



Conférence Européenne  
des Directeurs des Routes

Conference of European  
Directors of Roads



# DiREC

Digital Road for evolving Connected & Automated Driving

## Digital Road Operations

Final Version

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**Digital Road for Evolving Connected and Automated Driving**

**D4**

**Digital Road Operations**

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## Abbreviations

Abbreviation	Definition
ASAM	Association for Standardisation of Automation and Measuring Systems
CAD	Connected and Automated Driving
CAV	Connected and Autonomous Vehicle
CBA	Cost Benefit Analysis
CEDR	Conference of European Directors of Roads
C-ITS	Cooperative Intelligent Transport Systems
CRF	CAV-Readiness Framework
DENM	Decentralized Environmental Notification Message
DiREC	Digital Road for evolving Connected and Automated Driving
ETSI	European Telecommunications Standards Institute
GLOSA	Green Light Optimised Speed Advisory
GNSS	Global Navigation Satellite System
HCM	Highway Capacity Manual
HLN	Hazardous Location Notification
InterCor	Interoperable Corridors deploying Cooperative Intelligent Transport Systems
ISAD	Infrastructure Support Levels for Automated Driving
ITS	Intelligent Transport System
IVI	In-Vehicle Information
IVS	In-Vehicle Signage
LoS	Level of Service
MEC	Multiaccess Edge Computing
NRA	National Roads Authority
ODD	Operational Design Domain
OEM	Original Equipment Manufacturer
PKI	Public Key Infrastructure
PVD	Probe Vehicle Data
RWW	Road Works Warning
RWW-LC	RWW Lane Closure
RWW-RC	RWW Road Closure
RWW-M	RWW Mobile
RWW-WM	RWW Winter Maintenance
SAE	Society of Automotive Engineers
TMA	Truck Mounted Attenuator
TRB	Transportation Research Board
WP	Work Package

## Glossary

Term	Meaning
C-ITS	Cooperative Intelligent Transport Systems. Refers to transport systems, where the cooperation between two or more ITS sub-systems (personal, vehicle, roadside and central) enables an ITS service to offer higher quality or an enhanced level of service, compared to the same ITS service provided by only one of the ITS sub-systems.
C-ROADS	The platform of harmonised C-ITS deployment in Europe, a joint initiative of European Member States and road operators for testing and implementing C-ITS services in light of cross-border harmonisation and interoperability.
CAV Readiness Framework	Defines the needs of CAD in terms of the physical and digital infrastructure, services, and operational policies and procedures that NRAs could provide to support CAD.
DATEX II	DATEX II or DATEX 2 is a data exchange standard for exchanging traffic information between traffic management centres, traffic service providers, traffic operators and media partners. It contains for example traffic incidents, current road works and other special traffic-related events.
HD Mapping	High Definition mapping is highly accurate mapping used in various applications including positioning, driver-assistance and smart mobility applications which can be used to support autonomous driving.
ISAD Infrastructure Support Levels for Automated Driving	The ISAD levels were developed under the Inframix project. They categorise the digital information support given by physical and digital infrastructure to CAD.
Road Works Warning (RWW)	An example of a C-ITS service. In the Road Works Warning service, warnings are provided to road users about road works, which can be mobile or static, short-term or long-term. Road works cover all types of operations undertaken by the road operator including operations involving road operator vehicles.
SAE Levels of Automation	The SAE J3016, "Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles" are widely used in defining the levels of driving automation. It defines six levels of driving automation, from Level 0 (no driving automation) to Level 5 (full driving automation) in the context of motor vehicles and their operation on roadways.

# 1 Producing a Roadmap

## 1.1 Introduction to DiREC

The DiREC CAV-Readiness Framework (CRF) is a framework that aims to help an NRA assess their capability with respect to the deployment of Connected and Automated Driving (CAD) solutions, their ability to influence the use of CAD on their network via investment in digital and physical infrastructure, and the impacts and outcomes of any investment decision.

## 1.2 Introduction to the CRF

DiREC structured the CRF around C-ITS Services and Use Cases as defined under the C-ROADS project. C-ROADS is a joint initiative of European Member States and road operators for testing and implementing C-ITS services, with a desire for cross-border harmonisation and interoperability.

The CRF is thus a framework which can be used by NRAs to help assess their aspirations and readiness to support CAD, and to implement individual C-ITS services and use cases. See Figure 1. It does this by:

- Defining the C-ITS services to be provided;
- Breaking those services down into use cases and enablers;
- Scoring the NRAs readiness, aspirations and high-level assessment of costs and impacts of each enabler to help plan and prioritise the NRA support for CAD.

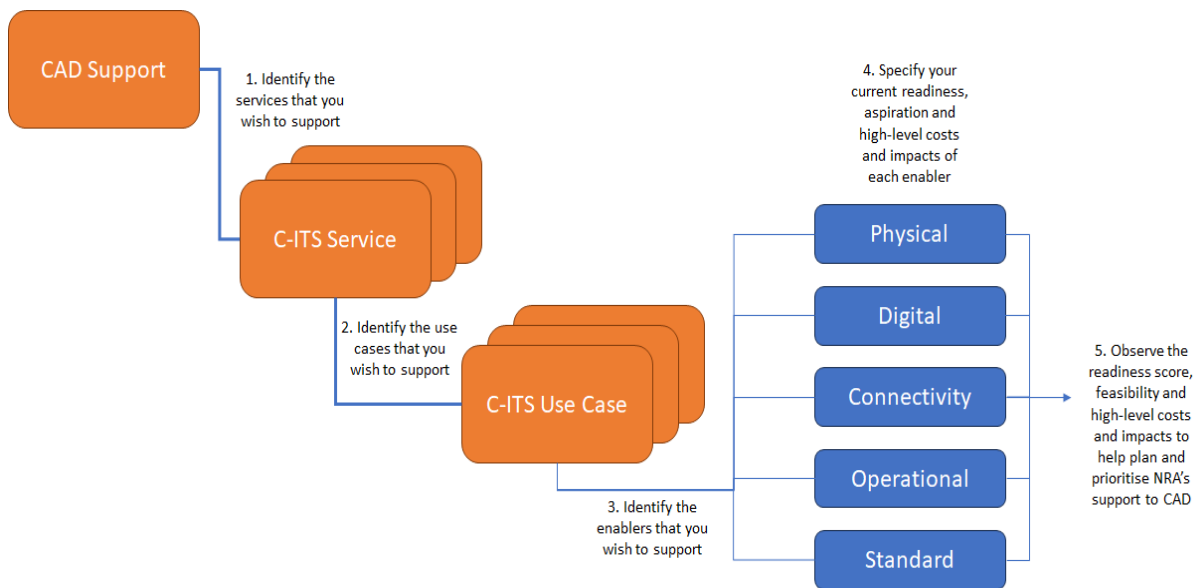


Figure 1. Overview of the CRF

## 1.3 How does the CRF help produce a Roadmap?

The CRF helps define an NRA’s readiness in terms of its current capability, aspirations, and feasibility of supporting C-ITS services. It can be used to graphically illustrate the NRA’s current readiness to support C-ITS services, its aspirations and the threshold levels at which services become viable. The gap between current readiness, aspirations and feasibility threshold allows the NRA to identify the



steps it needs to take to deliver specific services, and to form a roadmap of actions for implementation.

## 2 Producing a Roadmap for Road Works Warning – Lane Closure

This chapter describes the application of the CRF to help define a roadmap for NRA support of a given C-ITS service and use case. The example chosen is provision of support for a Road Works Warning - Lane Closure (RWW-LC) service.

The diagrams below have been produced using screenshots from the CRF tool. This tool can be found at <https://direcproject.com>.

Two scenarios are described: a “gold-plated” scenario in which an NRA might aspire to provide support for RWW-LC across all areas (standards, operations, digital, connectivity, and physical) and where this example NRA is ready and capable of providing such support; and a “base” scenario in which an example NRA also aspires to provide support across all areas, but does not yet have the capacity or readiness to provide such support.

Using the CRF, the NRA can identify where they are now in terms of their priorities, the associated enablers necessary to deliver the service, as well as the interventions it needs to deliver change.

Table 1 show the enablers needed to provide the C-ITS service and use case, and the scoring of the aspiration and readiness of the NRA to provide that service in the “gold-plated” scenario. Figure 2 shows a diagrammatic representation of the scoring across all categories of enabler for that service. In the gold-plated solution, the aspiration and the readiness overlap and are at their highest.

Table 1 Gold Plated Assessment Table for NRA for provision of RWW-LC

Infrastructure item information		Readiness								
Enabler	Category	Importance	Readiness	Readiness score	Aspiration	Aspiration score	Feasibility threshold	Threshold score	Feasible	
Stationary Roadside Unit (R-ITS-S)	Physical	High	High	9	High	9	Medium	6	1	
Variable Messaging Signs	Physical	High	High	9	High	9	Medium	6	1	
Equipped vehicles (trailer, patrols) – Mobile RSU - V-ITS-S	Operation	High	High	9	High	9	Medium	6	1	
Response Plan	Operation	High	High	9	High	9	Medium	6	1	
DENM messaging (ETSI EN 302 637-3)	Digital	High	High	9	High	9	Medium	6	1	
ITS G5 C-ITS	Digital	High	High	9	High	9	Medium	6	1	
ETSI TS 102 894-2	Standard	High	High	9	High	9	Medium	6	1	
Datex II	Standard	High	High	9	High	9	Medium	6	1	
ISO TS 19321:2015	Standard	High	High	9	High	9	Medium	6	1	
Cloud from car industry	Connectivity	High	High	9	High	9	Low	3	1	
4G cellular	Connectivity	High	High	9	High	9	Medium	6	1	
C-ITS Mobile Roadside ITS G5 System Profile	Connectivity	High	High	9	High	9	Medium	6	1	

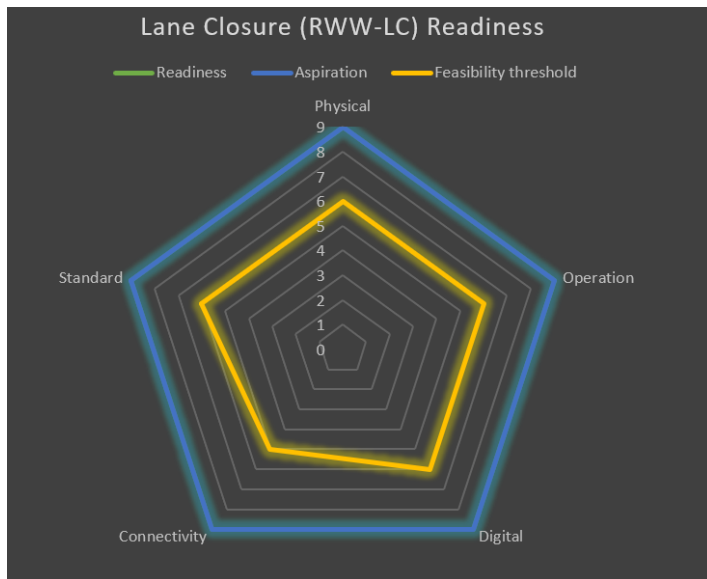


Figure 2. Gold Plated Radar Diagram

In the “base scenario”, the lowest end of the scale provides the boundaries between which the NRA can make decisions. This is shown in Table 2 and the Radar diagram of Figure 2 is generated. Table 2 shows the enablers needed to provide the C-ITS service and use case, and the scoring of the aspiration and readiness of the NRA to provide that service in the “base” scenario. Figure 3 shows a diagrammatic representation of the scoring across all categories of enabler for that service. In the gold-plated solution, the aspiration and the readiness overlap are at their highest. The feasibility of implementing change is directly attributed to the aspirations and what guides these as well as the importance defined by the NRA.

Table 2 Minimum Impact Assessment Table for NRA for provision of RWW-LC

Infrastructure item information		Readiness							
Enabler	Category	Importance	Readiness	Readiness score	Aspiration	Aspiration score	Feasibility threshold	Threshold score	
				Stationary Roadside Unit (R-ITS-S)	Physical	Low	Low	1	High
Variable Messaging Signs	Physical	Low	Low	1	High	3	Medium	2	
Equipped vehicles (trailer, patrols) – Mobile RSU - V-ITS-S	Operation	Low	Low	1	High	3	Medium	2	
Response Plan	Operation	Low	Low	1	High	3	Medium	2	
DENM messaging (ETSI EN 302 637-3)	Digital	Low	Low	1	High	3	Medium	2	
ITS G5 C-ITS	Digital	Low	Low	1	High	3	Medium	2	
ETSI TS 102 894-2	Standard	Low	Low	1	High	3	Medium	2	
Datex II	Standard	Low	Low	1	High	3	Medium	2	
ISO TS 19321:2015	Standard	Low	Low	1	High	3	Medium	2	
Cloud from car industry	Connectivity	Low	Low	1	High	3	Low	1	
4G cellular	Connectivity	Low	Low	1	High	3	Medium	2	
C-ITS Mobile Roadside ITS G5 System Profile	Connectivity	Low	Low	1	High	3	Medium	2	

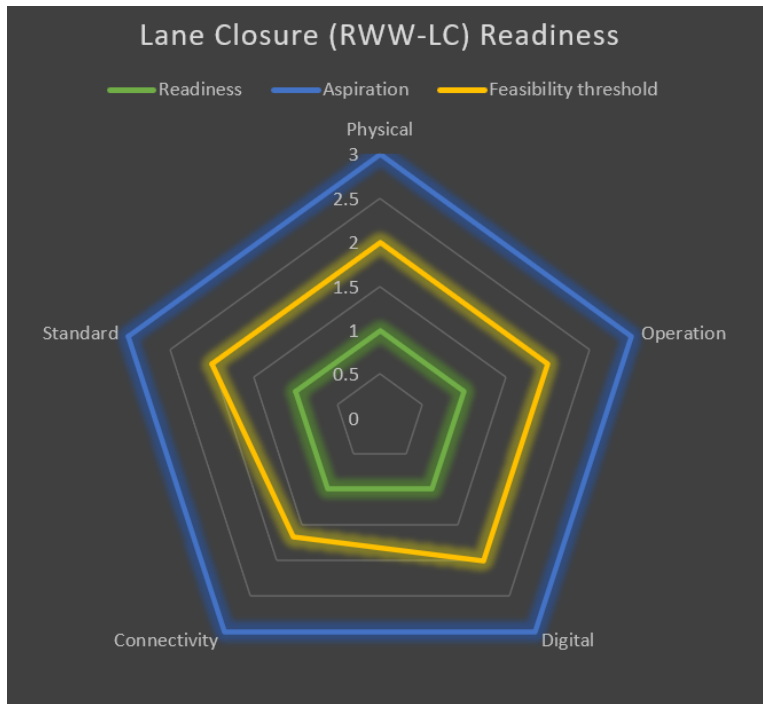


Figure 3. Base Scenario Radar Diagram

## 2.1 General CAD Considerations

The orange enablers in Table 2 are the support that needs to be developed in order to meet the NRA's aspirations. However, in order to plan for support for these, it is necessary for the NRA to ask itself to a series of questions relating to the aspirations, feasibility and readiness of providing such support. Many of those questions will relate to general support for CAD, and the answers may well be the same across different C-ITS services. However, as C-ITS services evolve in future, it may be necessary to ask those questions again for each new service being considered for implementation.

### 2.1.1 Aspirations

1. Political – where do the political priorities lie and is there a political will to undertake change and how does that manifest itself within the organisation?
2. Policy – is there a Policy direction in place that supports the investment of public funds to support the CRF's impacts around CAVs. This is borne out in the need to ensure alignment of the decision maker's priorities with the impacts of the services being provided?
3. Strategy – Does the NRA have a strategy for support for CAVs that links to the Policy and how is that integrated with the spend profile of the organisation?
4. Readiness – where does CAD stand in terms of priority for investment and how is the organisation geared up to exploit the increased information opportunities from CAVs?

### 2.1.2 Feasibility

1. Organisational - How feasible is it, not just from a technical perspective but from an organisational one, to implement the change? What are the timelines to adjust this if there is a desire and a capacity to implement it?
2. Systems – What systems are utilised at present? How may they need to be refashioned or replaced, particularly in light of the growing volumes of data?
3. Stakeholders - The implementation of the service may also be dependent on external stakeholders (stakeholders outside the road authority or road operator). For example, vehicles are mostly regulated at a European level, but road authorities (and road operators) operate on national and regional levels though also guided by activities at a European level. Does deployment of a service depend on the implementation of European regulation as investment either by the OEM or the NRA ? Would the NRA be too dependent on other parties following suit ? As such, the NRA should be aware of regulatory discussions in areas such as vehicle regulation, cyber security and communications, and the implications of them.

### 2.1.3 Readiness

In terms of creating an environment for CAVs, the organisation, covering both their technical and management elements and underpinned by a strategic view, has to be ready. Therefore, the NRA will have to assess what is the readiness level like and importantly, what is needed to be ready. The NRA needs to decide:

1. How can it measure readiness from a total Organisation perspective?
2. Who owns the CRF and its implementation within a multi-faceted Authority?
3. Is there a budget line item in place and an associated business case developed to justify the investment?
4. Is international collaboration needed for the technical and strategic aspects of C-ITS, focused on ensuring cross-border compatibility and harmonisation of standards and technologies?

## 2.2 Impacts

The CRF also identifies the range of impacts for the service. The interventions by the NRA, based on a review of the various questions outlined above, must be considered against the Impacts as outlined by the CRF Framework, namely:

- Safety – How will the delivery of the service affect the safety of the travelling public and others who may be on the network e.g. road workers.
- Efficiency – How will the service affect the efficiency of the network in terms of traffic flow and resource utilisation?
- Environment – Do the solutions contribute to a positive and sustainable environment and how is this achieved?
- Inclusion – is the service inclusive to a broad range of users e.g. those on lower incomes who may not have access to the latest vehicle technology, and if not, how are the impacts assessed and identification of other measures to make it inclusive.
- Cost – The work undertaken by DiREC in the benefits versus costs need to be considered also as part of the implementation and deployment plans.

The impacts of a new service may be positive, negative or neutral in each of these areas. For example a service may improve safety by forcing vehicles to maintain a greater separation from the vehicle ahead, but in the process will reduce the overall efficiency of the network by reducing capacity.

## 2.3 Specific Considerations

For a NRA to support the service, a number of factors need to be considered. These are across the various elements outlined in the CRF. As the CRF will be adapted to local needs and drivers, it is especially important that the intervention assessments outlined below are contextualised to the user environment.

### 2.3.1 Physical Interventions

A physical intervention relates in general to the equipment and the support activities needed to help ensure an installation base that is fit for purpose and providing the necessary impacts as detailed in the CRF. There are a range of considerations linked to these and as such, the elements identified below help the NRA to consider the base point of current activities and link to the radar diagrams, outline the elements that need clarity and/or further discussion. A physical asset has a capital, operational and maintenance cost. There are also requirements to ensure that the management of the contract linked to the asset is fully aligned with the needs of the business and that all decisions and governance are driven by a clear investment strategy and policy. The NRA assessments are subdivided across a range of categories as outlined below:

Type	NRA Assessment
Strategic	<p>Is there a CITS or ITS Strategy in place to account for the process and responsibilities and wider Governance linked to RWW-LC?</p> <p>How is the RWW-LC deployment managed in an active fashion and who is contractually responsible for its performance?</p> <p>Does the NRA know how many devices exist on the network and their outputs?</p> <p>Does a Concept of Operations exist for RWW-LC and how is it initiated?</p>

	<p>Is the RWW-LC and the wider aspects of C-ITS services integrated into the broader sustainability goals of reducing emissions, supporting multi-modal transport and creating a net zero transport capability.</p> <p>Is there an internal lead for Connected and Automated systems and is this the same person for the RWW-LC scenario or are the scenarios linked to different reporting lines and performance assessment?</p> <p>How is the C-ITS/CAV activity communicated with the wider travelling public?</p> <p>Consideration of deployment situation for different environments/situations for deployment of the particular C-ITS service? (e.g. high-traffic stretches of the network, high-crash stretches of the network, urban settings)?</p>
Technical	<p>What specifications are available for current and future technology acquisition linked to deployment of RWW-LCC and wider RWW-LC scenarios?</p> <p>How is performance measured and integrated with existing technology deployments?</p> <p>Is there spare capacity to link current camera deployment to future deployment?</p> <p>Is the Camera compliant with an agreed specification and how is this managed?</p> <p>What is the enterprise level architecture in place to ensure non-silos of systems and solutions to add value to the data from the RWW-LC environment?</p> <p>Is there clear bandwidth capability for messaging between the in-station and out-station?</p> <p>What level of redundancy exists in both the sensors deployed for the RWW-LC and the communications network?</p>
Asset Management	<p>What level of RSU/Cameras/Detectors are in place and can the RWW-LC environment integrate seamlessly?</p> <p>Do new deployments fit into the existing maintenance regimes and how are the maintenance rigs setup for the RWW-LC scenario?</p> <p>Do I have a GIS representation of where my RSUs are deployed?</p> <p>Are the existing Gantries available for use?</p> <p>What beacons/signs/lights are needed in addition to what is currently available?</p>
Data	<p>What data is required to manage the scenario, and who initiates the data transfer, and how is it linked to the physical assets going forward?</p> <p>What are the agreed timing requirements for immediate RWW-LC management but also in advance of the deployment to assess against previous and future interventions linked to RWW-LC?</p> <p>How is data taken from vehicles/mobile devices linked to both the RWW-</p>

	LC management and wider traffic dissemination?
Policy	<p>What is the GDPR policy in place for RWW-LC and wider CITS?</p> <p>How do I ensure data protection in a connected environment, both for RWW-LC and other services and scenarios.</p> <p>How are cameras considered in terms of data management and utilisation for RWW-LC and beyond?</p>
Security	<p>Does the intelligent equipment deployed for RWW-LC follow existing or new cyber security standards.</p> <p>Is the physical infrastructure of the scheme secure against attack, theft or other malicious activity.</p>
Integration	How is the NRA back end environment managed and the systems linked to current operating systems. What is their specification in terms of interfacing and integration?
Skills	<p>Are the existing skills complete to manage any new systems?</p> <p>What skills pathways exist for the staff?</p> <p>How are new requirements identified?</p>

### 2.3.2 Digital Interventions

A Digital intervention relates, by and large, to the data elements supporting or driven by the physical assets. For the digital asset to be of value, there must be clarity on the data to be shared and/or extracted, the value associated with the data and governance and engagement relating to the wider stakeholder community. Data requires both a technical and strategic approach to its creation and its utilisation and the elements outlined below help point the NRA to areas of consideration:

Type	NRA Assessment
Strategic	<p>Which stakeholders are needed to provide a functional service implementation? (e.g. vehicle manufacturer, aftermarket equipment manufacturer, mobile network operator etc.)</p> <p>Does the road authority have a strategy for ensuring the collaboration of critical stakeholders along the digital chain?</p> <p>(How is the deployment of vehicle ITS stations expected to take place? (e.g. OEM or aftermarket, voluntary deployment or mandated by regulation etc.)</p> <p>How are changes in technology managed by the road authority in its own digital infrastructure? (e.g. changes in mobile network technologies, new or updated communication protocols etc.)</p> <p>What will be the role of the National Access Platform (NAP) in implementation and operation of C-ITS services? (EU ITS Directive requires certain data types to be made available via NAP)</p>

	<p>What is the strategy for Digital Twins in the Organisation? Are Digital Twins agreed as a mechanism to support C-ITS services? How would a Digital Twin to support C-ITS operate within an ecosystem of other Digital Twins in the organisation and/or with any national Digital Twin strategy or programme?</p>
Operations	<p>Is there an existing Deployment and Maintenance regime in place that can manage the deployment of Roadside Units (RSUs) and Automated Incident Detectors (AIDs)?</p> <p>What Service levels of performance are defined in the Contract and how is this measured?</p> <p>What is the Governance around the AIDs and their alerts?</p> <p>How are false positive/negative alerts managed at the control centre level and at the contract level?</p> <p>What specialised equipment might be needed if any – such as trailers with technology elements etc?</p>
Technical	<p>How are the RSUs deployed?</p> <p>Is there an ongoing polling required for the RSU and what system(s) manages that and crates necessary alerts for failure to respond?</p> <p>Can the RSU be deployed at the location required or is there interference/line of sight considerations?</p> <p>How are the DENM messages packed up and what system undertakes that?</p> <p>Is the messaging system tested already or is there a need to consider a Pilot activity prior to full deployment?</p> <p>Is the Control centre module proprietary and what level of interaction is needed/required by the NRA as part of the messaging activities?</p> <p>What deployment considerations are there for the AID – mounting/angle/height etc?</p> <p>How is power given to the AID and the RSUs – and can PoE or equivalent be used?</p> <p>How is the feed from the AID fed back into the Control Centre</p>
Standards	<p>Are ETSI standards adopted within the organisation or are new standards required for in-house alignment?</p> <p>Are ETSI discussions linked to the ongoing activities of the NRA and how are they adopted for deployment?</p> <p>How are standards linked to the Procurement activities?</p> <p>For the Automated Incident detection, what is the performance standard required?</p>
Data	<p>Is there a data repository available for the NRA and linked to the activations from the Automated Incident Detectors to link false positives and false negative alerts?</p> <p>Is the communications network aligned to the NRA scenario and how is</p>



	the mobile network managed?
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### 2.3.3 Operation Plan Interventions

From an Operations perspective, the NRA will need to understand how the system and systems will work and who is responsible for them both in a day-to-day way but also in terms of when things do not work and the escalation elements needed.

Type	NRA Assessment
Accountability	<p>Is there transparency on the accountability of all elements linked to RWW-LC deployment, both at a technical level and an operational level?</p> <p>What is the escalation route and the response plans in place?</p> <p>What Service Level agreements are in place and how are they linked to contractual performances?</p> <p>How are the sign gantries utilised and who co-ordinates this?</p>
Timeliness	Does the Response plan identify the timings required in terms of interventions and are these contractually based and reported upon?
Performance	<p>Is the data feed of the RSU/AIDs etc linked to a performance requirement at the control centre and how is this managed operationally (i.e. if there is a loss in a data packet, or communications is not 100% reliable, how is it identified and what happens then)?</p> <p>Consideration of the type and level of performance metrics needed to evaluate the effectiveness of C-ITS applications and infrastructure</p>

### 2.3.4 Connectivity

A CRF depends on elements within the deployed ecosystem being connected. They are connected through the digital environment and the data sharing considerations but also by the communications network itself and how this is both defined, utilised, and managed to ensure value for money to the NRA and to the public purse as well as the travelling public. Outlined below are a range of considerations for the communications network and how this will help define the local NRA investment decisions when linked to the CRF.

Type	NRA Assessment
Performance	<p>Is the existing communications network suitable for the RWW-LC deployment – and is it clear what that performance level is?</p> <p>Can the network manage latency such that the service is not impacted?</p> <p>Is the ITS G5 security requirements known and defined prior to procurement?</p> <p>Has the performance been reviewed by a pilot or can the requirements of the deployment be directly matched by a commercial off the shelf unit?</p>
Market	Is the preferred communications solution defined by the NRA to date?

	<p>Is the market providing suitable guidance to the NRA on the choices available?</p> <p>It is important to make sure that the intended communication technology (e.g. ITS-G5 roadside stations or LTE/5G mobile network) is available on the road links and at the intersections where the service is expected to be active.</p>
<p>Business Case</p>	<p>Has the NRA developed a Business case to cover the communication requirements?</p> <p>Has the NRA explored a mixed communication environment between Mobile and ITS-G5?</p>

### 3 Components of a Roadmap

The answers to each of the questions above will help form the components of a Roadmap for an NRA to provide support to a particular C-ITS service. Table 3 lists the components of such a roadmap.

These interventions can be broken down into the categories and sub-categories. The NRA should develop a roadmap based on the answers to the questions in the tables in the previous chapter. The roadmap would consist of a series of activities to address the key issues identified. Table 3 shows a set of sample activities that might be included in a roadmap, based on an NRA's answer to the questions. Each activity should have an associated timeline and is likely to have dependencies on other activities. The sample activities shown are by no means detailed or comprehensive, each may be broken down into multiple sub-activities, they are shown for illustrative purposes only.

*Table 3. Components of a roadmap for an NRA*

Intervention Category	Sub-Category	Sample Activities
<b>Physical</b>	Strategic Policy Technical Asset Management Data Security Integration Skills	<ul style="list-style-type: none"> <li>• Conduct or commission research on impacts of individual C-ITS services on safety, emissions, support to multi-modal transport etc.</li> <li>• Develop a strategy for physical support (e.g. which sections of network or characteristics of the network require specific intervention in order to make them more suitable for CAD)</li> <li>• Maintain asset register of communications equipment</li> <li>• Develop/enhance physical security policies and procedures to mitigate the risks of malicious activity</li> <li>• Conduct public or stakeholder awareness campaigns on support to CAD</li> </ul>
<b>Digital</b>	Strategic Operations Technical Standards Data	<ul style="list-style-type: none"> <li>• Engage with C-ITS standards development</li> <li>• Develop service levels for the C-ITS service</li> <li>• Develop metrics for measurement and monitoring of provision of C-ITS services</li> <li>• Develop strategy for information sharing and usage from CAVs</li> <li>• Develop architecture and systems for data storage, management, analysis and modelling of data from CAVs</li> </ul>

Intervention Category	Sub-Category	Sample Activities
<b>Operations</b>	Accountability Timeliness Performance	<ul style="list-style-type: none"> <li>• Develop testing / trialling plans for implementation of the service</li> <li>• Procurement of vehicle-ITS stations</li> <li>• Deployment of vehicle-ITS stations</li> <li>• Develop procedures for handling of false positive / negative alerts</li> <li>• Develop and implement additional protocols and procedures with emergency services</li> <li>• Review and revise use of sign gantries</li> </ul>
<b>Connectivity</b>	Performance Market Business Case	<ul style="list-style-type: none"> <li>• Identify performance requirements and level of service for the C-ITS service and use case</li> <li>• Develop metrics and measurement protocols</li> </ul>