



DiREC

Digital Road for evolving Connected & Automated Driving

Ianto Guy
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Final Conference
Day 1

slido

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Aim of the call

The aim of this research programme was to prepare the national road authorities on future challenges of connectivity, digitalization and automation to get to an autonomously well-managed traffic flow. If NRAs do not act proactively, the vehicle manufacturers will determine the automation of traffic flow alone, the NRAs will fall behind and huge investment will be needed to safeguard NRAs' objectives. NRAs goals and roles in the Cooperative, Connected and Automated Mobility of the future must be clear. Exchange of data, digital twins and the digital road operator are now hot topics in the European Commission. NRAs need to determine and act before other parties decide in our place where we need to invest.

The call has the following sub-themes:

- (a) Digital Infrastructure**
- (b) Connectivity**
- (c) Traffic management

Project Vision and objectives



Vision Statement

DiREC's vision is to empower NRAs with the tools and techniques to make measurable assessments of their investment decisions that will facilitate the adoption of Connected or Automated vehicles on their road networks.

DiREC Mission

The DiREC project's mission is to deliver a CAV Readiness Framework (CRF) for NRAs that supports current and future requirements of the network.

This Framework will act as a key tool for NRAs to understand the role they play and the actions needed to facilitate safe and secure CAV deployments. The tool and associated methodologies will provide guidance for NRAs not only to plan infrastructure projects, but also to develop a long-term strategy for their networks in terms of the types of infrastructure and services they may provide, including digital mapping, localisation, navigation and other services around traffic management.

Key findings and challenges

- So far there have been very few full deployments of the kind of systems and services relevant to CAVs
 - this makes the task of deriving accurate estimates for cost and benefit extremely challenging
- Where CAVs are concerned, interventions by NRAs need to be assessed at a system level
 - i.e. the cost of a single intervention may be high, but multiple “services” may be made possible by that intervention thus spreading the cost and multiplying the benefits
- The widespread adoption of CAVs will require a paradigm shift in the way NRAs view their relationship with their customers
 - NRAs will have to be much more active in their interactions with users and will need a much better understanding of the needs and capabilities of their vehicles
- The automotive industry has not yet reached a definitive “theory” of automation or produced a robust list of the enablers it will require

- How should an automated vehicle behave here, and what are the implications for NRAs?



- How should an automated vehicle behave here and how could NRAs make this decision easier?



- Many challenges are common to human driven and automated vehicles – is there a common solution to this problem that benefits all vehicle users?



- It's unlikely to be the responsibility of the NRA to provide connectivity
- But it could be a metric by which NRAs are judged anyway – what percentage of the network has 4G connectivity?
- Connectivity is obviously crucial for “connected” vehicles, but not necessarily vital to automated vehicles
- NRAs may wish to consider how they can influence the development of connectivity services on their networks.



- How do operational decisions change when you must take automated vehicles into account?



- NRAs may be uniquely placed to provide information about the current and future state of their networks





Digital Framework (Concept)



Service Level 4

Information is received from, and rebroadcast to, connected vehicles

Service Level 3

Information is received from connected vehicles

Service Level 2

Predictive information is provided digitally (A road will be closed tomorrow etc.)

Dynamic information is provided digitally (Traffic light status, lane closures etc.)

Static information is provided digitally (speed limits, junction priority etc.)

Service Level 1

Physical information formats are standardised across countries

Better quality of information is provided via physical means (we clean the road signs)

Information is provided only via physical means (road signs, traffic lights etc)



Positive

Economic Effect

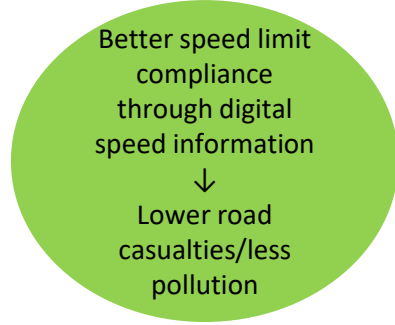
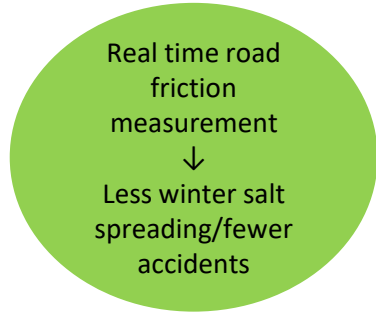
Current NRA
spending
model

Less NRA Spending

More NRA Spending



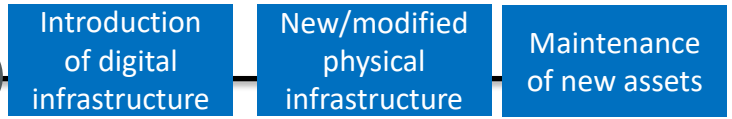
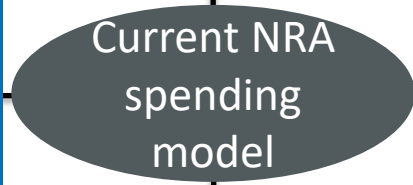
Negative



Economic Effect

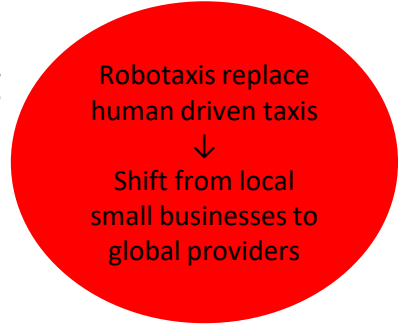
Positive

- Pollution reduction
- Road casualty reduction
- Journey time reduction



More NRA Spending

Less NRA Spending



- Increased congestion
- Job losses
- Network disruption

Negative



What can mobile phones teach us about CAVs?

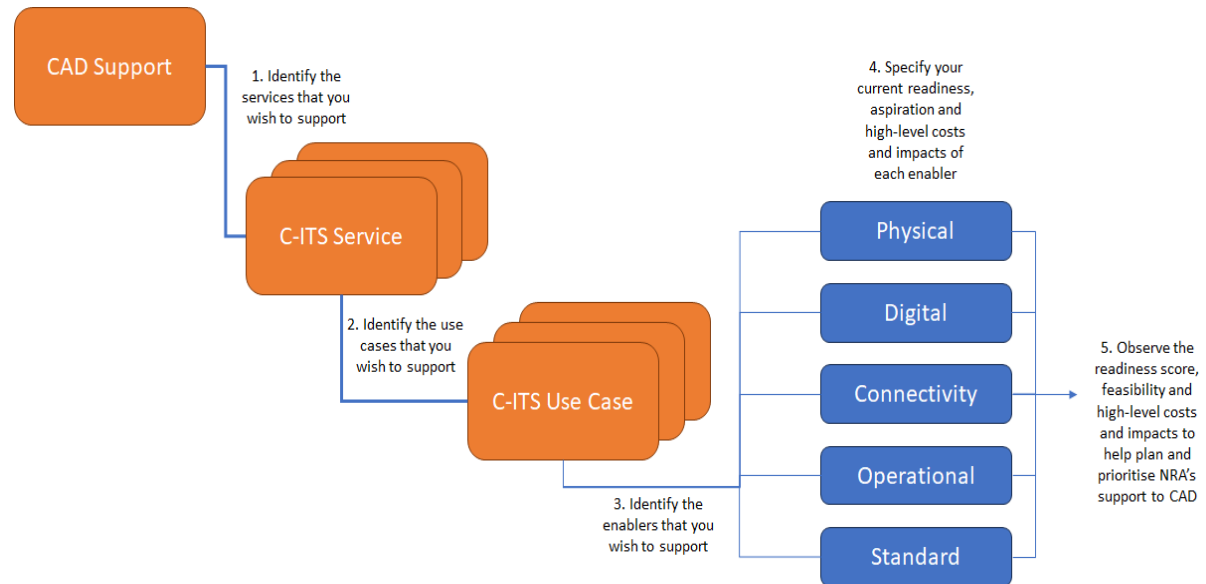


- NRAs are likely to be the unwitting victims of national and international legislation rather than its architects
- There is a growing disconnect between vehicle and road circulation regulations as technology begins to take a greater role in safety
- There are potentially enormous benefits for NRAs working with vehicle regulators to support novel safety or emissions technologies e.g. building a better Intelligent Speed Assistance (ISA) system.
- Regulations on data sharing are key and will have impact on the uptake of CAD.
- Cyber-security and connectivity are other areas with legal concerns.
- Questions of data ownership are still to be resolved – OEMs are protective of their IP.
- AI regulations will potentially have a great impact but the method for validating the performance of safety critical AI systems is still to be developed.
- NRAs may wish to carefully consider the liability they are accepting by delivering safety critical data products for use by automated or connected vehicles.

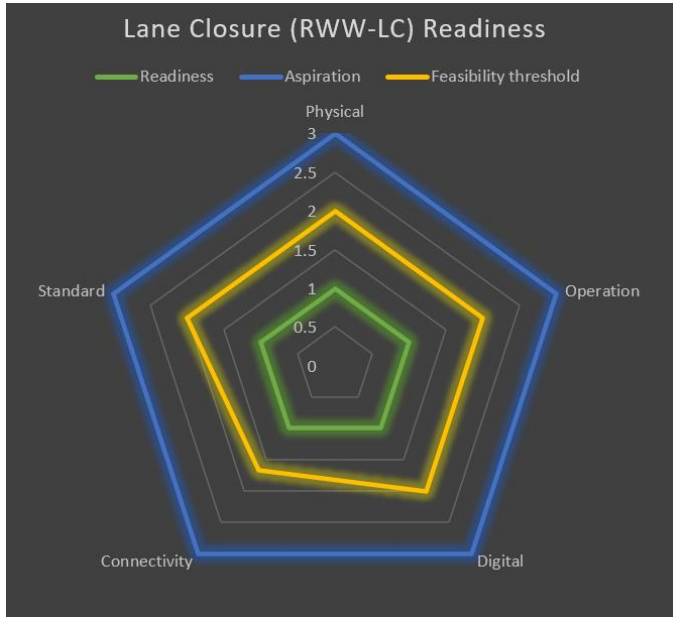
- Positioning
 - GNSS is sufficient for vehicle routing
 - Augmentation of GNSS or other positioning technologies are needed for determining vehicle position inside the lane
 - Solutions are needed for locations where GNSS is unavailable (tunnels, parking garages...)
- Emerging roadside provision options
 - ODD prediction service for automated vehicles?
 - Positioning in situations in which lane markings are not visible and satellite positioning is inaccurate or unavailable (e.g. magnetic or inductive guidance)

Structure of the CAV readiness framework

- DiREC structured the CRF around C-ITS Services and Use Cases as defined under the C-ROADS project.



CAV Readiness Framework



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	3	Medium	2
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

Level of Service Approach

- The CRF LoS is a quality and performance evaluation metric based on a set of enablers with predefined requirements.

SAE	Class A Status-sharing		Class B Intent-sharing	Class C Agreement-seeking	Class D Prescriptive
C-ITS	Day 1 I share where I am	Day 2 I share what I see	Day 3 We share our intentions	Day 4 We coordinate maneuvers	
ISAD	Class B Cooperative perception		Class A Cooperative driving		
	Road Works Warning (RWW)	54%			
	Lane Closure (RWW-LC)	67%			
	Road Closure (RWW-RC)	65%			
	Road Works – Mobile (RWW-RM)	4%			
	Winter Maintenance (RWW-WM)	80%			

- The CRF provides a framework to help NRAs understand their current readiness to provide or deploy C-ITS services and to understand potential investment decisions and link them to an overall strategic approach to deployment and delivery of a range of services.
- In addition to measuring the readiness of the NRA to support individual services and use cases, it also adds the concepts of the *aspiration* of the NRA to provide or deploy each enabler, and helps identify a *feasibility threshold* for the service which defines the minimum level of support provided by the NRA to make implementation of this use case feasible.

Conclusions

- The CRF should allow the NRA to define the impact of deploying each use case or service, in terms of five key impact factors (cost, safety, efficiency, environment, and inclusion).
- The CRF can illustrate the relative costs and benefits of each use case or each service, and can be used by the NRA to help prioritise development or implementation of services, although clearly there is significant scope for improvement in this if accurate and more granular costing is available.
- DiREC Deliverable D4 provides a set of detailed questions that an NRA planner should ask when developing a roadmap for future support to CAD, and illustrates the types of component that should be in such a roadmap.



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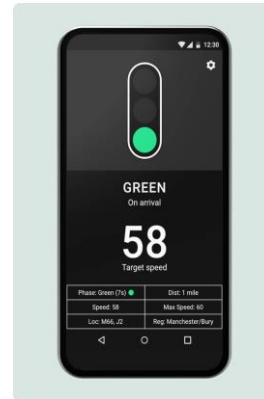
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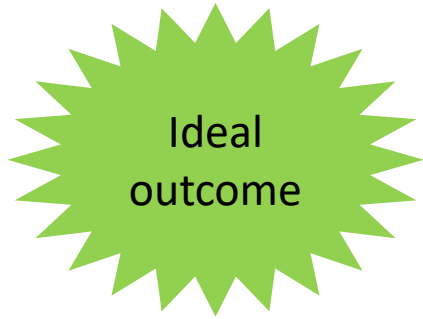


DiREC's core aim – to develop a CAV readiness framework (CRF)

...but readiness for what?



What is your ambition for connected or automated vehicles on your network?



Positive

Economic Effect

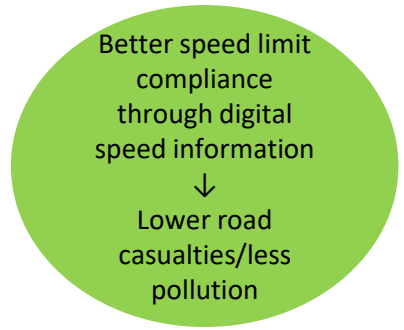
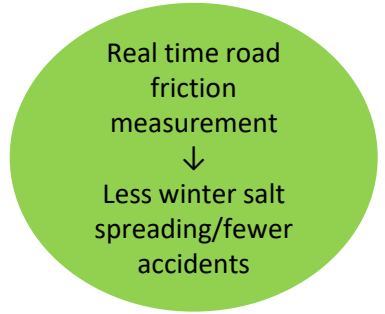
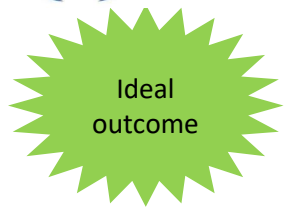
Current NRA
spending
model

Less NRA Spending

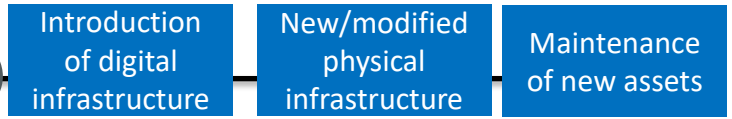
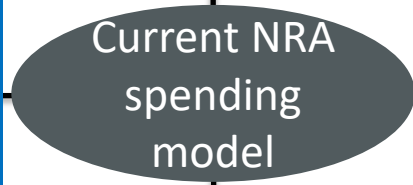
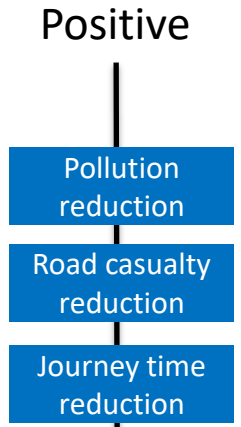
More NRA Spending



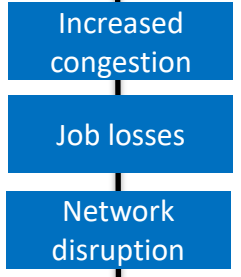
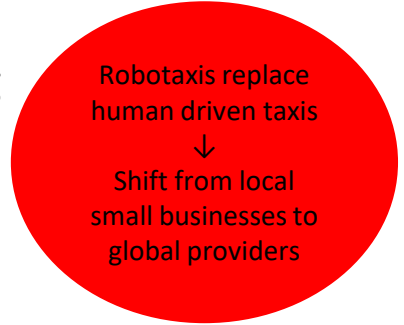
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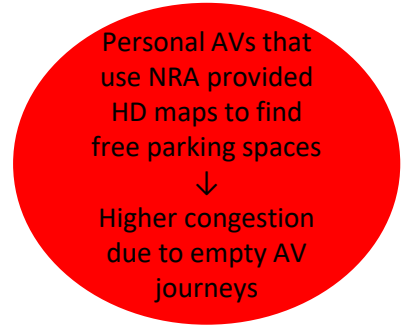
Economic Effect



Less NRA Spending



More NRA Spending



- Do NRAs regard supporting OEMs, software developers or service providers based in their country as being a key factor in their investment decisions?
- Should an NRA factor in driver job losses or the availability of new services into their cost-benefit assessments?

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?

- 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.

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?

- **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.

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. The NRA assessments are subdivided across a range of categories as outlined below:

- Strategic
- Technical
- Asset Management
- Data
- Policy
- Security
- Integration
- Skills

A Digital intervention relates, by and large, to the data elements supporting or driven by the physical assets. 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:

- Strategic
- Operations
- Technical
- Standards
- Data

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.

- Accountability
- Timeliness
- Performance

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.

- Performance
- Market
- Business Case

- In C-ITS terminology, a service is a clustering of use cases based on a common denominator, for example an objective such as awareness of road works.

C-ITS Services
In-Vehicle Signage (IVS)
Hazardous Location Notification (HLN)
Road Works Warning (RWW)
Signalized Intersections (SI)
Automated Vehicle Guidance (AVG)
Probe Vehicle Data (PVD)

- There is a one-to-many relationship between services and use cases. Take as an example the C-ITS Road Work Warning (RWW) service. C-ROADS currently identifies four use cases within that service:

C-ITS Service	Use Cases
Road Work Warnings (RWW)	Lane closure (RWW - LC) Road closure (RWW - RC) Road works - Mobile (RWW - RM) Winter maintenance (RWW - WM)

Example Enablers

- In DiREC terms, and for the purposes of the CRF, each of these use cases can be described using a set of enablers.

Enabler	Enabler Category
Roadside Units (RSUs)	Physical
DENM messaging (ETSI EN 302 637-3)	Digital
ETSI EN 302 637-3	Standard
C-ITS Mobile Roadside ITS G5 System Profile	Connectivity
Cameras	Physical
Response plan	Operation

- Task 4.1 aimed to identify NRAs for two case studies - the first to demonstrate how the CRF can be used to produce a tailored roadmap for the NRA for planning of their support to CAD; and the second to demonstrate how cost-benefit analysis can be applied using the CRF to refine and prioritise planning of support to CAD.
- However, it proved difficult to identify NRAs (from the earlier stakeholder engagement workshops) that were in a position to assist in the application of the CRF. The first phase of C-ROADS piloting had come to an end in 2021, and there has been relatively little literature published on the results of the pilots in terms of whether anticipated costs and benefits were realised, and whether the result of the pilots could be used to plan further rollout of services.
- The technical knowledge associated with owning and operating C-ITS services often lies with subcontracted parties, not the NRA, and it is very difficult to identify and engage with individuals several years after the completion of a pilot.

- The granularity of cost data is dispersed across multiple contracting entities, which makes it challenging to get cost information to aggregate and analyze for a cost-benefit analysis of C-ITS service ownership and operation.
- Further discussions were held with stakeholders, but it became clear that no NRAs closely engaged with the project were actively planning a strategy to support CAD. Therefore, the approach taken in the Case Studies was to demonstrate how the CRF could be used by “any” NRA to help plan their future support for CAD, based on general information derived from the consultation across NRAs that had already taken place in the project.

- i) To support effective use of the CRF, NRAs should undertake a number of internal workshops and discussions to help articulate their position on the topics raised. Such workshops in themselves will help drive utilisation of the CRF within the organisation and within CEDR. Indeed, it is possible to use the CRF as the centrepiece of the debate in order to stimulate engagement and outcomes linked to the various questions raised when considering a roadmap for CAD deployment.
- ii) Consolidate through internal discussions in the NRA, the list of enablers and the impacts associated with the various investment decisions. Each NRA will have different drivers and philosophies, so it is important that the NRA's utilise the CRF at a local level to help their investment decisions.
- iii) Use the CRF to develop further services and use cases in order to align with the work underway at a European level, such as C-Roads, to then fully consolidate the CRF tool itself a link between European engagement direction and the needs of the local Road authorities.

- i) The CRF can be contextualised for every NRA. However, at present it requires a good understanding of the CRF spreadsheet tool itself and the impact one change has on various other parameters. The development of a visualisation platform and dashboard view of the CRF would allow for ease of adoption and development.
- ii) Utilise existing asset management tools and Digital Twins in road operators to help consolidate the various equipment types, utilisation, impacts, and costs and benefits linked to the CRF and the deployment of CAD on the road network. This would also provide the basis for indicators to measure the extent to which a road network supports C-ITS services.
- iii) Develop a database at a National and European level to help inform the various parameters linked to the CRF and the wider Mobility sector, as well as developing the granularity and functionality of the CRF.

NRA Actions - Soon

- iv. Discussion with the wider stakeholder community around the use and impacts of the various telecommunication options to help articulate the business case linked to the service deployment around these options.
- v. Use the CRF against a current deployment to help assess areas of refinement, both for the project itself and variances needed possibly for the CRF to help manage activities at a local level.

- i) Create a European CRF approach to help consolidate investments linked to the European Directives and local modification to allow for national investment decisions to take place.
- ii) Link ongoing Road Investment decisions to the utilisation of the CRF and help articulate the business cases of the wider road network in this way.
- iii) Propose future CAD funded projects linked to the CRF to support consistent and transparent approaches to investment and underline engagement by the NRAs and the wider community.