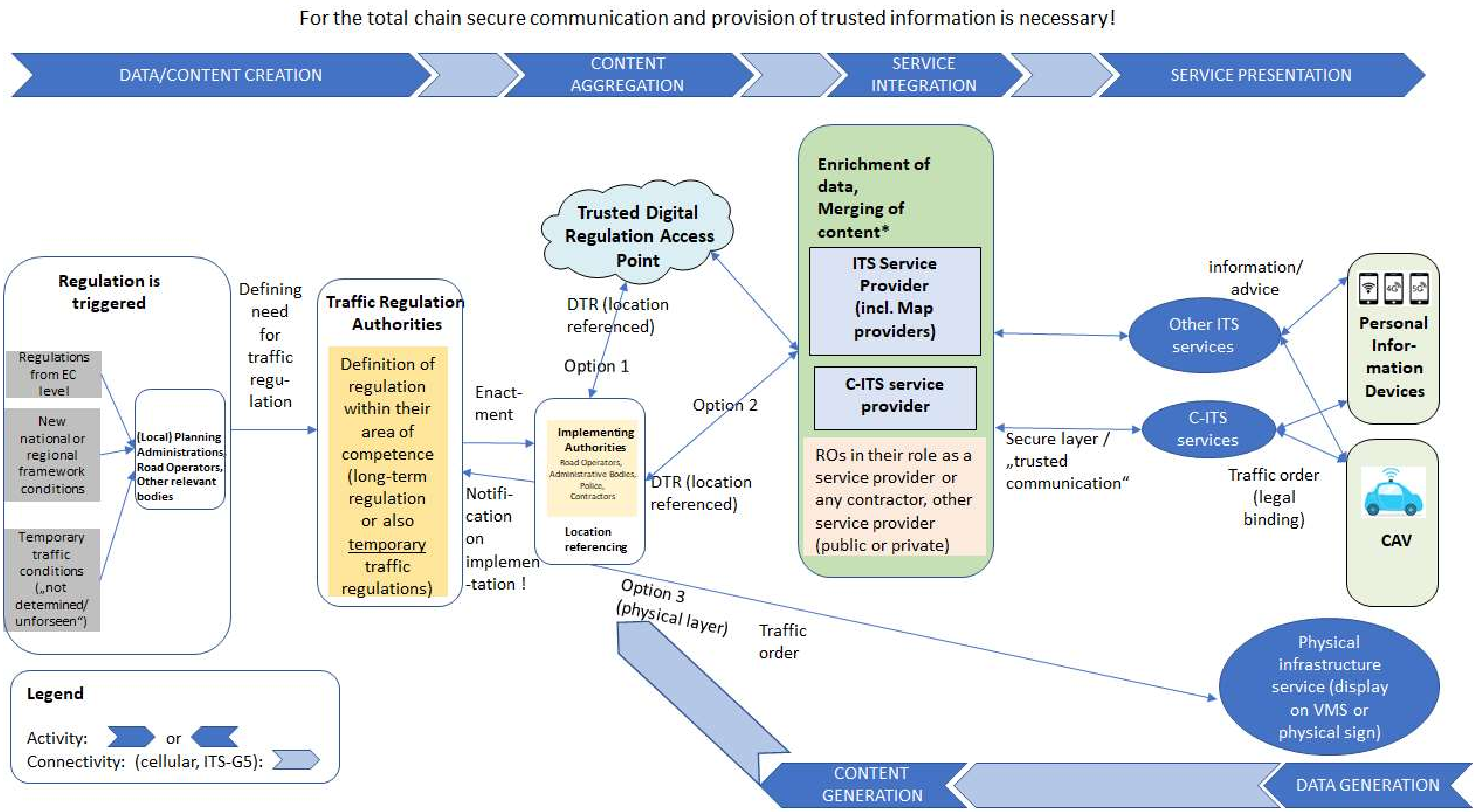

Figure 3: Process flow diagram for distribution of digital traffic regulations (DTR)

There are three options for communication of the digital traffic regulations to road users as depicted in Figure 3. The first two options require a secure communication and the usage of a Public Key Infrastructure (PKI). The purpose of a PKI is to facilitate the secure electronic transfer of information for a range of network activities. It is required for activities where more rigorous proof is required to confirm the identity of the parties involved in the communication and to validate the information being transferred. Options 1 and 2 also allow Service providers to provide information back to the Implementing Authority, for example, if inconsistencies are found.

- Option 1 is for the implementing authority to provide the regulations to a Trusted Digital Regulation Access Point. These regulations must be picked up by Service providers, for use in their C-ITS services, integrating the binding information to vehicles and (portable) electronic devices. The application of a PKI should lead the driver or automated vehicle to trust the information and observe the traffic regulation.
- Option 2 is for the implementing authority to provide the regulations via a bidirectional communication with service providers. The further communication is similar to option 1
- Option 3 shows what already takes place: the regulations are displayed via physical infrastructure via static signs or on VMSs.

This use case makes clear that communication takes place in a trusted environment and its delivery ensured. CEN/TC 278 WG17 states that "this service needs strong security support. Regulations need legal proof from the generating entity all the way to the end user, so that all main security features like confidentiality (privacy), integrity (trust) and availability (Denial of Service (DoS)) is present. This includes security services new to the ITS domain like non-repudiation. Luckily the PKI structure developed for C-ITS will work directly out of the box, so this work is mainly related to apply C-ITS security in the context of METR" [Evensen (2018)].

There are mixed traffic conditions on the infrastructure (i.e. non-automated and automated vehicles). However, most of the vehicles are expected to be connected and automated in the long term.

4.2 Use Case Evolution

The paragraphs below sketch the evolution of the use case, for the short (1-3 years), medium (3-7 years) and long (>7 years to the year 2040) terms. The activities related to standards borrow from the working items identified in [Everson, 2018].

Short term:

- Appropriate standards (which include a data model and definitions, terminology, organizational framework, roles and interfaces, technical content of the regulation, and constraints per service) to support the use case have been introduced. Typically developed as one standard per service. Many of these services are under development or already defined in DATEX II, TPEG, C-ITS,... although under a different service concept than digital traffic regulations, so re-use and integration with these services is strongly suggested. Standardization may extend into the medium term.
- Agreement at least at EU level

Medium term:

- Relevant traffic regulations and relevant infrastructure elements are gradually digitised. In this context "relevant" is the minimum infrastructure data required to facilitate implementation of digital traffic regulations at each stage of maturity.

- The ROs and authorized parties have implemented dedicated processes within their organisation that control the traffic regulations in a dynamic fashion. It acts as a data collection point and assigns roles/tasks to relevant stakeholders. The system is partially automated with the NRAs/Road operators fully controlling its actions.
- Conformance testing of digital traffic regulations and quality parameters: for an approved digital traffic regulation distribution, conformance tests and a set of parameters have been introduced.
- Definition of interface for the regulatory body permitted to generate digital traffic regulations. For Public Access, the definition of the interface includes protocols, access rules, etc. Since digital traffic regulations needs to be pan-European, this interface should be the same as, or co-located with, the ITS National Access Point
- Operational constraints for Trusted Digital Traffic Regulations Access Point defined.
- The distribution of digital traffic regulations needs strong security support. Regulations need to be legal proof from the generating entity all the way to the end user, so that all main security features like confidentiality (privacy), integrity (trust) and availability (denial of service - DoS) is present. The PKI structure developed for C-ITS will work directly out of the box, so this work is mainly related to applying C-ITS security in the context of digital traffic regulations.

Long term:

- NRAs have introduced Trusted Digital Regulation Access Point(s) i.e. a common platform where they can share real-time traffic regulation data. Furthermore, other stakeholders, e.g. digital map providers can exploit that data providing HD maps enriched with dynamic traffic regulations.
- Automated vehicles automatically observe the current traffic regulations and act accordingly.

4.3 Data needs for provision of digital traffic regulation

Currently, first standardisation activities in the light of digital traffic regulations have started. Therefore, this use case is in a nascent stage. The data will be both static, as listed in use case 1 on HD maps, and dynamic. Dynamic regulations include dynamic speed limits; road, lane and bridge closures; and road works. The definition of the specific content of the digital traffic regulation also needs further to be defined, standardized, and profiles need to be developed. The profile will include many of the same data definitions already defined for C-ITS use cases, for example, Road Works Warning.

4.4 Standards and gaps in standardisation

The digital traffic regulations should be in a format readable by the digital maps and automated vehicles. Currently DATEX II and TN-ITS could be used partially but have to be extended.
Digital traffic regulation distribution standardisation crosses over/shares contents with other standardisation activities: Transmodel (CEN TC278/WG3), TPEG (CEN TC278/WG4, ISO RC204/WG10), C-ITS (CEN TC278/WG16, ETSI TC ITS)

Gaps in standardisation identified in [Eversen, 2018] are include in the use case evolution above.

5 Use Case 3: Infrastructure support services for CAD

5.1 Description

Infrastructure Support for Automated Driving (ISAD) for CAD is digitized information, on top of the HD map and the digitized traffic regulations, to support CAV functioning. The use of a HD map is assumed. Thus, this core topic covers vehicles in a mixed environment, supporting connected and automated vehicles (CAVs) by extending their Operational Design Domain (ODD) and improving safety, traffic flow and environmental impacts. The focus within this use case is the infrastructure support services provided by the road operator. The type of data that CAVs need to extend their ODD are related to the local traffic situation, by definition beyond its sensor system scope, like data based on measurements of other vehicles' real-time speeds and travel times, traffic volumes, and detection of incidents and accidents, on the road segment level and, if possible, at the lane level.

Some of these data can already be supplied by other sources: real-time speeds and travel times on road segments or trajectories by ROs and third party service providers. In the future, the infrastructure-based detection and measurement systems can be complemented by other sources of data, such as probe vehicle data (locations, travel times, speeds, braking actions, weather conditions, road slipperiness, temperature, ..). Additionally, the standardization of road signs to enable the signs to be read by cameras in CAV is required, but is not further discussed within DIRIZON.

The work in DIRIZON makes use of ISAD concepts developed in the on-going INFRAMIX project. See Figure 4. A webpage of INFRAMIX states, "The ISAD levels start with the conventional infrastructure without any support for automation (Level E). The availability of a digital map with static regulatory information (e.g. speed limits) is assigned to Level D. At Level C begins the full digitalization of infrastructure elements and thus the availability of all relevant digital information in digital form, esp. VMS, traffic lights, which can be extended by further environment information. Level B describes infrastructures that are able to perceive complete traffic situations on a microscopic basis by specialized sensors (e.g. fixed infrastructure radars). This sensor data could be augmented by data coming from vehicles such as probe vehicle data, and more advanced cooperative perception messages. However, using this data alone does not provide microscopic traffic perception capability as it relies on the equipment of vehicles. At Level A the infrastructure uses its traffic perception capabilities for microscopic traffic management. Microscopic traffic management goes beyond dynamic speed limits (currently displayed on VMS) and provides optimal speed advice, lane usage and lane change recommendations, advice on inter-vehicle gaps etc. to automated and connected vehicles." [INFRAMIX, 2019]

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

Figure 4: Levels of the Infrastructure Support for Automated Driving (ISAD Levels) Source: INFRAMIX, 2019.

INFRAMIX will extend the electronic horizon, based on a combination of data from vehicles and the infrastructure, to contain dynamic information about traffic flow (e.g. speed and density of vehicles, if possible in certain situation even separately for trucks and private cars) as a basis for individualized speed and lane recommendations. The estimation tools (to be developed) for extending the electronic horizon will receive info provided by connected vehicles and will fuse them with measurements stemming from a minimum number (necessary for flow observability) of spot sensor measurements; and will deliver in real-time reliable estimates of traffic density and traffic flow by segment and even by lane, as well as travel times and incident detection. The tools will provide a necessary tool for real-time traffic control tasks with various requirements regarding the estimation granularity (e.g. estimation per lane), the estimated variables or the underlying architecture [Lytrivis, P., et al., 2018].

The Data Task Force launched a proof of concept to collect data for road safety [Felici, 2019]. The Data Task Force is populated by a group of European governmental organisations (German Federal ministry of Transport and Digital infrastructure, Dutch Ministry of Infrastructure and Water management, The Ministry of the Economy of the Government and Grand Duchy of Luxembourg, the Spanish ministry of the Interior, Directorate General of Traffic, Finnish transport and communications Agency), and industry (BMW, Ford, HERE, Mercedes-Benz, TomTom and Volvo). At the time of the writing of this report, it was known but not yet officially communicated that the number of participants in the Data Task Force Proof of Concept would be increased.

The Data Task Force defined levels of vehicle data:

- Level 1: Raw sensor data (e.g. a wheel sensor). This information does not leave the vehicle and is not part of the data distribution.
- Level 2: Data necessary for providing the road safety related minimum universal traffic information service and collected via any private and/or public source, also referred to as ‘Road Safety Related Traffic Data’ (as defined in article 2-m of Regulation 886), also referred to as “Level 2 Data”. In common terminology, Level 2 Data are produced by one vehicle. A vehicle can use one or more sensor readings to detect an event;

- Level 2’: Data (L2’) provides the basis for road safety related minimum universal traffic information services, collected via any private and/or public source, also referred to as “Level 2 Prime Data” or “Road Safety Related Traffic Data” (as defined in article 2-m of Regulation 886). In common terminology, Level 2 Prime Data is an enriched version of Level 2 Data created by cross referencing the data (L2) across multiple vehicles, vehicles from different brands and/or through data harmonization and cleansing of the Data (L2);
- Level 3 – Information: Any extracted, aggregated and processed road safety related traffic information, offered by public and/or private road operators and/or service providers to end users through any delivery channels, also referred to as “L3 Information” or ”Road Safety Related Minimum Universal Traffic Information” or SRTI (as defined in article 2-n of Regulation 886);

Level 3 as defined by the Data Task Force has the scope of SRTI, covering: 1. temporary slippery road; 2. animal, people, obstacles, debris on the road 3. unprotected accident area 4. short-term road works 5. reduced visibility 6. wrong-way driver 7. unmanaged blockage of a road 8. exceptional weather conditions

The Memorandum of Understanding (MoU) established for the Proof-of-Concept stipulates the following with respect to the provision of data:

- (L2) and Data (L2’) provided by Licensor is provided strictly on an “as is”, “where is” and “as available” basis and Licensor gives no assurance or warranty that Data (L2) is accurate, complete, up-to-date, available, error-free, and fit for purpose, etc. The Data (L2) delivered by Licensor can also be limited to data originating from a test fleet due to GDPR reasons such as but not limited to user consent.
- Subject to the preceding provision, Data (L2) and Data (L2’) needs to be provided to the State and Licensee in accordance with the protocol as described. Data (L2) and Data (L2’) needs to include at least the following components: event identification number, event; heading of travel; longitude; latitude; and time stamp.

The Proof-of-Concept of the Data Task Force does not yet include data quality checking or information on the level of automation of the vehicle. Future activities can incorporate these challenges as well as what is learned from the Proof-of-Concept.

The MoU shall remain in force until June 3rd, 2020.

Figure 5 shows the process flow diagram for the infrastructure support for automated driving. Data on traffic, incidents and accidents and environmental data generated by various sources (loops, cameras, etc) are collected and made available, either via the National Access Point and/or the Traffic Management Centre.

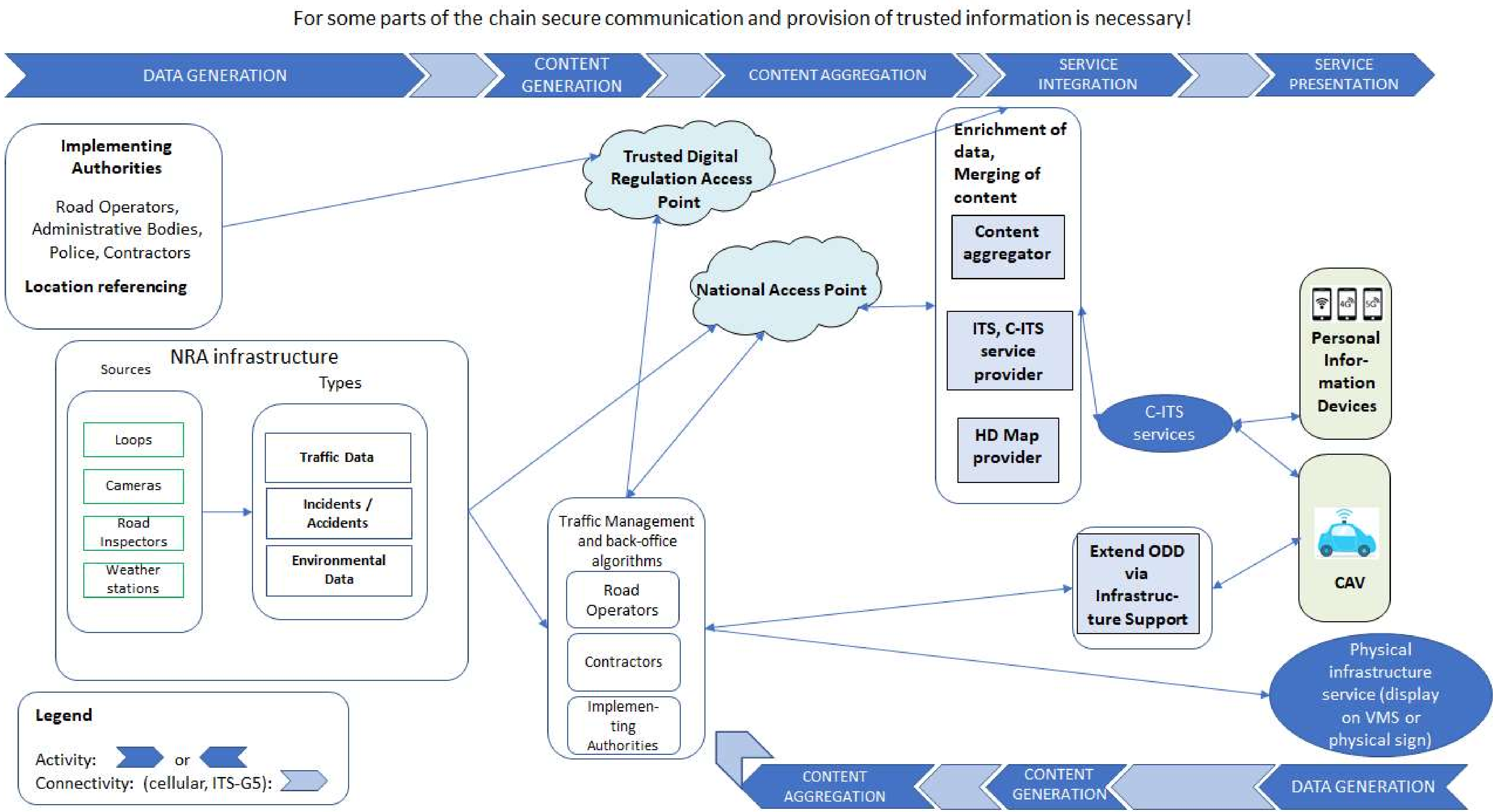

Figure 5: Process flow diagram for Infrastructure Support for Automated Driving

The Traffic Management Center makes use of the data on traffic, incidents and accidents and environmental data to carry out its traffic management functions. The binding traffic management measures are provided to the Trusted Electronic Regulations Access Point. Traffic management data, advice, information and warnings (non-binding) are provided to the NAP. The Traffic Management Center also provides advice to individual CAVs in order to extend their ODDs, using all available sources of data including vehicle sensor data [Lytrivis, P., et al., 2018]. The Traffic Management Center provides its traffic management services in the traditional manner on VMSs or signs.

Content aggregators, (C-)ITS service providers and HD map providers enrich their own services using data from the National Access Point, providing these services to vehicles and (portable) electronic devices. These information are "visualized" for the user. The user can be a driver or an automated vehicle. The final decision on how to use the advice or warning lies with the driver or vehicle. Regulations have to be followed.

(Portable) electronic devices and CAVs provide vehicle sensor data (e.g. speed, type of vehicle). These data are collected via roadside stations and via C-ITS Service Providers.

The 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, connected and conventional vehicles coexist at different levels of (automation) technology.

Infrastructure support services and vehicle equipment can be used to collect dynamic or real-time data to extend the ODD of cooperative automated vehicles.

5.2 Use Case Evolution

The paragraphs below sketch the evolution of the use case, for the short (1-3 years), medium (3-7 years) and long (>7 years to the year 2040) terms.

Generally speaking the ability for Road Operators to support automated vehicles by extending the ODD will take into account agreements on where decision-making will take place (most likely within the vehicle). Road Operators need to better understand under which conditions would automated vehicles use data generated outside the vehicle into an automated vehicle decision-making process. This information will inform which data are desired and the data quality criteria. Likewise, Road Operators will be able to use this information in achieving their own goals of improving road safety, traffic efficiency and reduced environmental damage from road users.

There are mixed traffic conditions on the infrastructure, i.e. there are various levels of automation in the short, medium and long term with increasing percentages of automated vehicles. The maximum automation level that is expected by the end of long term is level 4. There is not much V2V communication in the short term (compatibility issues) while most of the vehicles can communicate in the long term. 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.

Additionally different aspects for the step by step evolution can be considered:

- Short term:
    - Introduction of standards pertinent to data format, quality criteria, and data exchange is expected
    - Introduction of the capability automation at Traffic Management Centers to support the processing of the data flows and monitor the traffic flows.

  - Agreements on which data to share, data quality criteria and levels, agreement on responsibility for data quality checks. Pilots will take place to test these data, quality levels and processes, followed by implementation (see also above)
  - Vehicles equipped with HD maps have the ability to share data with ROs and/or other vehicles.
- Medium term:
  - The automated traffic management system generates advice to vehicles based on microscopic traffic flow measurements.
  - Cooperative Traffic Management is state-of-the-art
- Long term:
  - The automated traffic management system generates advice to vehicles based on microscopic traffic flow measurements, making use of its data on the penetration rate of automated vehicles in the traffic flow.

5.3 Data needs for Infrastructure Support for Connected and Cooperative Automated Driving

All of the data needed for HD maps and Distribution of Digital Traffic Regulations are needed for Infrastructure Support for Connected Automated Driving. At this point in time, there is no definitive list of data required to provide ISAD.

There are some indications of which type of data are necessary, on the basis of existing documents and direct contact with the INFRAMIX project, and from the Proof-of-Concept currently being carried out by the Data Task Force [Felici, E, 2019].

Traffic data include (as examples) traffic volume, speed, occupancy, and travel times per lane, percentage of automated vehicles in the traffic stream (in space and time), if possible, enriched with vehicle sensor data. The concepts in [INFRAMIX, 2018] require knowledge of SAE-levels.

Events or conditions are primarily safety-related and are covered by the SRTI. These include temporary slippery road, animal etc. on the road, unprotected accident area, short-term road works, reduced visibility, wrong-way driver, unmanaged blockage of a road, and exceptional weather conditions.

Additional data include location and length of traffic queues, accidents and incidents, availability of parking and parking costs, and weather conditions.

5.4 Standards and gaps in standardisation

- C-ITS standards: ISO and ETSI standards for messages (CAM, DENM, SPAT, MAP, IVI)
- DATEX II develops standards for the exchange of traffic-related data [DATEX II, October, 2019]. Content-wise, DATEX II covers traffic situations (event-driven), traffic status (status-updates per unit of time), traffic related (VMS settings and parking information), and work in the progress including support of METR. [De Vries, 2019].
- TPEG: The Transport Protocol Experts Group (TPEG) is a data protocol suite for traffic and travel related information. TPEG is a set of data protocols for carrying traffic & travel related information. TPEG can be carried over different transmission media (bearers), such as digital broadcast or cellular networks (wireless Internet). TPEG applications include, among others, information on road conditions, weather, fuel prices, parking or delays of public transport [TPEG, October, 2019].

Further standardisation of data formats and data exchange mechanisms are needed for the flows. There is no compliance and quality control of the data at EU level. Many issues occur at cross borders. Different technology is used amongst EU countries.

The GDPR and the fact that an SAE-level is context and OEM-model specific may impede the provision of vehicle sensor data and of SAE-level information, or whether the vehicle is automated or not.

6 Data Categories and Literature Review of Data Quality Criteria

The data types and data quality criteria for the three use cases were developed using the conceptual framework of the layered HD map shown in Figure 1. At this point in time, there are no publications that make explicit the data quality criteria or requirements for data to be used by automated vehicles. Therefore, this work focuses on providing a framework classes of data, thinking about which data quality criteria are appropriate, and making initial suggestions for the data criteria requirements levels.

This chapter is organized as follows. Section 6.1 presents the data categories, followed by the data quality criteria from the literature in Section 6.2.

6.1 Data Categories

Chapters 3, 4, and 5 provide detailed information on the data needed in the use cases. All of these data have been collected and are considered together. The paragraphs below provide by category all the data collected. This is not an exhaustive list.

- Static data means the digitized information about the road and traffic regulations. These include the road model, road classification, location of tolling stations, lane model including speed limits, access conditions, and other traffic regulations, the HD localization model (beacons, landmarks), the locations of, for example, parking spaces and service areas, charging points, public transport stop, and delivery areas. Note that HD map providers may provide this information in a basic map or in a premium version, depending on the specific client group.
- Traffic data include for examples traffic volume, speed, occupancy, and travel times per lane, plus vehicle types and the SAE levels. The concepts in INFRAMIX require knowledge of SAE-levels in the traffic stream [INFRAMIX, 2018]. It is not clear if these are of individual vehicles or at an aggregate level.
- Events or conditions are primarily safety-related and are covered by the SRTI. These include temporary slippery road, animal etc on the road, unprotected accident area, short-term road works, reduced visibility, wrong-way driver, unmanaged blockage of a road, and exceptional weather conditions. This list can be expanded to include additional services, like end-of-queue warning.
- Dynamic regulations include dynamic speed limits; road, lane and bridge closures; and road works.

These four categories place requirements on the data quality criteria for CAVs.

6.2 Data Quality Criteria

This section provides an overview of data quality criteria identified in the literature and through interviews.

The EU-EIP platform aims to “provide a recommendation on quality requirements for the European SRTI and RTTI as well as the data content of them. Criteria are developed to make more concrete the levels of service and quality for RTTI and SRTI provided by the C-ITS” [EU-EIP, 2018, p.3]. The guidance provided focus on the initial steps in the information service value chain (content detection and content processing). The EU-EIP platform states that the later parts of the value chain (service provision and service presentation) are planned to be developed by the project in 2016-2020 [EU-EIP, 2018]. Thus, these aspects are not available to the DIRIZON project at the time of working on this deliverable.

The EU-EIP platform provides a basis for DIRIZON by defining quality criteria for provision of RTTI and SRTI [EU-EIP, 2018]. These criteria are:

Table 2: EIP definitions of (minimum; in parentheses) service and quality criteria for actual event based and status oriented information

	Definition of Criteria for RTTI and SRTI from EU-EIP, 2018, pp 9-10	
Level of Service	Geographical Coverage	Percentage of the road network covered by the (content provision) service. (event and status-oriented information)
	Availability	Percentage of the time that the (content provision) service is available. (event and status-oriented information)
Level of Quality	Timeliness (Start)	The time between the occurrence of an event and the acceptance of the event. (event information)
	Reporting period	The time interval for refreshing / updating the status reports. (status-oriented information)
	Timeliness (update)	The time between the end or (safety) relevant change of condition and the acceptance of this change. (event information)
	Timeliness (update)	The average age of the sensor data used in the most recent reporting period. (status-oriented information)
	Latency (content side)	The time between the acceptance of the event or its end or (safety) relevant change of condition and the moment the information is provided by the content access point. (event information)
	Latency (content side)	The time between the calculation for the reporting data and the moment information is provided to the content access point. (status-oriented information)
	Location accuracy	The relative precision of the referenced location for the published event with respect to the actual location of the actual event (area or road). (event information)
	Reporting accuracy	The relative accuracy of the reported quantity (speed or travel time) versus the actual value (average experience of road users in a given reporting period). (event information)
	Classification correctness	100% - percentage of the published events known not to be correct (concerning actual occurrence of this event type / class). (event information)
	Classification correctness	The percentage "A" of the reported locations for which the relative inaccuracy of the status report is larger than percentage "B" in a given reporting period. Expressed as A/B. (status-oriented information)

	Event coverage	Percentage of the actually occurring events which are known to be correctly detected and published by type / class, time and location (i.e., detection rate). (event information)
	Report coverage	The percentage of reporting locations for which a status report is received in any given reporting period. (status-oriented information)

The process flow focusses on operations, thus the criteria in Table 2 related to *event information* are relevant for determining the levels for quality criteria. Although the focus is on the initial steps in the information service value chain, the concepts can be used for the whole service, from detection to provision to the driver or vehicle.

The C-Roads criteria focus on technical performance of C-ITS services themselves, which are not immediately translatable to data requirement criteria. However, there are several measures that are relevant, and are described below. Technical evaluation in C-Roads focusses on Reliability of C-ITS systems and applications, interoperability and compliance to function and technical specifications, detection of technical flaws or failures, and the filtering out of events with technical issues to avoid bias in the evaluation and assessment [C-Roads, 2018].

- Correctness of advice: The validity of warnings and information; that they are not outdated or expired, and that the warnings and information are real. These criteria are similar to the EU-EIP criteria timeliness/ latency and refreshment rate, and classification correctness.
- Accuracy of advice to drivers in time and space of the advice. These criteria are similar to the EU-EIP criteria location accuracy and timeliness/latency.
- Availability of the service to drivers in time and geographical area. These criteria are similar to the EU-EIP criteria geographical coverage and availability.

A Dutch report of criteria produced by Calvert et. al identified requirements of traffic-related applications of C-ITS [Calvert, 2016]. Most criteria were not quantified. The criteria are:

- Frequency concerns how frequently the data are updated (H=less than 1 minute, M = every 2-3 minutes; and L = every 15 minutes). This criterion can be called the refreshment rate.
- Timeliness concerns how quickly the information should be made available to the road user, in other words, similar to the EU-EIP timeliness.
- Accuracy concerns how important it is to obtain the information at the right location and at the right time. This is similar to the EU-EIP criteria location accuracy and timeliness
- Error probability refers to the level of importance attached to the correctness of the information for the recipient. This is similar to the EU-EIP criteria classification correctness and event coverage.

A study in Germany investigated quality criteria for congestion tail information, and developed a concept for a test field to enable the practical evaluation of these requirements [Van Driel, 2016]. Traffic messages for congestion tail information are not covered by the Directive or by [SRTI, 2013]. However, these criteria are interesting to take into account to check for completeness. The requirements are:

- Hit rate: Percentage of actually occurring congestion tail events that were correctly identified. This is similar to the EU-EIP criteria classification correctness and event coverage.

- Error rate: Percentage of falsely identified congestion rail events (false-positive rate). This can be derived from the EU-EIP criterion classification correctness.
- Timeliness (start and detection): Delay between occurrence of congestion tail events and the provision of congestion tail data. This is similar to the EU-EIP criterion timeliness (start).
- Timeliness (update): Delay between detected changes in a congestion tail and the provision of new congestion tail data (update frequency). This is similar to the EU-EIP criterion timeliness (update).
- Positional Accuracy: Accuracy of the reported position [of the congestion tail] with respect to the position of the actual congestion tail. This is similar to the EU-EIP criterion location accuracy.

A follow-up project to [Van Driel, 2016] will include a field test, assessing real-life “end of traffic jam“ warnings from service providers, for which the results/reports are expected for 2020.

The Data Task Force Proof-of-Concept document [Felici, 2019] does not describe data quality criteria, requirements or checks. For the National Access Point (NAP) of the Netherlands, called the National Data Warehouse (NDW), the Proof-of-Concept has agreed to the following:

- Current delivery: pulls the data from HERE and Daimler every 10 seconds; shows pulled events for 15 minutes in viewer; and pushes new events to TomTom
- Future developments (Q3 2019 – Q3 2020) focus on standardized access and distribution within the SRTI-ecosystem; migration to NCIS (central system) including service level agreements and monitoring; and research how to effectively transform L2 and/or L2` to L3 for use by road authorities.

The Proof-of-Concept does address privacy issues:

- Licensor shall take appropriate measures to ensure that the Data (L2) and Data (L2’) does not consist of any personal data as referred to in article 4 of the General Data Protection Regulation (GDPR).
- Licensee shall take appropriate measures to ensure that the Information (L3) does not consist of any personal data as referred to in article 4 of the GDPR. Licensee shall not perform any activities that aim at or result in Data (L2) or Data (L2’) becoming non-anonymous. Licensee shall inform Licensor if he deems that the Data (L2) and Data (L2’) consist of personal data as defined in article 4 of the GDPR

That document also describes obligations of actors to other actors in the eco-system.

A running TKI[2] project in the Netherlands is investigating CAD applications in mixed traffic. Cooperative Adaptive Cruise Control in combination with 5 separate services (Road Works Warning, Green Light Optimal Speed Advisory, In-Vehicle Signage, Traffic Jam Ahead Warning and Slow Vehicle Warning) are implemented with 3 passenger cars or 3 trucks. The project has no reports available at the time of the writing of this report, as the project will run through mid-2020. An interview with project participant about criteria led to the addition of two criteria for CAD. They are:

- Variance: for many or all of the criteria, a variance should be provided. This provides the CAV extra information to judge the reliability of the provided information, for the vehicle to decide how to use the information.

[2] A TKI project is a Dutch Public-Private Partnership programme for research and innovation.

- Predictability: this criterion results from the experience of Service Providers with data provided for Green Light Optimal Speed Advisory (GLOSA). In countries with traffic lights with dynamic cycles, the predictability (or reliability) of the advice is adversely affected by the possibility by a jump in the cycle length (shorter or longer), and thus the (implicit or explicit) prediction of the Time-to-Green or Time-to-Red. This requirement is specific to GLOSA, but may be extended.

7 Data Quality Criteria for Cooperative Automated Driving

7.1 Introduction

Using the data categories, the findings on data quality criteria and the quantification of these criteria presented in Chapter 6, this chapter proposes the following data quality criteria for CAVs. These criteria are developed from the point of view of the vehicle or driver. The criteria cover the whole chain of delivery, thus at a high abstraction level. These data quality levels pertain to Infrastructure-to-Vehicle (I2V) communication. These data quality levels were developed using the three use cases. The data quality levels will be different from those developed for Vehicle-to-Vehicle (V2V) services. Note that not every criterion will be used in every category.

7.2 Proposed Data Quality Criteria

Consolidating and summarizing the data quality criteria from the literature in Section 6.2, DIRIZON proposes the following data quality criteria based on the three use cases of Chapters 3, 4, and 5.

- Geographical coverage: Road classification in the road network covered by the service. This definition differs from that used in the EU-EIP. Here, the perspective of CAVs is used. Thus, specific road classifications are used to define geographic coverage. For the road classifications included, the coverage is expected to be very high (close to 100%). Assuming that CAVs of level 4 will first operate on motorways, geographic coverage uses a road classification approach in which the minimum level is defined to be motorways, the medium level covers motorways plus main roads and connectors, and the highest levels covers all roads (including urban roads). Geographic coverage for CAVs will follow the technical capabilities of vehicles to operate at SAE level 4 on specific road types.
- Refreshment rate: The rate at which the data are updated in the vehicle, regardless if there has been a change in the data provided or not. This criterion is expressed in refreshments per unit of time. It can be seen as the sum of latency and timeliness.
- Availability: Percentage of the time that the service is available with fresh data. Expressed as a percentage of the time. It can be interpreted as “up time” of the system.
- Timeliness/ Latency: the total time between the detection of an event or a change, and the delivery to the user.
- Location accuracy: Accuracy to within a specific distance
- Classification correctness: Correct identification of, e.g., a static road element, a vehicle type, event or condition, or a dynamic regulation.
- Event coverage: Percentage of the actually occurring events which are known to be correctly detected and published by type / class, time and location
- Variance: for many or all of the criteria, a variance should be provided. This provides the CAV extra information to judge the reliability of the provided information, for the vehicle to decide how to use the information.

- Predictability: this criterion results from the experience of Service Providers with data provided for Green Light Optimal Speed Advisory (GLOSA). In countries with traffic lights with dynamic cycles, the predictability (or reliability) of the advice is adversely affected by the possibility by a jump in the cycle length (shorter or longer), and thus the (implicit or explicit) prediction of the Time-to-Green or Time-to-Red. This requirement is specific to GLOSA, but may be extended.

Using the level concept from EU-EIP and Calvert et. al, [EU-EIP, 2018; Calvert, 2016], a proposal for data quality levels is made below for each data category. The concept of levels needs to be seen as a proposal, to be discussed among Road Operators and with other actors for usefulness and desirability. Furthermore, the quantification of the criteria suggested need to be addressed as well.

For each suggested quantification level, existing quantifications were used as a basis, if available. The tables contain the source of the data used as the basis and the reasoning for modifications, if any.

The quantification distinguishes between the data categories.

The consortium has not yet provided levels for variance and predictability.

7.3 Data Quality Criteria Levels for Static Data

Table 3 presents the proposed data quality criteria levels (low (L), medium (M), and high (H)) for static data. The right-most column of Table 3 provides the source and / or reasoning for the proposals.

Table 3 Quality criteria for static data

Criterion	L	M	H	Source / Reasoning
Refreshment	Monthly / quarterly / yearly	Weekly	Daily	Estimate of HD map developer
Availability	92% (=48/52 weeks of the year)	96% (=50/52 weeks of the year)	98% (=51/52 weeks of the year)	Estimate of HD map developer: If the newer data are not available, the old map data is available.
Timeliness / latency	Within a month / quarter / year	Within a week	Within a day	Consistent with refreshment
Location accuracy	10m (e.g. for navigation)	1m	10 cm	Based on current discussions in HD map development
Classification correctness	80%	90%	99.9%	Expert assessment, based on classification of road signs.
Event coverage	80%	90%	99.9%	Estimate of HD map developer: Completeness of the information for the geographic coverage provided

Geographic coverage[3]	only Motorways/National Roads	Motorways/ National Roads +Main Roads, connectors	whole road network, including local roads	Estimate of HD map developer.

7.4 Quality Criteria levels for Traffic Data

The data quality criteria for traffic data used the EU-EIP RTTI quality criteria levels, and INFRAMIX ISAD level A [EU-EIP, 2018; INFRAMIX, 2018] as bases. The ISAD levels defined by INFRAMIX plan to provide data requirements in the future, but these data requirements are not yet available.

Traffic data are not safety-critical. Here, an automated vehicle relies on its sensors to manoeuvre in its environment, if traffic data are not available.

Table 3 presents the proposed data quality criteria levels (low (L), medium (M), and high (H)) for traffic data. The right-most column of Table 4 provides the source and / or reasoning for the proposals.

Table 4 Quality criteria for traffic data

Criterion	**L**	**M**	**H**	**Source / Reasoning**
Refreshment	15minutes	5 minutes	30-60 s	H comes from [INFRAMIX, 2018], pp 55, 58; M from [EU-EIP, 2018] 4 stars, L from [EU-EIP, 2018] Enhanced
Availability	95% (347 days/year)	99% (361 days/year)	99.9% (365 days/year)	[EU-EIP, 2018]: H 4 stars, M Enhanced, L Basic.
Timeliness / latency	<15minutes	<8 minutes	<5 minutes	[EU-EIP, 2018]: sum of timeliness (start) and Latency; H 4 stars, M Advanced, L Enhanced.
Location accuracy	10km	5km	500m	Because unequipped vehicles are also on the road, the highest level of quality is analogous to the provision of data by gantries, located 500m apart. The M is based on [EU-EIP, 2018] Advanced and L on [EU-EIP, 2018] Enhanced. The data will be provided for links or trajectories.

[3] Geographic coverage data quality levels reflect limitations to specific road classifications.

Classification correctness	>90%	>90%	>95%	The M is based on [EU-EIP, 2018] Advanced and L on [EU-EIP, 2018] Enhanced. H is an estimate.
Event coverage	>75% (no specification from EU EIP)	>80% of roads falling into geographic coverage	>90% of roads falling into geographic coverage	DIRIZON estimate
Geographic coverage[4]	only Motorways/National Roads	Motorways/ National Roads +Main Roads, connectors	whole road network, including local roads	Estimate of HD map developer

7.5 Data Quality Criteria Levels for Safety-Related Events or Conditions

Safety-related events are critical for automated vehicles to have information on in order to operate appropriately in unforeseen situations. The vehicle can react to the information that it gets from sensors. Outside of sensor range, information provided to the vehicle can help it to prepare to react in a safe and timely way.

Refreshment is related to latency and timeliness. It is the time between updates of any kind, taking into account the latency. Thus, refreshment > timeliness + latency. EU-EIP put forth the 4-star level of timeliness start (<1 minute) and latency (<1 minute) for SRTI events. Consortium experts estimate that a refreshment period shorter than 2 minutes is needed for automated driving for safety-related events.

Table 5 presents the proposed data quality criteria levels (low (L), medium (M), and high (H)) for data related to safety-related events or conditions. The right-most column of Table 5 provides the source and / or reasoning for the proposals.

Table 5 Quality criteria for safety-related events or conditions

Criterion	**L**	**M**	**H**	**Source / Reasoning**
Refreshment	5 minutes	3 minutes	<1 minute	The semi-dynamic information from the HD map indicates < 1 minute; the M and L are estimates, based on SRTI [EU-EIP, 2018].
Availability	95% (347 days/ year)	99% (361 days / year)	99.9% (365 days / year)	Based on SRTI [EU-EIP, 2018] p.16: H 4 stars, M Enhanced, L Basic.

[4] Geographic coverage data quality levels reflect limitations to specific road classifications.

Timeliness plus latency	<10 minutes	<7 minutes	<2 minutes	Based on SRTI [EU-EIP, 2018] p.16: H 4 stars, M Enhanced, L estimate.
Location accuracy	10m (e.g. for navigation)	1m	10 cm	Estimate based on HD map accuracy discussions.
Classification correctness	>85%	>90%	99.9%	H estimate; Based on SRTI [EU-EIP, 2018] p.17: M Advanced, L Enhanced.
Event coverage	>85%	>90%	99.9% (higher than EU-EIP	Based on SRTI [EU-EIP, 2018] p.17: but all estimates are higher
Geographic coverage[5]	only Motorways/National Roads	Motorways/ National Roads +Main Roads, connectors	whole road network, including local roads	Estimate of HD map developer

7.6 Data Quality Criteria Levels for Dynamic Regulations

The exploration of digital regulations has recently started. The requirements for the data, let alone the requirements for digitized dynamic data, are unknown. DIRIZON assumes that the quality requirements for dynamic regulations are similar to static regulations, but the quality requirements with respect to time differ.

To address the time element, the following exercise was carried out. It makes use of how current road users experience dynamic traffic regulations, specifically dynamic speed limits. Consider that dynamic speed limits are shown on gantries which are spaced at 500m. If a vehicle has just passed under a gantry, the vehicle covers 500m before passing under the next gantry. The driver will see the matrix signs on the gantry before passing under the gantry. If a vehicle is moving at 100 km/hour, it takes 18 seconds to cover the distance between the gantries. If a change in speed limit takes place, the driver will see the change in the speed limit when passing the next gantry. The maximum amount of time that passes before the driver sees the new speed limit, travelling at 100 km/hour, is 18 seconds. Using this logic, 18 seconds would be a threshold for refreshment rate of dynamic regulations.

Table 6 presents the proposed data quality criteria levels (low (L), medium (M), and high (H)) for traffic data. The right-most column of Table 6 provides the source and / or reasoning for the proposals.

Table 6 Quality criteria for dynamic traffic regulations

Criterion	**L**	**M**	**H**	**Source / Reasoning**

5 Geographic coverage data quality levels reflect limitations to specific road classifications.

Refreshment	5 minutes	1 minute	<18 s	See explanation immediately above for H. M and L are estimates
Availability	95% (347 days/ year)	99% (361 days / year)	99.9% (365 days / year)	Based on SRTI [EU-EIP, 2018] p.16: H 4 stars, M Enhanced, L Basic.
Timeliness plus latency	<10 minutes	<7 minutes	<2 minutes	Based on SRTI [EU-EIP, 2018] p.16: H 4 stars, M Enhanced, L estimate.
Location accuracy[6]	10m (e.g. for navigation)	1m	10 cm	Based on current discussions in HD map development, consistent with static data
Classification correctness	>85%	>90%	99.9%	H estimate; Based on SRTI [EU-EIP, 2018] p.17: M Advanced, L Enhanced.
Event coverage	>85%	>90%	99.9% (higher than EU-EIP)	Based on SRTI [EU-EIP, 2018] p.17: but all estimates are higher
Geographic coverage[7]	only Motorways/National Roads	Motorways/National Roads +Main Roads, connectors	whole road network, including local roads	Estimate of HD map developer

7.7 Proposal for Data Quality Criteria Levels by Data Category

Finally, after having estimated the quality levels, the project suggests the data quality level required in the use cases, using Table 3 - Table 6 as input. The row “static data” in Table 7 uses the levels defined for each criterion defined in Table 3. Likewise for the other rows.

[6] Geographic coverage data quality levels reflect limitations to specific road classifications.
[7] Geographic coverage data quality levels reflect limitations to specific road classifications.

Table 7: Overview of proposed data quality levels by data category

Data type	Data quality criteria level					
	Refresh-ment	**Avai-lability**	**Location accuracy**	**Classification correctness**	**Event coverage**	**Geographic coverage[8]**
Static data	M/H	H	H	H	H	H
traffic data	H*	L	H*	H	L	L
safety-related events or conditions	H	H	H	H	H	L**
Dynamic traffic regulations	H	H	H	H	H	L**

* To support ISAD level A

** from the view of a National Road Operator

[8] Geographic coverage data quality levels reflect limitations to specific road classifications.

8 Summary and Conclusions

This report investigated the implications of digitalisation and automation on three use cases. Digitalization and automation will bring about changes in how NRAs and ROs do their work. The three use cases, identified in work package 2, are provision of High-definition maps for automated mobility, distribution of digital traffic regulations, and infrastructure support services for Cooperative Automated Driving. These use cases were extended to understand how they would evolve over time, changing the actors involved and how the services are provided, and identifying the data needs and requirements. Ultimately, these data needs and requirements are needed by ROs to understand what they need to digitize, with whom they need to work and cooperate, in order to continue meeting their goals in a more efficient way. It opens opportunities for ROs to work with other stakeholders.

The approach made use of a conceptual framework: a high-definition map. The HD map is composed of layers, ranging from static to dynamic, representing the extent to which the data contained in the map are static or dynamic. Each use case was explored to determine which data are needed to provide the service to a CAV. The list of data created is extensive but not exhaustive for digitalisation of road networks and automated driving.

Process flow diagrams were developed to create understanding of the activities to be carried out in service delivery, as well as the roles to be filled by actors in the chain of delivery. These process flow diagrams are generic, for a point in the future, and not country-specific. The process flows suggested in this deliverable are based on the knowledge of the consortium. Other implementations and considerations may be possible.

Standards for the quality of the data for the use cases were investigated, although there is limited information available on automated driving at this point in time. Work to investigate data needs and data quality the field of Cooperative and Connected Intelligent Transport Systems (C-ITS) were used as a basis. These were complemented with discussions with actors in the fields of HD maps, traffic regulations, and automated driving.

The work resulted in four data classifications and a proposed list of data quality criteria. A proposal for a preliminary quantification of these criteria is provided.

To take the work further, actions in several areas are recommended:

- Learn from the Proof-of-Concept of the Data Task Force and other pilots: determine additional standards for data exchange, agree on standards for access, and explore where the quality checks need to take place and by which actors.
- Use pilots to refine data needed, data quality standards, implementations and profiles: implementations should be correct, taking into account the coverage and range of communication. For example, if ITS-G5 coverage is incomplete, the revocation of a message can fil due to a vehicle being out of range. Uniform profiles are required: the data need to have clear definitions and explanations so that they can be used regardless of the data source.
- Engage with OEMs to achieve ODD extension of CAVs. For example, work with OEMs to determine under what conditions will OEMs use data from outside the vehicle, that is, data not generated by the CAV's own sensors.
- Consider the use cases in a pan-European context. Does the service work in two different countries with possibly different implementations?

In the future, the amount of data stored and exchange can grow enormously. Traditional monitoring means collect traffic data each minute-kilometre level while C-ITS does at millisecond-meter level, which is a factor of 10^3 to 10^5 more data. To keep the service provision manageable the implications of the amount of data need to be investigated. Intelligence needs to be built into the system to reduce storage needs and the amount of data that is transferred. This has implications for individual vehicles, personal electronic devices such as mobile phones, and roadside units. It is also expected that the data needed will change over time, given technology evolution and changes in the marketplace.

Synergies can be realised. Digitalisation efforts at lower levels of government (e.g., provincial, regional , and city-levels) can provide a synergy with the work at the national and European levels. The “lower” levels of government can make use of data standards, profile development, criteria and sharing mechanisms, being established at the national and European level. Likewise, the non-national levels initiate the process of digitizing the other remaining categories, using the already established-process. Examples of “other categories” in the Netherlands include event data, intelligent traffic light data, including topology, data for logistics, and cycle data [website digitalisering overheden].

Realization of Mobility as a Service (MaaS) can benefit from the data-exchange platforms established for CAV. MaaS analyses of data required goes beyond the data needs for road-based traffic, examined in this study. MaaS data needs include data on other modes such as public transport and other innovative forms of transport, including schedules and real-time (availability) data, data on pricing and stipulations, and transaction data. Enabling MaaS means enabling parts of road-based data as described here.

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10 Appendix: CEDR/CAD Tallinn Workshop

Goals of DIRIZON WS CEDR/CAD meeting

Through interaction with the PEB and CEDR/CAD group, align and launch the DIRIZON project work packages on data needs, stakeholder relationships and views, digital platform and business models, and ensure alignment on use cases.

What will we do in the workshop?

- identify the different roles to be filled in the use cases
- Assign the actors/organisations to the different roles, from different delivery perspectives (Public/Road Operator only, Road Operator-private cooperation, market-driven)
- Collect input on data and data sources relevant to the different use cases (incl. the data providers for each data category)
- Collect view on the preconditions/prerequisites on data exchange
- Identify opportunities and risks with respect to security/data protection, privacy, architecture and governance
- Develop perspectives on what aspects the NRAs can cooperate in realizing the use cases in Europe

How will we achieve this?

- The WS will alternate between plenary and interactive sessions
- Interactive part: To make sure all participants will formulate their ideas and views, the WS planned an interactive part with work in small groups.

The WS

Approximately 10 CAD/CEDR members took part in the DIRIZON WS. These participants divided themselves over three use cases in DIRIZON. To make the use cases more tangible, the groups were encouraged to choose a specific example. The following use case and examples have been discussed:

No.	Use Case	Example
1	Provision of HD maps for automated mobility	General activities needed to provide HD maps in the vehicle/ for the driver
2	Distribution of Digital traffic regulation	Controlled zones
3	Infrastructure support services for CAD	Short-term road works

Each group answered the following three sets of questions, and visualized the results on posters:

- What activities or roles are needed to deliver the use case, and which actors or parties could carry out this activity? (first poster)
- Which data are needed, who can provide it, and under which conditions? (second poster)
- What are the relations among the actors in delivering the service to the end user, from data generation, through data processing/ analysis / management, through to presentation to the end user (through distribution and communication). When possible, indicate whether the delivery system is “NRA-driven”, NRA-market cooperation”, or “market-driven”.

All three groups produced thoughtful and well-discussed results. These results will be converted to a digital format for distribution to the CEDR CAD members. Since the composition of the groups was fixed, additional validation, like inputs or comments from those CAD members who didn't join the DIRIZON WS is welcome.
Please let the DIRIZON team know of any additional comments or suggestions on the WS results by sending an email to the project coordinator TNO. (max.schreuder@tno.nl)

In the course of the 2-day meeting and the DIRIZON workshop, it became clear that contact with the CAD Task Group on Data is necessary in order to incorporate already existing ideas regarding the requirements for a data exchange platform. The project will follow up with the leader of the CAD Task Group on Data and discuss a next step.

Results of the workshop are shown below, in powerpoint format.

CONTENT

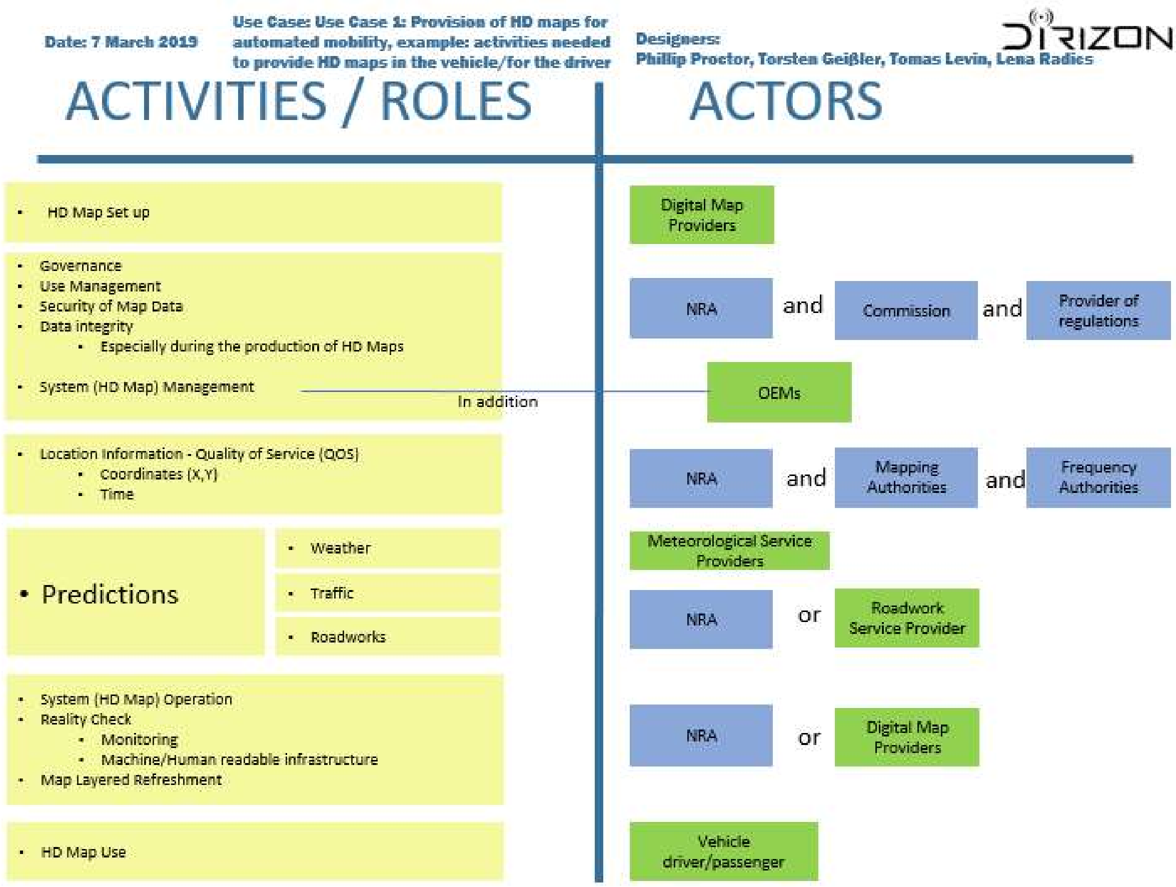
- Digital representations of the posters created by workshop participants
  - Use Case 1: Provision of HD maps for automated mobility
  - Use Case 2: Distribution of Digital Traffic Regulations
  - Use Case 3: Infrastructure Support for Cooperative Automated Driving
- Appendix: Photographs of posters for each use case

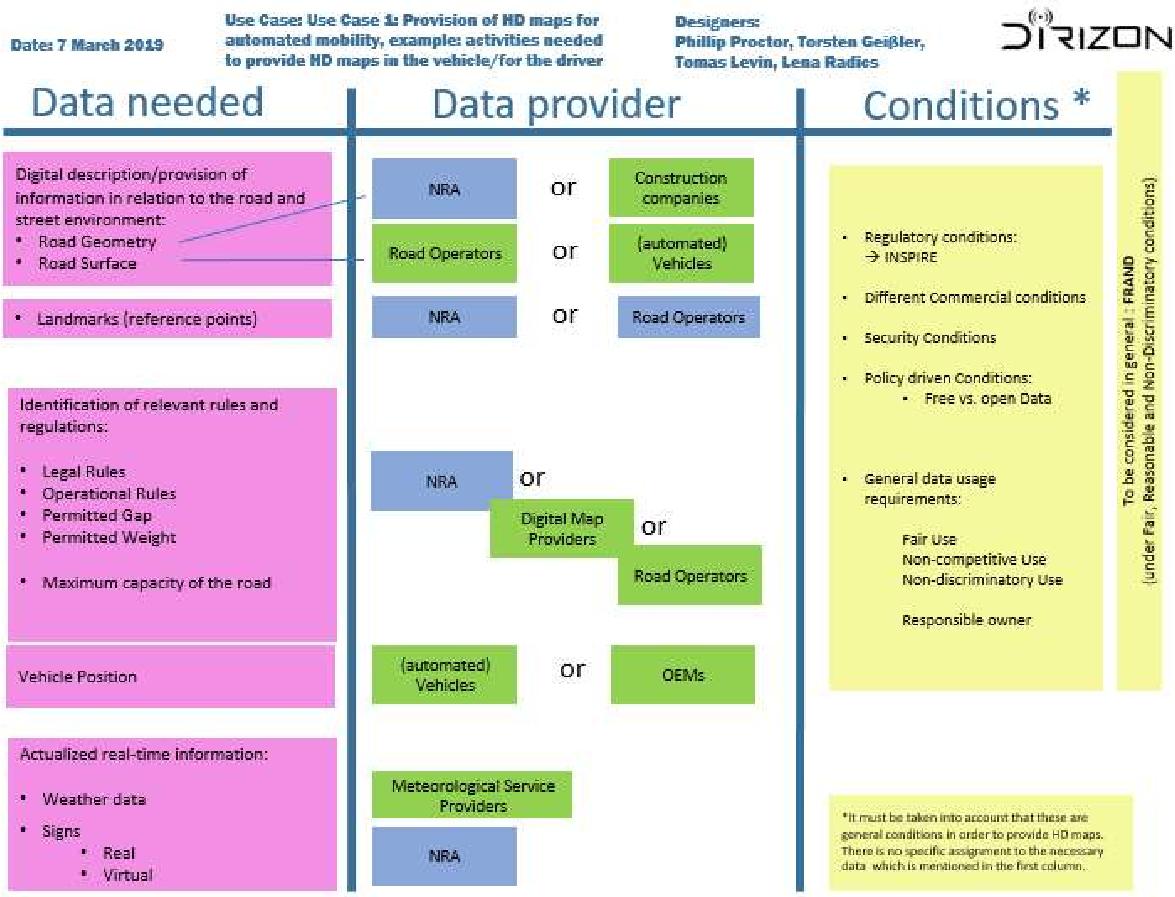
1

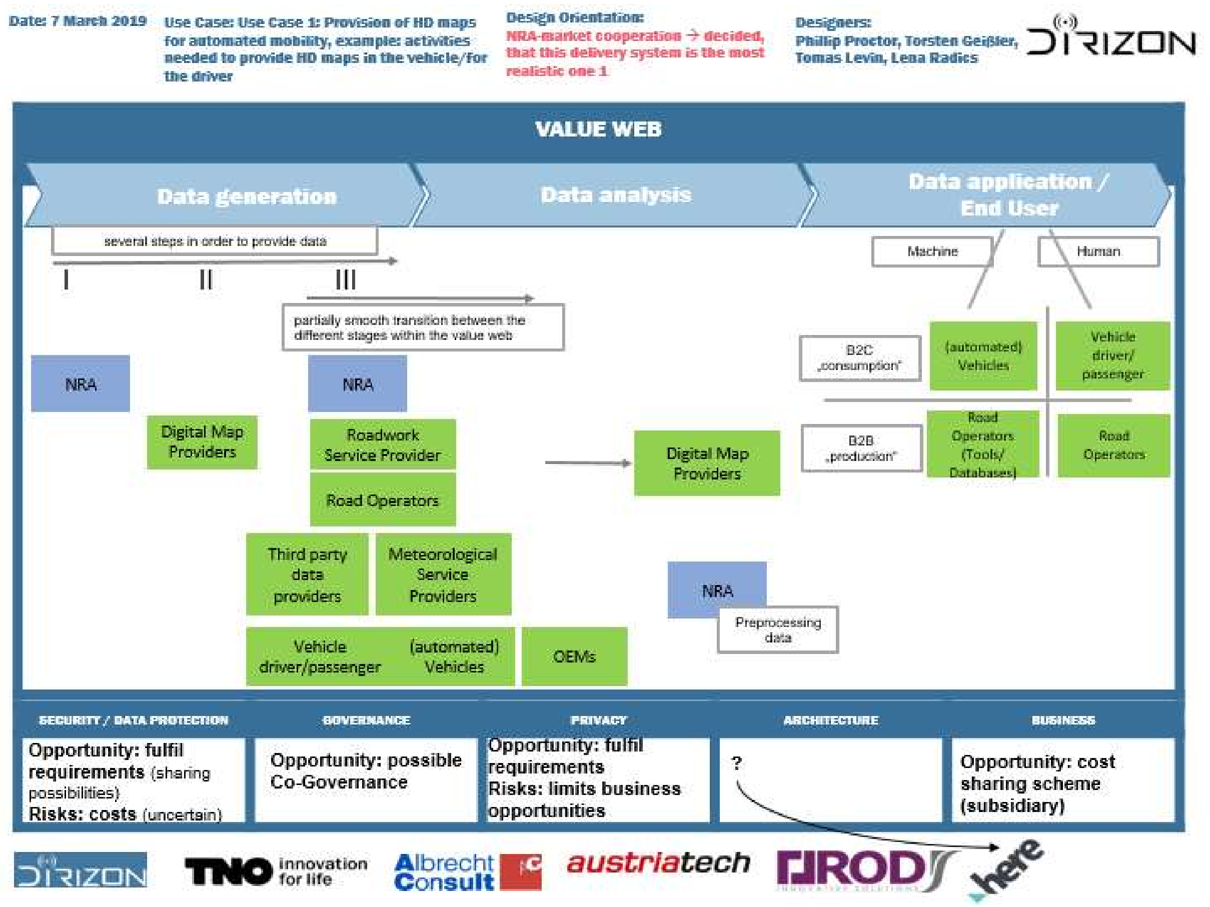
USE CASE 1: PROVISION OF HD MAPS FOR AUTOMATED MOBILITY

› Use Case 1 example: activities needed to provide HD maps in the vehicle/for the driver

1


Date: 7 March 2019
Use Case: Use Case 1: Provision of HD maps for automated mobility, example: activities needed to provide HD maps in the vehicle/for the driver
Designers:
Phillip Proctor, Torsten Geißler, Tomas Levin, Lena Radics
ACTIVITIES / ROLES
ACTORS
HD Map Set up
Digital Map Providers
Governance
Use Management
Security of Map Data
Data integrity
Especially during the production of HD Maps
System (HD Map) Management
In addition
NRA
and
Commission
and
Provider of regulations
OEMs
Location Information - Quality of Service (QOS)
Coordinates (X,Y)
Time
NRA
and
Mapping Authorities
and
Frequency Authorities
Predictions
Weather
Traffic
Roadworks
Meteorological Service Providers
NRA
or
Roadwork Service Provider
System (HD Map) Operation
Reality Check
Monitoring
Machine/Human readable infrastructure
Map Layered Refreshment
NRA
or
Digital Map Providers
HD Map Use
Vehicle driver/passenger


Date: 7 March 2019
Use Case: Use Case 1: Provision of HD maps for automated mobility, example: activities needed to provide HD maps in the vehicle/for the driver
Designers: Phillip Proctor, Torsten Geißler, Tomas Levin, Lena Radics
Data needed
Data provider
Conditions *
Digital description/provision of information in relation to the road and street environment:
• Road Geometry
• Road Surface
NRA
or
Construction companies
Road Operators
or
(automated) Vehicles
• Landmarks (reference points)
NRA
or
Road Operators
Identification of relevant rules and regulations:
• Legal Rules
• Operational Rules
• Permitted Gap
• Permitted Weight
• Maximum capacity of the road
NRA
or
Digital Map Providers
or
Road Operators
Vehicle Position
(automated) Vehicles
or
OEMs
Actualized real-time information:
• Weather data
• Signs
• Real
• Virtual
Meteorological Service Providers
NRA
• Regulatory conditions:
→ INSPIRE
• Different Commercial conditions
• Security Conditions
• Policy driven Conditions:
• Free vs. open Data
• General data usage requirements:
Fair Use
Non-competitive Use
Non-discriminatory Use
Responsible owner
To be considered in general : FRAND
(under Fair, Reasonable and Non-Discriminatory conditions)
*It must be taken into account that these are general conditions in order to provide HD maps. There is no specific assignment to the necessary data which is mentioned in the first column.

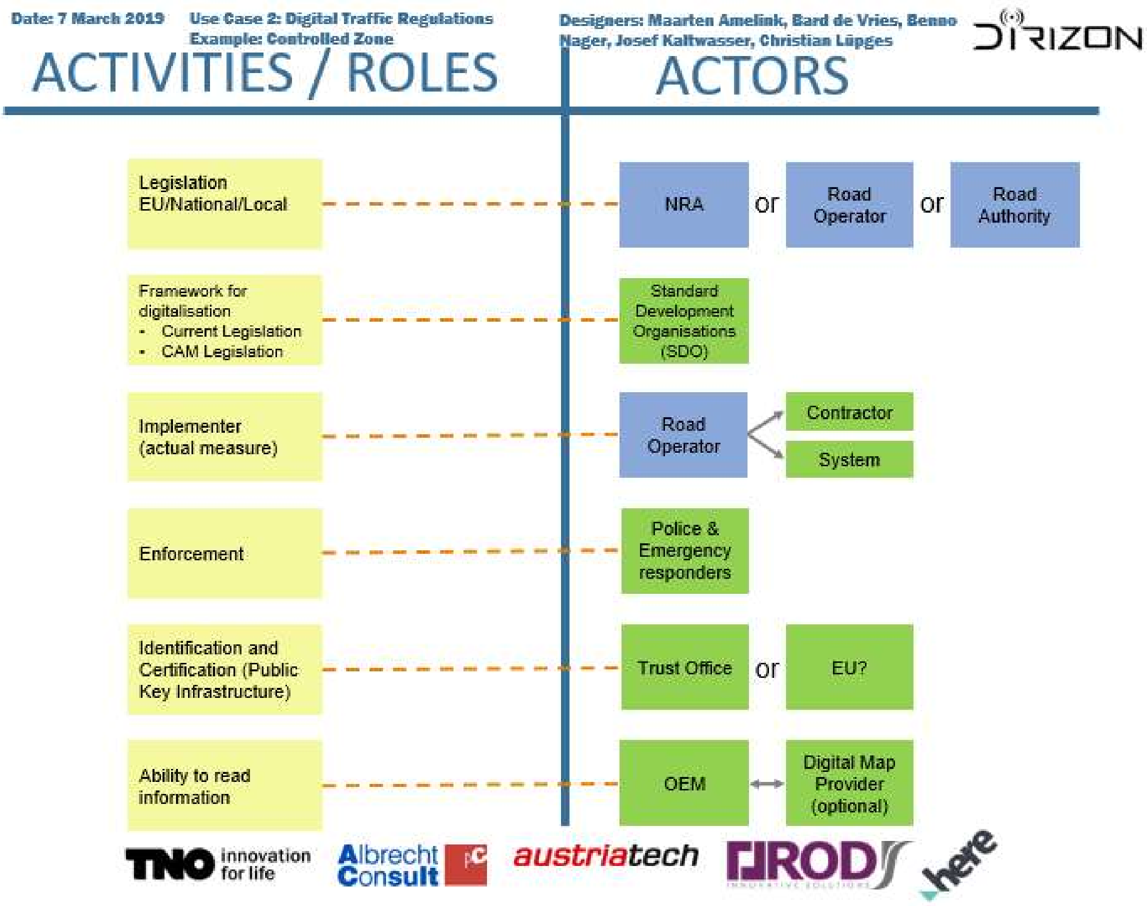

Date: 7 March 2019
Use Case: Use Case 1: Provision of HD maps for automated mobility, example: activities needed to provide HD maps in the vehicle/for the driver
Design Orientation:
NRA-market cooperation → decided, that this delivery system is the most realistic one 1
Designers:
Phillip Proctor, Torsten Geißler, Tomas Levin, Lena Radics
VALUE WEB
Data generation
Data analysis
Data application / End User
several steps in order to provide data
I
II
III
partially smooth transition between the different stages within the value web
NRA
Digital Map Providers
NRA
Roadwork Service Provider
Road Operators
Third party data providers
Meteorological Service Providers
Vehicle driver/passenger
(automated) Vehicles
OEMs
Digital Map Providers
NRA
Preprocessing data
Machine
Human
B2C „consumption"
(automated) Vehicles
Vehicle driver/ passenger
B2B „production"
Road Operators (Tools/ Databases)
Road Operators
SECURITY / DATA PROTECTION
GOVERNANCE
PRIVACY
ARCHITECTURE
BUSINESS
Opportunity: fulfil requirements (sharing possibilities)
Risks: costs (uncertain)
Opportunity: possible Co-Governance
Opportunity: fulfil requirements
Risks: limits business opportunities
?
Opportunity: cost sharing scheme (subsidiary)
innovation for life
Albrecht Consult
austriatech
here

USE CASE 2: DISTRIBUTION OF DIGITAL TRAFFIC REGULATIONS

- Example: Controlled Zone

  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. A Controlled Zone access condition can contain a restriction related to emissions of a vehicle (e.g. Diesel driving ban) and/or 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.

1


Date: 7 March 2019
Use Case 2: Digital Traffic Regulations
Example: Controlled Zone
Designers: Maarten Amelink, Bard de Vries, Benno Nager, Josef Kaltwasser, Christian Lüpges
ACTIVITIES / ROLES
ACTORS
Legislation EU/National/Local
NRA
or
Road Operator
or
Road Authority
Framework for digitalisation
- Current Legislation
- CAM Legislation
Standard Development Organisations (SDO)
Implementer (actual measure)
Road Operator
Contractor
System
Enforcement
Police & Emergency responders
Identification and Certification (Public Key Infrastructure)
Trust Office
or
EU?
Ability to read information
OEM
Digital Map Provider (optional)
TNO innovation for life
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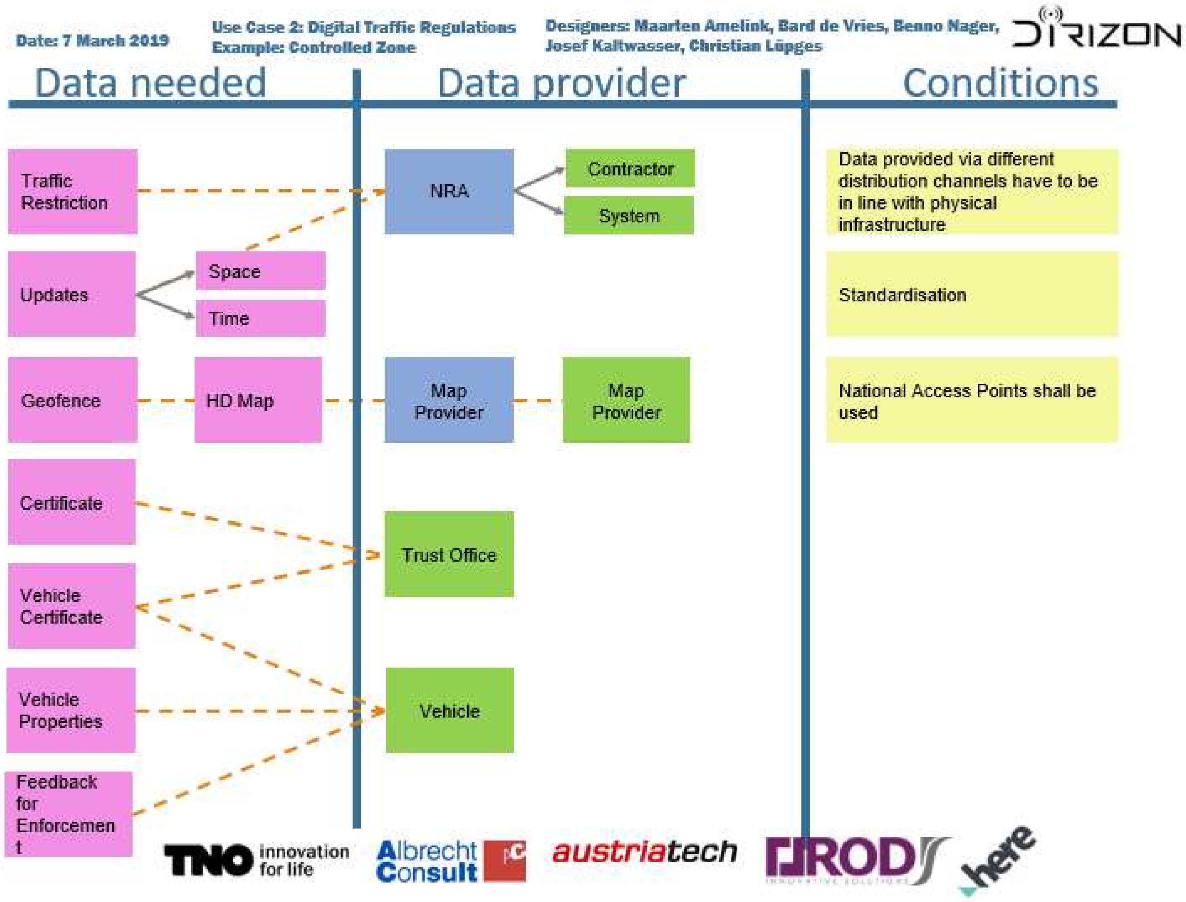
here


Date: 7 March 2019
Use Case 2: Digital Traffic Regulations
Example: Controlled Zone
Designers: Maarten Amelink, Bard de Vries, Benno Nager, Josef Kaltwasser, Christian Lüpges
Data needed
Data provider
Conditions
Traffic Restriction
NRA
Contractor
System
Data provided via different distribution channels have to be in line with physical infrastructure
Updates
Space
Time
Standardisation
Geofence
HD Map
Map Provider
Map Provider
National Access Points shall be used
Certificate
Trust Office
Vehicle Certificate
Vehicle Properties
Vehicle
Feedback for Enforcement
innovation for life
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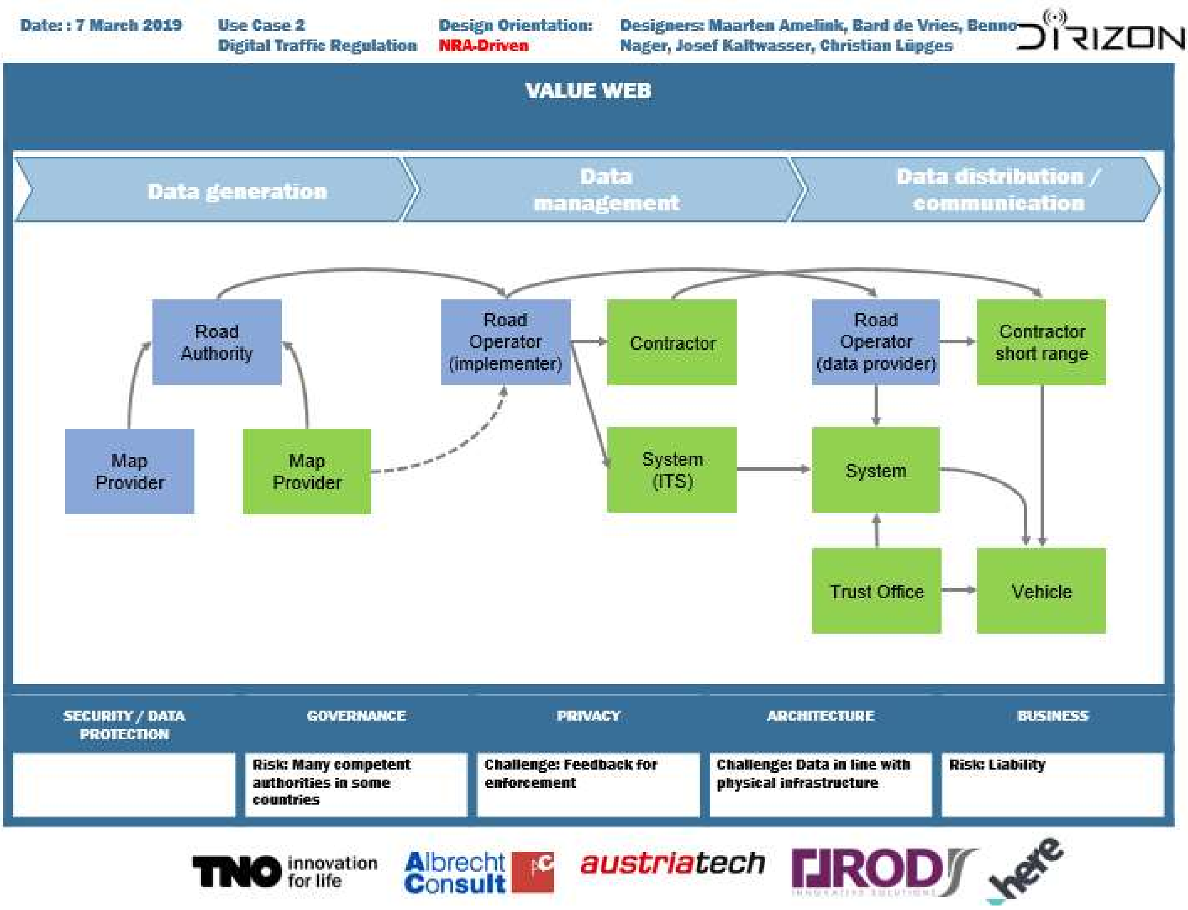
Date: : 7 March 2019
Use Case 2
Digital Traffic Regulation
Design Orientation:
NRA-Driven
Designers: Maarten Amelink, Bard de Vries, Benno Nager, Josef Kaltwasser, Christian Lüpges
VALUE WEB
Data generation
Data management
Data distribution / communication
Road Authority
Map Provider
Map Provider
Road Operator (implementer)
Contractor
System (ITS)
Road Operator (data provider)
Contractor short range
System
Trust Office
Vehicle
SECURITY / DATA PROTECTION
GOVERNANCE
Risk: Many competent authorities in some countries
PRIVACY
Challenge: Feedback for enforcement
ARCHITECTURE
Challenge: Data in line with physical infrastructure
BUSINESS
Risk: Liability
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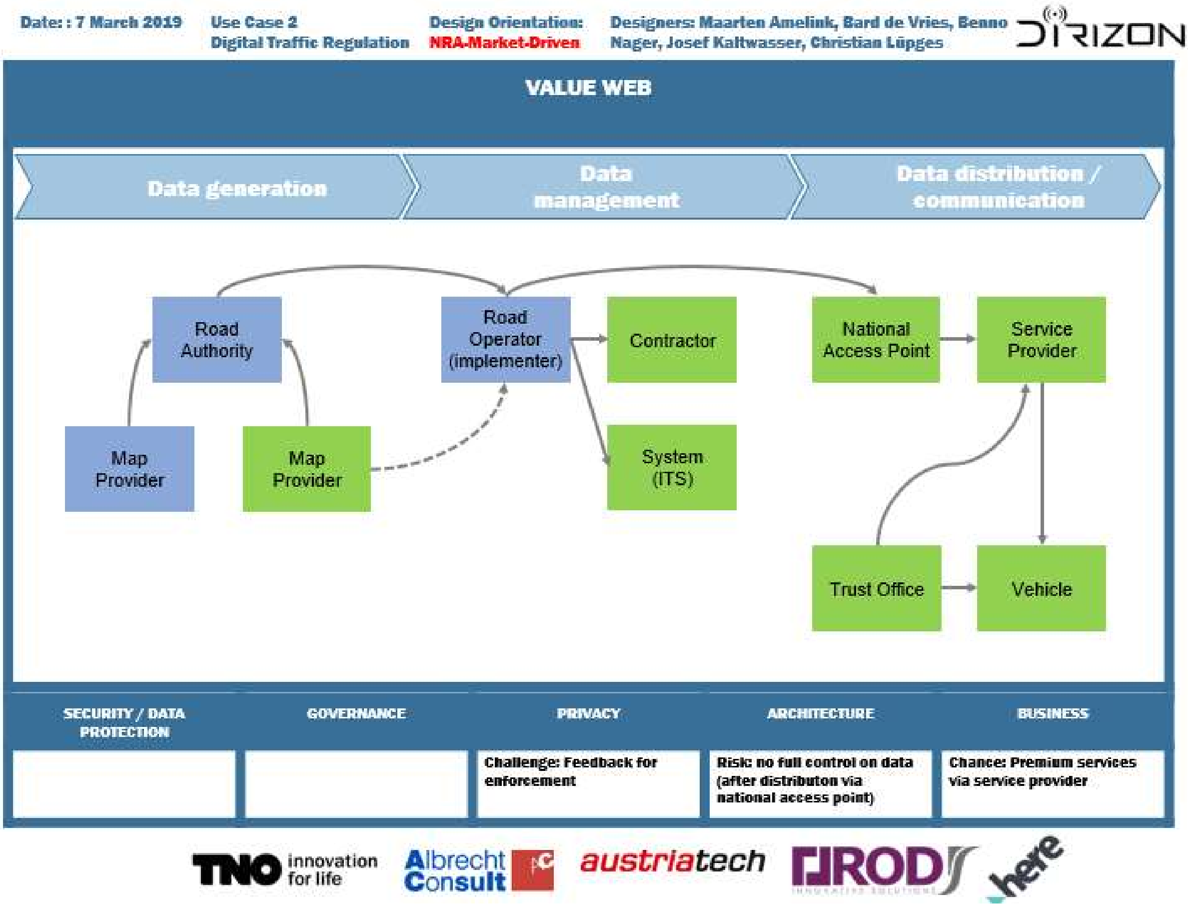
Date: : 7 March 2019
Use Case 2
Digital Traffic Regulation
Design Orientation:
NRA-Market-Driven
Designers: Maarten Amelink, Bard de Vries, Benno Nager, Josef Kaltwasser, Christian Lüpges
VALUE WEB
Data generation
Data management
Data distribution / communication
Road Authority
Road Operator (implementer)
Contractor
National Access Point
Service Provider
Map Provider
Map Provider
System (ITS)
Trust Office
Vehicle
SECURITY / DATA PROTECTION
GOVERNANCE
PRIVACY
ARCHITECTURE
BUSINESS
Challenge: Feedback for enforcement
Risk: no full control on data (after distributon via national access point)
Chance: Premium services via service provider
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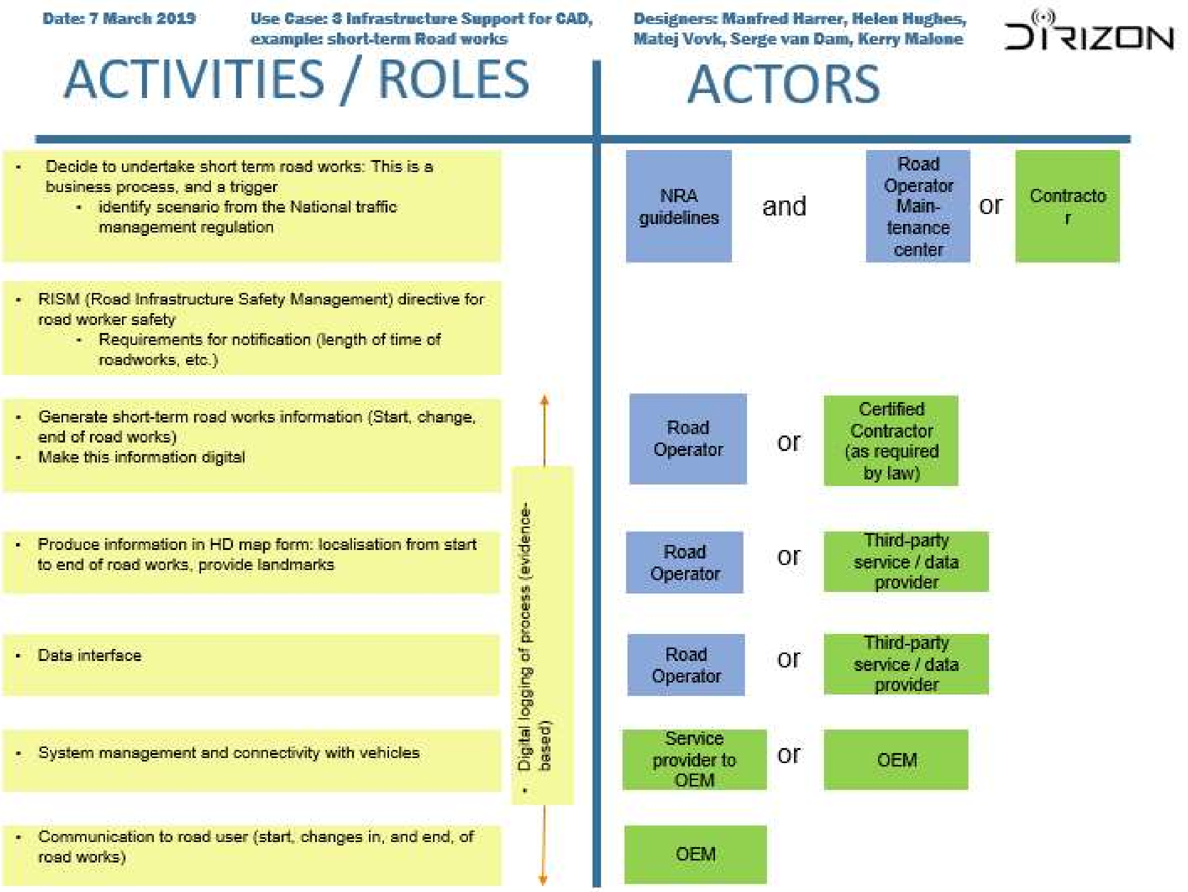
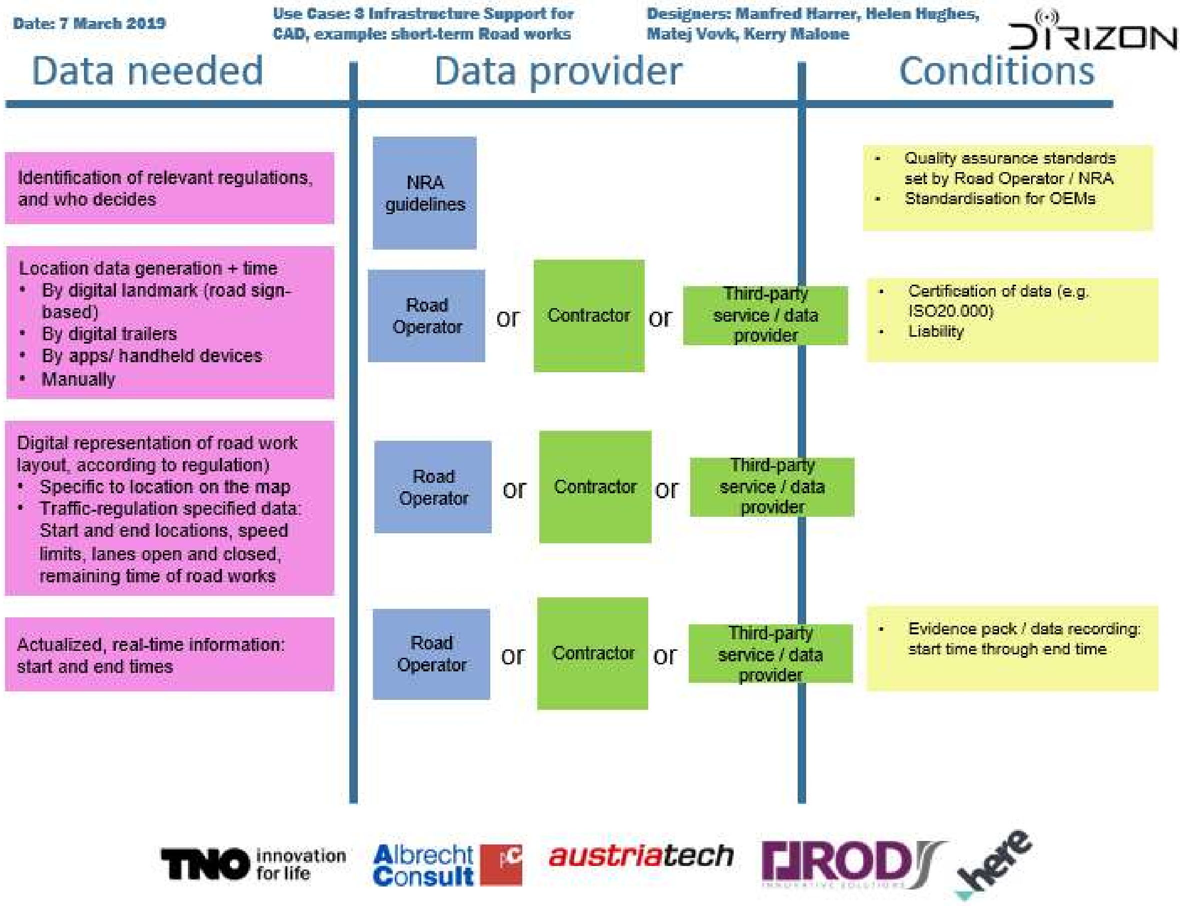
USE CASE 3: INFRASTRUCTURE SUPPORT FOR COOPERATIVE AUTOMATED DRIVING

› Use Case 3 example: Short-term Road Works

1


Date: 7 March 2019
Use Case: 3 Infrastructure Support for CAD, example: short-term Road works
Designers: Manfred Harrer, Helen Hughes, Matej Vovk, Serge van Dam, Kerry Malone
ACTIVITIES / ROLES
ACTORS
Decide to undertake short term road works: This is a business process, and a trigger
identify scenario from the National traffic management regulation
NRA guidelines
and
Road Operator Main-tenance center
or
Contractor
RISM (Road Infrastructure Safety Management) directive for road worker safety
Requirements for notification (length of time of roadworks, etc.)
Generate short-term road works information (Start, change, end of road works)
Make this information digital
Road Operator
or
Certified Contractor (as required by law)
Produce information in HD map form: localisation from start to end of road works, provide landmarks
Road Operator
or
Third-party service / data provider
Data interface
Road Operator
or
Third-party service / data provider
System management and connectivity with vehicles
Service provider to OEM
or
OEM
Communication to road user (start, changes in, and end, of road works)
OEM
Digital logging of process (evidence-based)


Date: 7 March 2019
Use Case: 3 Infrastructure Support for CAD, example: short-term Road works
Designers: Manfred Harrer, Helen Hughes, Matej Vovk, Kerry Malone
DIRIZON
Data needed
Data provider
Conditions
Identification of relevant regulations, and who decides
NRA guidelines
Quality assurance standards set by Road Operator / NRA
Standardisation for OEMs
Location data generation + time
By digital landmark (road sign-based)
By digital trailers
By apps/ handheld devices
Manually
Road Operator
or
Contractor
or
Third-party service / data provider
Certification of data (e.g. ISO20.000)
Liability
Digital representation of road work layout, according to regulation)
Specific to location on the map
Traffic-regulation specified data: Start and end locations, speed limits, lanes open and closed, remaining time of road works
Road Operator
or
Contractor
or
Third-party service / data provider
Actualized, real-time information: start and end times
Road Operator
or
Contractor
or
Third-party service / data provider
Evidence pack / data recording: start time through end time
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RODJ
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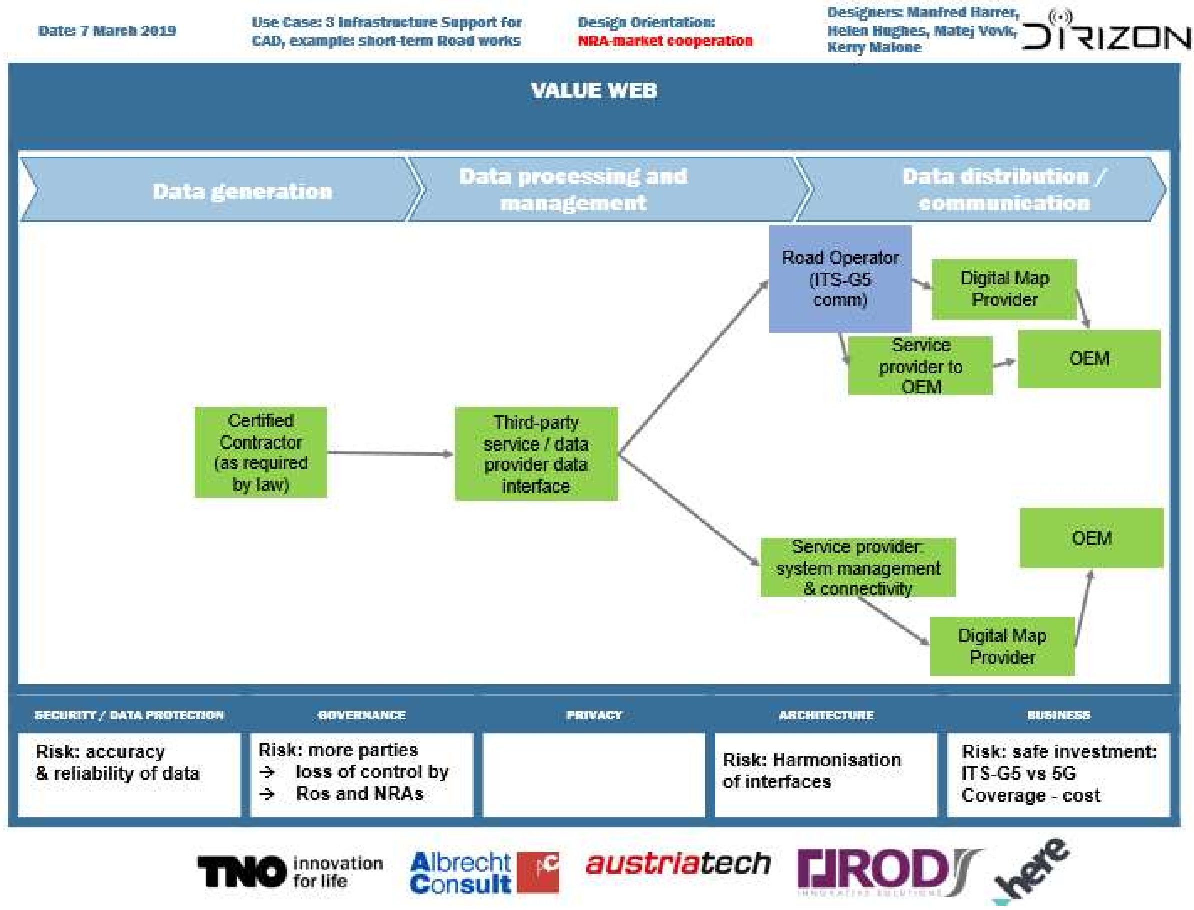
Date: 7 March 2019
Use Case: 3 Infrastructure Support for CAD, example: short-term Road works
Design Orientation: NRA-market cooperation
Designers: Manfred Harrer, Helen Hughes, Matej Vovk, Kerry Malone
VALUE WEB
Data generation
Data processing and management
Data distribution / communication
Certified Contractor (as required by law)
Third-party service / data provider data interface
Road Operator (ITS-G5 comm)
Digital Map Provider
Service provider to OEM
OEM
Service provider: system management & connectivity
OEM
Digital Map Provider
SECURITY / DATA PROTECTION
GOVERNANCE
PRIVACY
ARCHITECTURE
BUSINESS
Risk: accuracy & reliability of data
Risk: more parties
→ loss of control by
→ Ros and NRAs
Risk: Harmonisation of interfaces
Risk: safe investment: ITS-G5 vs 5G
Coverage - cost
innovation for life
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RODL