ZENZIC

SELF-DRIVING REVOLUTION

United Kingdom

# UK National and International V2X Capabilities

## STATUS AND EVOLUTION

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## Acknowledgments

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## Abbreviations

| | |
|---|---|
| 3GPP | 3rd Generation Partnership Project |
| 4G | Fourth Generation Wireless Broadband |
| 5G | Fifth Generation Wireless Broadband |
| 5GAA | 5G Automotive Association |
| 5QI | 5G NR standardised QoS Identifier (5GQI) |
| 5G-V2X | 5G Vehicle-to-Everything |
| 802.11p | IEEE standard for direct communication between road users and with roadside infrastructure |
| AASHTO | American Association of State Highway and Transportation Officials |
| ACC | Adaptive Cruise Control |
| ACEA | European Automobile Manufacturers' Association |
| ADAS | Advanced Driver-Assistance Systems |
| AI | Artificial Intelligence |
| API | Application Programming Interface |
| AV | Automated Vehicle |
| BSM | Basic Safety Message |
| C2C-CC | CAR 2 CAR Communication Consortium |
| CA | Carrier Aggregation |
| CACC | Cooperative Adaptive Cruise Control |
| CAD | Connected Automated Driving |
| CAM | Cooperative Awareness Message |
| CAV | Connected and Autonomous Vehicles |

| | |
|---|---|
| CCAM | Cooperative, connected and automated mobility |
| CCMS | C-ITS Security Credential Management System |
| C-ITS | Cooperative Intelligent Transport System |
| CMC | Connected Motorcycle Consortium |
| CPM | Collective Perception Message |
| C-V2X | Cellular Vehicle-to-Everything |
| DATEX II | Data Exchange standard for exchanging traffic information |
| DENM | Decentralised Environmental Notification Message |
| DfT | Department for Transport (UK) |
| DoT | Department of Transportation (US) |
| DSRC | Dedicated Short Range Communications |
| E2E | End-to-End |
| eCall | emergency call |
| EEI | Energy Efficient Intersection (service) |
| ERTRAC | European Road Transport Research Advisory Council |
| eSIM | Embedded SIM |
| ETSI | European Telecommunications Standards Institute |
| EV | Electric Vehicle |
| FCC | US Federal Communications Commission |
| FCW | Forward Collision Warning |
| FEA | Fuel Efficiency Advisor |
| FR1 | Frequency range 1 (410 MHz – 7125 MHz [1]) |
| FR2 | Frequency range 2 (24250 MHz – 52600 MHz [1]) |
| GBR | Guaranteed Bit Rate |
| GLOSA | Green Light Optimal Speed Advisory |
| GNSS | Global Navigation Satellite Service |
| HMI | Human Machine Interface |
| ICT | Information and Communication Technology |
| IEEE | Institute of Electrical and Electronics Engineers |
| IoT | Internet of Things |
| IP | Internet Protocol |
| ISG | Industry Specification Group |
| ITS | Intelligent Transport Systems |
| IVS | In-Vehicle Signage |
| KPI | Key Performance Indicator |
| LTE | Long Term Evolution |
| LTE-V2X | 3GPP standard for vehicle-to-everything communication |
| LTE-V2X (PC5) | Interface for direct communication between road users and with roadside infrastructure |
| LTE-V2X (Uu) | Interface for communication between vehicles and mobile network |
| MAP | Map Data (message) |
| MBMS | Multimedia Broadcast Multicast Service |

| | |
|---|---|
| MCM | Manoeuvre Coordination Message |
| MEC | Multi-Access Edge Computing |
| MFM | Midlands Future Mobility |
| MNO | Mobile Network Operator |
| NCAP | New Car Assessment Programme |
| NIST | National Institute of Standards and Technology |
| NR | New Radio – new radio access technology developed by 3GPP for the 5G |
| NSA | non-standalone |
| OBU | Onboard Unit |
| OEM | Original Equipment Manufacturer |
| PSM | Personal Safety Message |
| PVD | Probe Vehicle Data |
| QCI | QoS Class Identifier |
| QoS | Quality of Service |
| RHW | Road Hazard Warning |
| RLVW | Red Light Violation Warning |
| RSU | Roadside Unit |
| RWW | Road Works Warning |
| SAE | Society of Automotive Engineers |
| SDO | Standards Developing Organization |
| SIM | Subscriber Identity Module |
| SL | Sidelink |
| SLA | Service Level Agreement |
| SPAT | Signal Phase and Time (message) |
| SRTI | Safety-Related Traffic Information |
| SVCs | Single Vehicle Collisions |
| TCU | Telematics control unit |
| ToD | Tele-operated Driving |
| TR | Technical Report |
| TSP | Traffic Signal Priority |
| UE | User Equipment |
| USIM | Universal Subscriber Identity Module |
| Uu | air interface (radio interface) between UE and the base station |
| V2I | Vehicle-to-Infrastructure |
| V2M | Vehicle-to-Motorcycle |
| V2N | Vehicle-to-Network |
| V2P | Vehicle-to-Pedestrian (also includes cyclists) |
| V2V | Vehicle-to-Vehicle |
| V2X | Vehicle-to-Everything |
| VAM | VRU Awareness Message |
| VMS | Variable Message Sign |
| VRU | Vulnerable Road User |

# 1 Executive Summary

With this report the partners of the Zenzic V2X project Commsignia, HORIBA MIRA, Nokia, UTAC Millbrook and Vodafone provide an overview about the current UK V2X test capabilities, government and industry roadmaps, market needs and opportunities for alignment with other global V2X initiatives and systems, with a particular focus on defining optimal CAM Testbed UK V2X test and validation services.

The document describes the evolution of V2X use case supporting traffic safety, efficiency and later automated driving which rely on network and short-range communications. The report also provides details about the evolution of mobile networks and the digital road infrastructure which need further improvements since they are important for the deployment of many use cases.

A detailed assessment of test capabilities in the UK including CAM Testbed UK and the evaluation of the results and lessons learned from trials data is the basis for deriving recommendations to build an interoperable UK test environment for Connected Mobility.

The investment into an aligned test environment is justified by the key benefits to the main customers and stakeholders of V2X Data Services with a particular focus on traffic participants (vehicle drivers and VRUs), OEMs, mobility service providers, road operators, mobile network operators and data service providers. The report provides examples of those benefits also showing the impact on sustainability and emissions.

The document demonstrates how various standardisation and industry organizations, European and national initiatives work to provide the basis for deploying interoperable V2X technology and C-ITS services in a very complex ecosystem across the automotive and telecommunications industry as well as the road operations domain. The complexity of the ecosystem, differences between regions of the world, the need of intensive cooperation between private businesses and public authorities represent challenges for the fast adoption and deployment of C-ITS services which also creates new requirements to testing, validation and certification of emerging technologies and e2e use cases.

The exchange of data via well-defined interfaces and services between systems and of various stakeholders is considered to be a key element to enable true e2e digitalization and to establish sustainable cooperation and business models.

Based a comprehensive analysis of various aspects of the ecosystem, the document concludes with recommendations on optimal CAM Testbed UK V2X test and validation services which need to be defined with a particular focus on: firstly, developing a scalable V2X architecture template which can interface with multiple V2X standards, stakeholders and test activities and on and off-roads; and, secondly, implementing this architecture into a comprehensive CAM Testbed UK framework ready for commercial operation for various customers.

The commercial operation should include not only technology testing but also conformance assessment testing and certification. This includes enabling interoperability testing across the ecosystem – involving new technologies like precise positioning or road-side sensors and involving different OEMs, bikes, pedestrians as well as various types of road infrastructure and related data environments.

# 2 Future plans of ecosystem players

Connectivity, in the automotive context also called V2X communications, is considered to be one of the major trends in the automotive industry as shown on Figure 2-1. On the other hand, societal needs like traffic safety and efficiency, reduced emissions and increased comfort of new mobility concepts are essential for development of smart and attractive cities. These objectives can only be achieved if the main stakeholders of the ecosystem consider cooperation as a key success factor. The stakeholders include automotive and communications industries which are typically represented by private companies, and road operators which are in many countries public authorities. Service providers like map data providers or mobility service providers are also important elements of the mobility ecosystem.

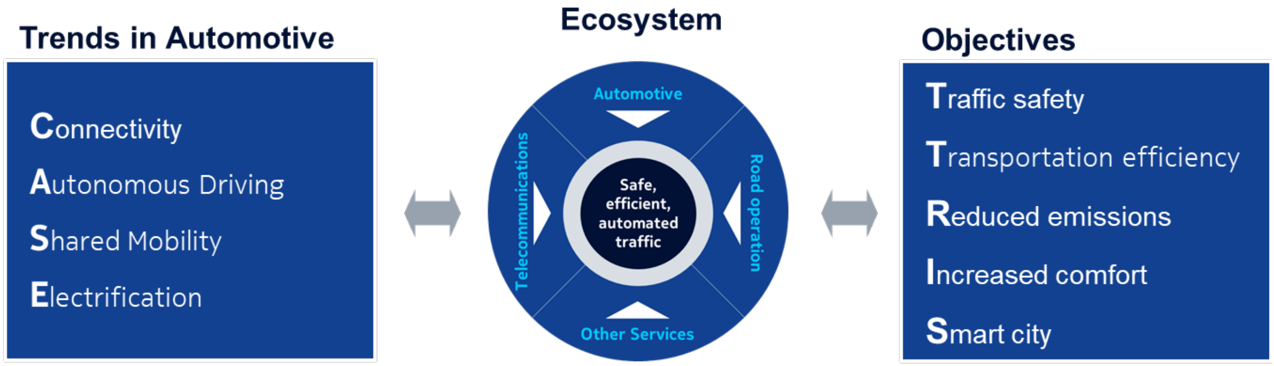


Figure 2-1: The role of the C-ITS ecosystem

The following sections of this chapter describe the evolution of use cases required to meet the societal objectives as well as the status of the communications network and road infrastructure. SDOs and industry organisations play an important role for the creation of technical specifications allowing the implementation of use cases and enabling the interoperability of all systems involved to deliver high quality services.

It is worth noting that the technical evolution needs to be complemented with new regulations, for example, related to automated driving on public roads or handling of data. Regulatory aspects are not in the scope of this document but are well described in a summary report[1] which the Law Commission of England and Wales and the Scottish Law Commission published in January 2022 as joint report recommendations on new laws to regulate automated vehicles (AVs) in Great Britain.[2]

Aspects of Human Machine Interface (HMI) are not in in the scope of this document.

[1] https://s3-eu-west-2.amazonaws.com/lawcom-prod-storage-11jsxou24uy7q/uploads/2022/01/AV-Summary-25-01-22-2.pdf
[2] https://www.lawcom.gov.uk/project/automated-vehicles/

## 2.1 Evolution of V2X use cases

V2X plays a growing role for the implementation of C-ITS use cases increasing traffic safety, efficiency, driving comfort and contributing to the reduction of emissions and supporting the path towards automated driving. Many OEMs have already deployed comprehensive use cases in their vehicles relying on connectivity ranging from eCall, telematics and infotainment to safety related applications.

This document focuses on use cases supporting traffic safety and efficiency, which will evolve towards supporting automated driving. These use cases rely on network-based connectivity (Uu) complemented more and more with short range communications. Network based communication using 4G has already become a standard feature for the majority of new vehicles, the first 5G connected cars have already been released into the market[3] [4]. The first vehicles supporting short range communications are on the roads, equipped with ITS-G5[5] or C-V2X [6] [7].

V2X use cases are well described by various SDOs and industry organisations focusing on functional aspects, protocols and process flows, message formats as well as KPIs like latency, positioning accuracy and necessary data rates which need to be met to guarantee the expected functions. Examples of such organisations are: ETSI ITS, C-ROADS, Car 2 Car communications consortium and 5GAA (see also section 2.5). SAE and the service packages of the National ITS reference architecture[8] developed for the US DoT describe the American versions of the use cases.

Roadmaps published by different organisations focus on various aspects of the evolution, for example the roadmap from ERTRAC[9] provides a view on the long-term development of Connected, Cooperative and Automated Mobility in Europe. ACEA's Roadmap for the deployment of automated driving in the European Union[10] focuses on regulatory and policy aspects. The Zenzic UK Connected and Automated Mobility Roadmap to 2030[11] provides a comprehensive overview of the activities of the ecosystem and aligns it on common goals.

5GAA's Visionary Roadmap for Advanced Driving Use Cases, Connectivity Technologies, and Radio Spectrum Needs[12] shows the evolution of automotive connectivity for the purposes of enhanced road safety, improved traffic efficiency, greener environmental impact and more comfortable driving. The milestones for mass deployment of selected use cases from 4 different categories are shown on a timeline – see Figure 2-2.

The 5GAA roadmap white paper describes that many day-1 basic safety use cases have been widely analysed in the past, and several of these use cases have already been deployed starting in 2016 and relying on network connectivity. OEMs like Ford[13] and Volvo Cars[14] also introduced such use cases during the last few years

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[3] http://autonews.gasgoo.com/m/Detail/70017850.html
[4] https://www.bmwblog.com/2021/09/02/bmw-ix-will-be-available-with-5g-connectivity-via-two-network-operators/
[5] https://www.nexusgroup.com/volkswagen-premieres-all-new-golf-with-v2x-capabilities/
[6] https://www.qualcomm.com/news/releases/2020/12/11/fully-featured-intelligent-electric-suv-flagship-hongqi-e-hs9-features
[7] https://media.gm.com/media/cn/en/buick/home.detail.html/content/Pages/news/cn/en/2020/Nov/1120-Buick.html
[8] https://www.arc-it.net/html/servicepackages/servicepackages-areaspsort.html
[9] https://www.ertrac.org/uploads/documentsearch/id75/Draft%20ERTRAC%20CCAM%20Roadmap%20V9%2030-09-2021.pdf
[10] https://www.acea.auto/publication/roadmap-for-the-deployment-of-automated-driving-in-the-european-union/
[11] https://zenzic.io/roadmap/
[12] https://5gaa.org/news/the-new-c-v2x-roadmap-for-automotive-connectivity/
[13] https://media.ford.com/content/fordmedia/feu/en/news/2021/01/21/ford-shares-connected-car-data-with-other-manufacturers-to-help-.html
[14] https://www.autoblog.com/2018/05/07/volvo-cars-volvo-trucks-share-data/?guccounter=1#slide-7324246

and in 2021 several OEMs extended the list of supported use cases, such as Audi enabling slippery road detection[15], Skoda with wrong-way driver warning [16] and Mercedes Benz with pothole detection[17].

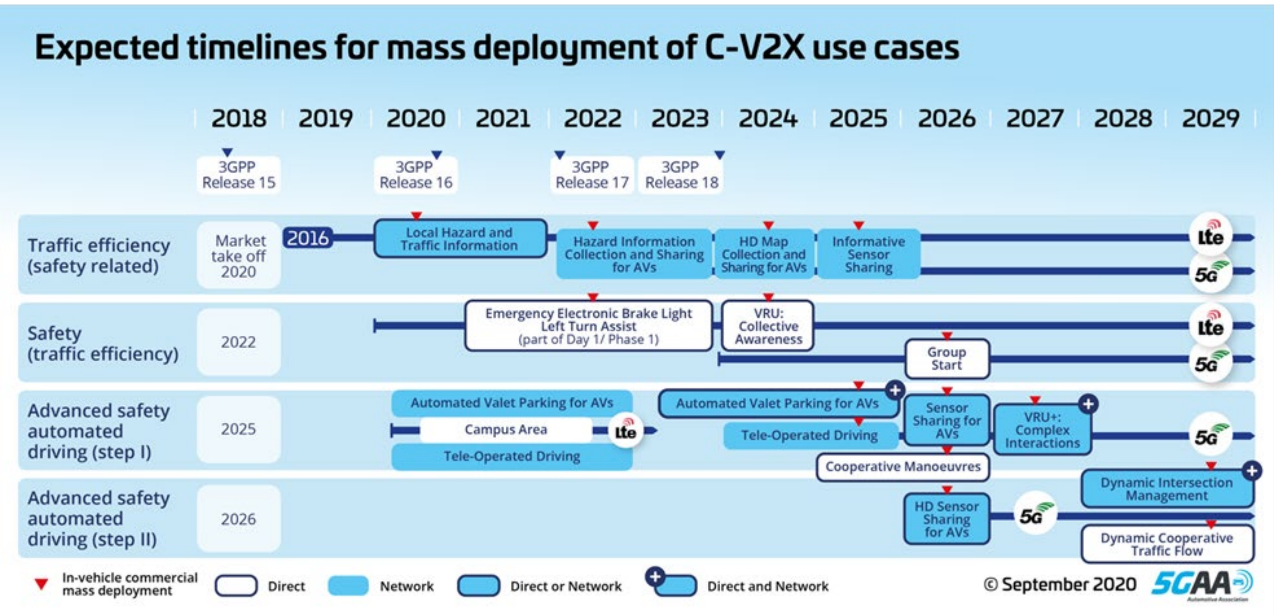


Figure 2-2: Timeline of C-V2X use case mass deployment (source: 5GAA[12])

Currently, these hazard warnings are typically distributed within the fleet of an OEM or OEM group. The Data for Road Safety[18] initiative was set up to enable sharing of SRTI messages (hazard warnings) between vehicles of different OEMs using the mobile network, the OEMs' cloud infrastructure, service providers as well as the National Access Points (see Section 5).

The 5GAA roadmap also outlines that many advanced driving use cases will require sensor and intention sharing, cooperative perception delivered with low latency and high reliability. 5GAA predicts that all new AD vehicles will be equipped with 5G-V2X from 2026, in line with their mass production and entry to the market. The advanced cooperative driving use cases including the protection of VRUs will rely on network and short-range communications. These complex use cases will also require new approaches for testing since the main functionality is about well-defined interaction scenarios between different traffic participants. Testing will also have to include other technology contributors to the use cases such as precise positioning technologies and methodologies.

[15] https://www.volkswagenag.com/en/news/2021/03/precise-data-for-greater-safety--audi-warns-its-drivers-about-sl.html
[16] https://www.bosch-presse.de/pressportal/de/en/boschs-wrong-way-driver-warning-system-now-a-feature-in-%C5%A1koda-vehicles-224448.html
[17] https://www.greencarcongress.com/2021/08/20210812-mbc2x.html
[18] https://www.dataforroadsafety.eu

 

## 2.2 Evolution of mobile networks

A number of countries in Europe combined their 5G spectrum licenses with road coverage obligations related to all roads or only a selection of roads. Mobile network operators (MNOs) as license holders have to fulfill those obligations within defined periods.

Ofcom, the UK regulator, regularly accesses the status in the UK. Its annual 'Connected Nations' report[19] presents a review of telecommunications connectivity in the UK. Much of the following data has been gathered from the 2021 edition of this report.

### 2.2.1 Current status of 5G Rollout in the UK

Connected Nations 2021 acknowledges the increased reliance on mobile networks, and subsequent increased data demand, due to the Covid-19 pandemic. It concludes that the UK mobile networks were able to handle the sudden increase in demand due to the Covid-19 effects on work practises, without significant loss of service quality. This can be attributed in part due to the flexibility introduced by the virtualisation and 'cloudification' of mobile communications network cores.

According to the Connected Nations 2021[19] report, 5G is estimated to be available from at least one operator outside 42-57% of UK premises. Rollout is now extending into busy suburban areas and transport corridors, although most 5G sites continue to be added in busy urban areas and are providing additional capacity to existing mobile data services.

While 5G connectivity can be thought of as defining the upper service level in urban and denser suburban areas, the rest of the UK landmass/geographic service is provided by 4G coverage, particularly as far as automotive services are concerned since very few, if any, vehicles are equipped with a 5G modem. In the 2021 document it was reported that the UK's MNOs provided a range of 79%-86% geographic coverage, with 8% of the landmass having a total 4G 'notspot' (no 4G coverage/connectivity at all). National roaming is not enabled in the UK although IoT devices are generally enabled to roam nationally through the deployment of 'always roaming' SIMs together with IoT-favourable roaming agreements.

Connected Nations 2021 also examines road coverage by considering 4G only. It is reasonable to assume that V2X services are only viable with 4G or later connections. Since 5G coverage is generally deployed to enhance existing 4G, it does not add significantly to the overall coverage statistics at this time.

"4G coverage is predicted to be available inside vehicles on motorways and A roads in a range between 82-88% across the MNOs. This falls to 72-77% for B roads. Outside vehicles, 4G coverage ranges between 93-98% across MNOs for motorways and A roads (up 1 percentage point from last year for both Vodafone and BT EE), and 89-94% for B roads." [19]

The Shared Rural Network programme[20] agreed in March 2020 will extend rural 4G coverage in the UK by 2025, through enhanced sharing of existing infrastructure and

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[19] Connected Nations 2021, Ofcom, https://www.ofcom.org.uk/__data/assets/pdf_file/0035/229688/connected-nations-2021-uk.pdf

[20] https://srn.org.uk/

the deployment of new sites (intended for sharing) in areas of no coverage, funded by the UK government. Under the agreement, each MNO is committed to reaching 88% coverage of UK landmass by 2024, and 90% of landmass within 6 years from 2020. 95% of UK landmass is expected to see at least one MNO signal by 2025. The focus of the SRN is by definition rural connectivity, rather than road connectivity, where continuous service provided to a vehicle by a single MNO is not a target objective.

In Scotland the 'Scottish 4G Infill' [21] programme has identified 47 new sites to provide additional 4G connectivity to rural areas with no exiting coverage. At the time of writing 24 sites are live, 18 are under construction and 5 are at pre-build stage.

It is to be expected that the above 2 programmes will lead to an improvement for geographic and population coverage statistics, compared to those reported in Connected Nations 2021, but because of their focus on rural areas, any improvement in road coverage will be indirect.

### 2.2.2 V2X specific network features

3GPP R14 LTE introduced some V2X QCIs (QoS Class Identifier) for V2X communications over the LTE-Uu interface. It is a mechanism that ensures network carrier traffic is allocated appropriate QoS. V2X messages can be transmitted via a non-GBR bearer (Guaranteed Bit Rate bearer), an IP transmission path with no GBR resources, or via a GBR bearer, an IP transmission path with GBR resources. To meet the latency requirements when delivering the V2X messages, the following V2X QCI values were defined in 3GPP TS 23.203[22]:

1. QCI 3 (GBR bearer) and QCI 79 (Non-GBR bearer) can be used for the unicast delivery of V2X messages.
2. QCI 75 (GBR bearer) is only used for the delivery of V2X messages over MBMS bearers.

QCI 3 was defined in 3GPP Rel-8. QCIs 75 and 79 were introduced in 3GPP LTE Rel-14.

The fundamental definition for 5G is the same as 4G QCI – it is also a mechanism for ensuring network traffic in 5G NR is handled appropriately by classifying carrier traffic into different classes. However, while 4G QCIs apply to the bearer within which there are expected QoS flows, 5QIs apply to the flows within a bearer. This means 5QI is a more granular version of the 4G QCI.
5QI values 3 and 79 correspond to the 4G QCI values 3 and 79 so these values apply both in LTE and NR. 4G QCI value 75 does not have a corresponding value in the table of 5QI values so is LTE-only.
5QI values 83, 85 and 86 are newly-defined in the NR specifications[23] without corresponding values in the LTE specifications, they only apply to NR. 5QI 83 and 85 were defined in 3GPP Rel-15. 5QI 86 was added in Rel-16.

[21] 'Scottish 4G Infill', https://www.gov.scot/publications/scottish-4g-infill-programme-progress-update/
[22] https://www.etsi.org/deliver/etsi_ts/123200_123299/123203/14.03.00_60/ts_123203v140300p.pdf
[23] https://itectec.com/archive/3gpp-specification-ts-23-501/

Other features like predictive QoS or edge computing are also relevant for the deployment of V2N.

### 2.2.3 Spectrum needs

Sufficient radio spectrum is a prerequisite for using 5G short range and network-based communications for the advanced use cases supporting automated driving in the future. 5GAA outlined additional radio spectrum needs in the C-V2X roadmap white paper [12] recommending that national administrations make the entire globally harmonised 5.855-5.925 GHz band available for use by ITS communications between road users and roadside ITS infrastructure. Given that both short range and network-based communication (Uu) enabled today and the more advanced and demanding driving use cases in the future, 5GAA also recommends that national and regional administrations ensure the availability of sufficient spectrum for mobile communication networks in the so-called low-bands and mid-bands for the support of services, including ITS services, in the coming decade[12]. Detailed spectrum needs for day 1 and advanced ITS use cases are outlined in spectrum needs studies for both short-range and network based (Uu) communications published in October 2021[24] as follows:

1. The delivery of day-1 use cases via LTE-V2X (PC5) for the support of basic safety ITS services will require between 10 and 20 MHz of spectrum at 5.9 GHz for V2V/I communications

2. The delivery of advanced use cases via LTE-V2X (PC5) and NR-V2X (PC5) for the support of advanced driving services will require an additional 40 MHz or more of spectrum at 5.9 GHz for V2V/I/P communications
3. At least 50 MHz of additional[25] service-agnostic low-band (< 1 GHz) spectrum would be required for mobile operators to provide advanced automotive V2N (Uu) services in rural environments with affordable deployment costs.
4. At least 500 MHz of additional[25] service-agnostic mid-band (1 to 7 GHz) spectrum would be required for mobile operators to provide high-capacity, citywide advanced automotive V2N (Uu) services.

China allocated 20 MHz in the 5.9GHz for C-V2X[26], which is the only short-range technology to be used on China's roads for C-ITS use cases.

In November 2020, the US Federal Communications Commission (FCC) also made a decision in favour of C-V2X and adopted a Report & Order (R&O)[27] revising its rules for the 30Mhz of the upper 5.9 GHz band, which had been dedicated exclusively for DSRC since 2003, and concluded that the United States should move forward with C-V2X. In December 2021 three car manufacturers, two state Departments of Transportations and nine equipment manufacturers submitted a request for a waiver

[24] https://5gaa.org/news/study-of-spectrum-needs-for-safety-related-intelligent-transportation-systems-day-1-and-advanced-use-cases/

[25] the term "additional" means availability of spectrum in addition to the bands that are currently identified for International Mobile Telecommunications (IMT) use by mobile communication networks

[26] https://www.itsinternational.com/its5/its7/feature/china-paves-way-enhanced-safety-c-v2x

[27] https://www.fcc.gov/document/fcc-modernizes-59-ghz-band-improve-wi-fi-and-automotive-safety-0

to the FCC[28] to waive its current rules applicable to the 30Mhz of the upper 5.9 GHz band to permit them to collectively deploy and facilitate deployment of C-V2X immediately.

Europe is in a different situation. The technology neutral approach taken by the European Commission allows the deployment of both short-range technologies, which are not compatible and interoperable on the physical layer. The ecosystem needs to agree how to deal with this situation. 5GAA proposed a way forward in a position paper on the deployment of band configuration for C-V2X at 5.9 GHz in Europe[29]. Not all ecosystem players support the 5GAA position – further work is required under the umbrella CEPT.

## 2.3 Evolution of digital road infrastructure

The digitization of road infrastructure is a necessary part of the development of improved transport. The progress to date has been patchy and has served mainly to highlight some of the challenges faced. These include

- High cost of upgrading legacy systems
- The need for high precision map data
- Where data does exist it doesn't necessarily correspond to the physical world
- Keeping data up to date as and when physical changes take place.
- It is not always clear which is definitive source digital or physical (eg TRO speed limits)
- Responsibility for the road network is a patchwork of public organisations (national road operators, local road operators, local councils) with a handful of private organisations (toll operators, parking operators etc.)
- There is a lack of standardisation of interfaces and data for the digital road infrastructure. Where standards do exist such as DATEXII it is not widely adopted.
- Systems providing data are frequently offline or provide inaccurate data.
- A lack of a common way of sharing available data in real time.
- A lack of international standardization; in many regions, drivers do cross national borders and would expect the same services and standards in both territories. OEM manufacture cars for a worlds market and don't want to customise the cars for each nation.

The roll out of C-ITS services brings about a paradigm shift. Traditionally, road operators provide the road infrastructure which can be standalone systems or integrated with other road infrastructure systems and OEMs provide vehicles with standalone technologies. With C-ITS services it is necessary for road infrastructure systems to interwork with vehicles and one manufacturers vehicles need to interoperate with other manufacturers vehicles. The regulatory frameworks and testing facilities all have to adapt to the new paradigm and are currently not in place.

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[28] https://ecfsapi.fcc.gov/file/1213991411128/C-V2X%20Waiver%20Request%2012%2013%202021.pdf
[29] https://5gaa.org/news/deployment-band-configuration-for-c-v2x-at-5-9-ghz-in-europe/

There are multiple SDOs and industry organisations working on individual standards or technologies, it is not clear which of these sometimes competing standards and technologies will be adopted or become dominant. A number of these standards and technologies are also undergoing local trials and some may make it to the stage of providing local services. This problem is compounded by regulatory confusion in some parts of the world e.g. North America, where the spectrum allocation and licensing has not been finalised leading to use of DSRC and in some locations with a possible change to PC5 needed in the near future.

This lack of clarity has led to a wait and see approach for some OEMs and road operators because of the high cost of backing unsuccessful technologies. This is compounded by the need for both road operators and OEMs to make the same choices and be able to test interoperability of their implementations.

Ultimately these individual standards need to be interoperable to be able to provide the improvements to traffic safety and efficiency.

The timescales for the digitization of the road network are inevitably quite long driven by the OEMs' development cycle for new vehicles, operating lifetime of existing vehicles and road infrastructure components before they are taken off the road and the number of roads, junctions and systems that would need upgrading.

So far, the journey to digital road infrastructure has comprised of multiple proof of concept trials or services for very small specific populations of road users.

Therefore, it is likely that the digitization of the road infrastructure will be rolled out in multiple local pockets with each installation having slightly different services.

Another challenge for both road operators and OEMs is that they have both traditionally been hardware and firmware deployments meaning that the services are fixed at installation or manufacture and adding new services afterwards, if even possible, is costly and hence not done very often.

With C-ITS it is likely that services will be evolving rapidly and both vehicles and infrastructure will need to have their software updated on a regular basis throughout their lifetime. For infrastructure this means a migration to cloud based services controlling firmware update of roadside installed equipment and for OEMs it means over the air updates of vehicles. This trend is already present but will need to be accelerated.

To speed up the digitization of the road infrastructure a number of strategies could be adopted these may include.

- Increasing the road coverage with digitalized infrastructure
- Reducing the quantity of V2X RSU's deployed by adopting a cellular network-based system
- Bypassing the need to add additional h/w modules and BoM cost to vehicles by adopting network-based services because a high proportion of vehicles are already fitted with 4G cellular and eSIM's.
- Bypass the long lead times of OEMs' development lifecycles and existing vehicle lifecycles by adopting aftermarket fit OBU's either as dedicated devices or as handset applications. This could be similar to the way satellite navigation was initially adopted with aftermarket devices until it became a common standard fit in many car models. With the latest trend being a move

away from using the built-in satellite navigation towards handset based apps because there maps are kept updated and often have additional real time data (e.g. Waze)

- Introduce initial local services from which local road operators can obtain short term benefits to justify the initial investment whilst the richer set of services can be evolved (e.g. as seen in the US state of Georgia where they are seeing benefits by installing signal priority for express busses when they are running behind schedule or directing port lorry traffic to uncongested port entrances.)
- Introducing some initial services at a national level as well as local services to encourage the adoption of aftermarket OBU's

## 2.4 SDOs

Several SDOs provide ITS related standards at global or regional levels.

3GPP provides reports and specifications that define 3GPP technologies covering cellular telecommunications technologies (radio access, core network and service capabilities). These specifications provide a complete system description for mobile telecommunications. The original scope of 3GPP was to produce specifications for the third generation (3G) mobile system. Since then, it has evolved to the fourth generation (4G also called LTE) and fifth generation (5G). With LTE release 14 3GPP complemented the mobile network communication (Uu) technology with a short-range communication LTE V2X (PC5) for the first time. Currently, the first 5G release 15 capabilities are available in the first vehicles as described in section 2.1.

3GPP continues to evolve the technologies with release 17 and 18, for example, with features improving short range communications (also called side link).

ETSI's Technical Committee (TC) ITS[30] develops European standards and technical specifications to enable interoperability. These standards support the development and implementation of ITS service provision across the network, for transport networks, vehicles and transport users. The scope includes interface aspects, multiple modes of transport, security, test and interoperability between systems. In line with Europe's technology neutral approach ETSI has standardized both short range technologies ITS G5 and C-V2X. The standard ETSI EN 303 613[31] defines the use of C-V2X as an access layer technology for ITS devices as an alternative to ITS G5. The standards defining the ITS protocols above the access layer have also been updated to support utilization of C-V2X as the underlying access layer. They are all included in ETSI TR 101 607[32], enabling the development of interoperable C-V2X ITS implementations and devices from multiple vendors. Interoperability test events have already been conducted by ETSI[33].

SAE International runs a Technical Standards Development Program for mobility industries with a focus on aerospace, automotive, and commercial vehicle. Its Motor Vehicle Council (MVC)[34] provides Technical Reports - Standards, Recommended

[30] https://www.etsi.org/committee/its
[31] https://www.etsi.org/deliver/etsi_en/303600_303699/303613/01.01.00_20/en_303613v010100a.pdf
[32] https://www.etsi.org/deliver/etsi_tr/101600_101699/101607/01.02.01_60/tr_101607v010201p.pdf
[33] https://www.etsi.org/newsroom/news/1810-etsi-c-v2x-plugtest-achieves-interoperability-success-rate-of-94
[34] https://www.sae.org/servlets/works/committeeHome.do?comtID=TEV

Practices, and Information Reports for the US market. V2X communications aspects are handled by the V2X Communications Steering Committee. A special C-V2X Technical Committee has been set up to work on C-V2X radio-access specific items. There is ongoing work to extend the standards for C-V2X to use it in deployments following the decisions made on the use of the 5.9GHz ITS spectrum for C-V2X described in section 2.5.

For example, there is work in progress on a standard SAE J3161/1[35] defining On-Board System Requirements for LTE V2X V2V Safety Communications. The standard is expected to ensure addresses the on-board system needs for ensuring that V2V safety communications provides the desired interoperability and data integrity to support the performance of the envisioned safety applications.

SAE standards are also adopted in other regions.

ISO’s Technical Committee 204[36] is responsible for the overall system aspects and infrastructure aspects of ITS. It works on standardisation of information, communication and control systems in the field of urban and rural surface transportation. Several working groups address topics like architecture, big data, toll collection, fleet management, vehicle/roadway warning and control systems. The following work in progress standard is an example of a communications oriented standard: ISO/DIS 23374-1 Intelligent transport systems — Automated valet parking systems (AVPS) — Part 1: System framework, requirements for automated driving, and communication interface[37].

## 2.5 Industry organisations

Several industry organisations work on connectivity aspects of C-ITS applications and ways of bringing the different parts of the ecosystem together, for example:

- 5G Automotive Association (5GAA)[38] bridging the automotive and telecommunications industries to define the next generation of connected mobility solutions at a global level
- CAR 2 CAR Communication Consortium (C2C-CC)[39] driving C-ITS developments and assisting to achieve vision zero. C2C-CC promotes ETSI ITS G5 as the cooperative V2X communication technology with a focus on Europe
- Connected Motorcycle Consortium (CMC)[40] - a collaboration between manufacturers, suppliers, researchers and associations to make Powered Two Wheelers (motorcycles and scooters) part of the future connected mobility by promoting and developing C-ITS on a global scale.

The European road operators have created the C-ROADS[41] platform as a joint initiative of European Member States and road operators for testing and implementing C-ITS services in order to harmonise the deployment activities of those C-ITS services. The goal is to achieve the deployment of interoperable cross-border C-ITS services for road users.

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[35] https://www.sae.org/standards/content/j3161/1/
[36] https://www.iso.org/committee/54706.html
[37] https://www.iso.org/standard/78420.html
[38] https://5gaa.org/
[39] https://www.car-2-car.org/
[40] https://www.cmc-info.net/
[41] https://www.c-roads.eu/platform.html

Industry organizations also play an important role in conformance assessment of communications technology. Work is underway in the 5GAA to establish a Sidelink/PC5 Conformance Assessment (CA) capability. The approach being taken is the same as that which the mobile network industry already has in place for CA of the device-network communications channel (Uu). This industry led scheme has proved highly effective and efficient and has shown its flexible and agile methodology to be well suited to an evolving technology platform like 3GPP [ref]. The non-direct involvement of Mobile Network Operators (MNOs) in the Sidelink/PC5 communications channel has means that this existing industry led scheme will not drive the CA of Sidelink/PC5 and hence a new stakeholder ecosystem has to be created consisting of such players as the automotive industry, the road operator industry, the Sidelink/PC5 device manufacturers and its supply chain, and the test equipment and test house/track community.

5GAA has already delivered the first issue of its CA specification for the lower layers of the Sidelink/PC5 stack [ref]. This has been done based upon 3GPP RAN5 work [ref] and in conjunction with the Global Certification Forum (GCF)[42], a key player in the existing Uu communication channel CA scheme. The commonality of the lower layers of the stack means that this CA specification is relevant worldwide. 5GAA is now working on defining its CA specification for the upper layers of the stack and is looking to do this in collaboration with other interested parties such as OmniAir[43], an established CA and certification organisation based in the USA with a background in road tolling and the WiFi version of Sidelink (IEEE 802.11p), and China's IMT-2020 Promotion Group [ref] and the China Academy of Telecommunications Technology (CATT). Differences in the stack fundamental specifications for the upper layers between Europe, North America and China mean that a single specification will not be possible but it is targeted to have a common specification with regional annexes as and where applicable. It is estimated that the first issue of this level CA specification will be available by the end of 2022.

## 2.6 Security

The V2X standards define a specific Public Key Infrastructure (PKI) for C-ITS. The aim of this system is to allow V2X messages broadcast over the short range communication links to be signed such that a receiving entity can use the PKI to validate that the message comes from a trusted source.

The system requires a master (European) list of trusted root Certificate Authorities (CA). The root CA's can then issue and revoke certificates to ITS system vendors. CA authorities have the responsibility to vet and audit organisations that they issue certificate to.

The trust list and CA infrastructure has not reached maturity with a number of root CA providers issuing certificates however its is currently not clear if consistent vetting and auditing processes are in place and what vetting and auditing of root CA provers is taking place.

The method of funding the necessary PKI infrastructure is unclear.

[42] www.globalcertificationforum.org
[43] www.omniair.org

Working PKI infrastructure is important to the trust in and ultimately the success of V2X services.

## 2.7 E-NCAP roadmap and impact on deployment

NCAP is seen as an important instrument to motivate the introduction of new safety-oriented technologies into vehicles and make the benefits available to drivers, passengers and more and more other traffic participants like VRUs.

Euro-NCAP assess vehicles and their embedded technologies in the field of consumer safety. Until recently, this was centred around passive safety (crash testing), but more recently, developments in Advanced Driver Assistance Systems (ADAS) have been included in the overall rating given to vehicles, both passenger car and light commercial. With several new developments, including V2X making an appearance, the emphasis has included safe driving, as well as the other pillars of crash avoidance, crash protection and post crash safety.

In their future roadmap series, vehicle connectivity is included for future assessments in the area of Safe Driving, with the anticipation that vehicles fitted with V2X features will start to be formally assessed in 2027, after a trial period. This will be formalized with a revision to the 2025 roadmap already in the public domain[44].

UTAC, the designated EuroNCAP test laboratory for France, is a leading group in the field of development and validation testing, automotive homologation and new technologies related to the autonomous, connected and electric vehicle, provides vehicle testing and validation services and equipment to the automotive, transport, tyre, petrochemical and defence sectors.

The group is active in the fields of testing, approval and regulation, special vehicle design, conception and manufacture of test systems, training, consulting, audit and certification, technical control, standardisation and events. UTAC is the only official Euro NCAP test centre in France (accredited since 2001) and has a unique position in Europe thanks to its ISO 17025 accredited test laboratories.

The group has 8 test centres in France, the UK, Finland and Morocco, test laboratories in the USA and subsidiaries in Germany, Russia, China and Japan. UTAC currently employs around 1,280 people at its various sites.

UTAC is the French technical service for homologation of vehicles regarding EU regulations. UTAC also acts as a Technical Service for the United Kingdom Vehicle Certification Agency (VCA) and the Netherlands RDW. UTAC in the UK also act as an accredited test laboratory for the Taiwanese vehicle safety certification centre (VSCC) and the Japanese national traffic safety and environment laboratory (NTSEL).

UTAC have led and are currently leading multiple partner projects to signpost new technologies towards inclusion into forward test protocols. A leading example is the SECUIR project (Safety Enhancement through Connected Users on the Road), working in support of informing the EuroNCAP 2025 roadmap.

A further example is the OASIM project (Overall ASEAN market Safety Improvement for Motorcycles), in conjunction with ASEAN NCAP. This takes into consideration the

[44] https://cdn.euroncap.com/media/30700/euroncap-roadmap-2025-v4.pdf

unique territory aspects of powered 2 and 3 wheelers in the ASEAN territories, and works towards development of robust safety pillars for future challenging protocols.

Motorcycle test protocol development is also relevant to other territories. The MUSE project (Motorbike Users Safety Enhancement) completed in 2019 informed the development of scenarios, test equipment and protocols for consideration in future roadmaps.

 

# 3 Assessment of V2X service benefits

V2X services bring a few direct benefits such as improved road safety, improved road efficiency and these have several secondary benefits such as reduced congestion, pollution and associated economic benefits with less time lost drivers in traffic congestion.

There are significant benefits possible for the stakeholders who need to work together to deploy V2X and realise these benefits. For vehicle OEMs the improved safety of their products provide am attractive sales feature. For road operators safer roads means less disruption due to traffic incidents, reduced costs of deploying new driver services, reduced costs of maintaining damaged road infrastructure, better insights into road usage etc.

## 3.1 Impact on traffic safety and efficiency

Research predicts V2X will lead to a fall in the number of fatalities, serious and minor injuries.

With 94% of all crashes involve some form of human error or miss judgement the American Association of State Highway and Transportation Officials (AASHTO) view is that V2X is the only technology that has the capability to reduce that by as much as 80%[45].

Whilst V2X will benefit the safety of autonomous cars adding the ability to augment their line of sight sensors with V2X capability that can see around corners and over the horizon. The initial and potentially big safety impact will be by driver assistance.

V2X enabled vehicles builds a local situational map based upon information received either directly from other vehicles or vulnerable road users in their vicinity or from V2X infrastructure.

There two sources of information are complementary adding different aspects to the vehicles situational map.

The V2X infrastructure may obtain its situational picture from both analysis of V2X data received and from external sources such as existing road traffic systems, traffic management centres or other information systems. For example, by analysing V2X data it is possible to detect stopped vehicles either directly from a V2X enabled vehicle or indirectly from anomalous vehicle flows, this could combined with other information sources to enable the driver warnings.

The V2X infrastructure is able to warn drivers of upcoming roadworks or hazardous locations causing the driver to mitigate their speed and improvement in driver alertness to the upcoming hazard.

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[45] National Transport Safety Board - Preserving the Future of Connected Vehicle Technology (Episode 3)

Infrastructure to vehicle communication was tested in various counties by a C-Road project[46] showing an overall positive impact upon safety.

The vehicle to vehicle (V2V) information enables the vehicle to build up a detail situational awareness map of other vehicles and vulnerable road users (VRU) in their vicinity allowing the prediction of impending collisions and warning the driver. This is particularly useful when there are complex scenarios that are difficult for a driver to process fully or where a driver is unable to see all of the other vehicles or VRU's due to visibility obstructions. For example, this would include heavy breaking of a vehicle ahead which may be obscured by an intervening vehicle.

The safety improvement doesn't just benefit the vehicle equipped with V2X technology it can also benefit non V2X equipped road users. If a V2X equipped vehicle receives an earlier warning and responds by moderately mitigating its speed any vehicles following the V2X equipped vehicle would also be able to respond. In the Autotalks blog[47] makes the case that for rear end collisions a 10% V2X penetration can reduce the fatalities resulting from a collision of two vehicles by 13% and the injuries by 17.6%. Which could save 300 lives per year in the US from reduction in rear end collisions.

In other studies on the effect V2V penetration one study[48] concludes that even the lowest penetration rate (40%) of V2V resulted in a dramatic improvement in the level of road safety by preventing all types of accidents. Another study[49] concludes that with 50% of vehicles equipped with V2V reduced the collision rate by 20% to 30%.

Most of the V2X safety research has concentrated on vehicle-based safety, there has been little research done into the potential safety improvements for VRUs. V2X technology could potentially have a significant impact of the safety on the growing number of VRU in particular the growing use of micro mobility in towns and cities. This growth in VRU has resulted in an increase in the number of fatalities from these users with UK pedal cycle deaths increasing from 100 to 141 in the year 2020[50], with all other road user categories falling.

Bringing the VRU's into the digital road space is more challenging that with traditional vehicles. There are a number of methods being explored.

- Detection of VRUs by camera for example at pedestrian crossings.
- Smart phone application.
- Building V2X OBU's into electrically assisted micro mobility devices.

Euro NCAP has recognised the important role V2X can play in safety and their roadmap indicates that in the future V2X capability will be necessary for vehicles to gain their highest 5-star safety rating.

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[46] C-Roads Working Group 3 – Evaluation and Assessment Final Report Version 1.0 16th of December 2021
[47] The high value of V2X in early market penetration
[48] Analyzing the Effects of V2V and ADAS-ACC Penetration Rates on the Level of Road Safety in Intersections: Evaluating Simulation Platforms SUMO and Scene Suite
[49] Examining the impact on road safety of different penetration rates of vehicle-to-vehicle communication and adaptive cruise control
[50] Reported road casualties Great Britain, annual report: 2020

It seems reasonable to conclude that safety benefits of V2X will be seen by relatively low V2X penetration rates and with only a small number of supported V2X safety use cases. The safety benefits will incrementally increase as the V2X penetration rate increase and the number of supported use cases increase.

## 3.2 Impact on emissions and efficiency

The proposed amendment to the EU ITS directive[51] clearly outlines the main strategic objective to "make transport truly more sustainable". The transportation ecosystem is challenged by the society and is expected to substantially contribute to the ambitious emission reductions which the European Commission outlined in the Strategy on Sustainable and Smart Mobility[52]. A combination of measures will have to deliver a 90% reduction in the transport sector's emissions by 2050.

It is well understood that just the general move to e-vehicles will not be sufficient and needs to be complemented with other measures. The traffic efficiency concepts outlined below also contribute to the reduction of emissions.

V2X technology will enable improved efficiency in the use of the road network and a corresponding drop in emissions for ICE vehicles.

Efficiency improvements can be achieved directly from V2X services such as

- Signalised Intersections and its associated use cases such as GLOSA, green wave and prioritisation for public transport.
- Maneuver assistances and its associated use cases such as platooning or co-operative adaptative cruise control.

Significant efficiency will also be gained as a result of improved safety and the reduction in vehicle crashes and the associated disruption to traffic.

Efficiency of road use can also be gained by directing traffic to less congested routes, this can be achieved by using the infrastructure situational awareness built up by V2X.

Long term efficiency can also be gained by the ability to use the situational awareness gained by V2X Infrastructure to be able to complete detail road survey before any planned road improvement schemes.

5GAA asked[53] TNO to conduct a study on "Environmental Benefits of C-V2X"[54]. The paper provides insights into the emission reduction potential of C-V2X deployment including and beyond day 1 services. It considers use cases relying on communication between vehicles and also vehicles and infrastructure.

The paper includes a comprehensive analysis of related literature and shows a summary of the impact of various applications on the reduction of emissions as shown in the following Figure 3-1:

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[51] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=COM:2021:813:FIN
[52] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0789
[53] https://5gaa.org/news/environmental-benefits-of-c-v2x/
[54] https://5gaa.org/wp-content/uploads/2020/11/Environmental-Benefits-of-C-V2X.pdf

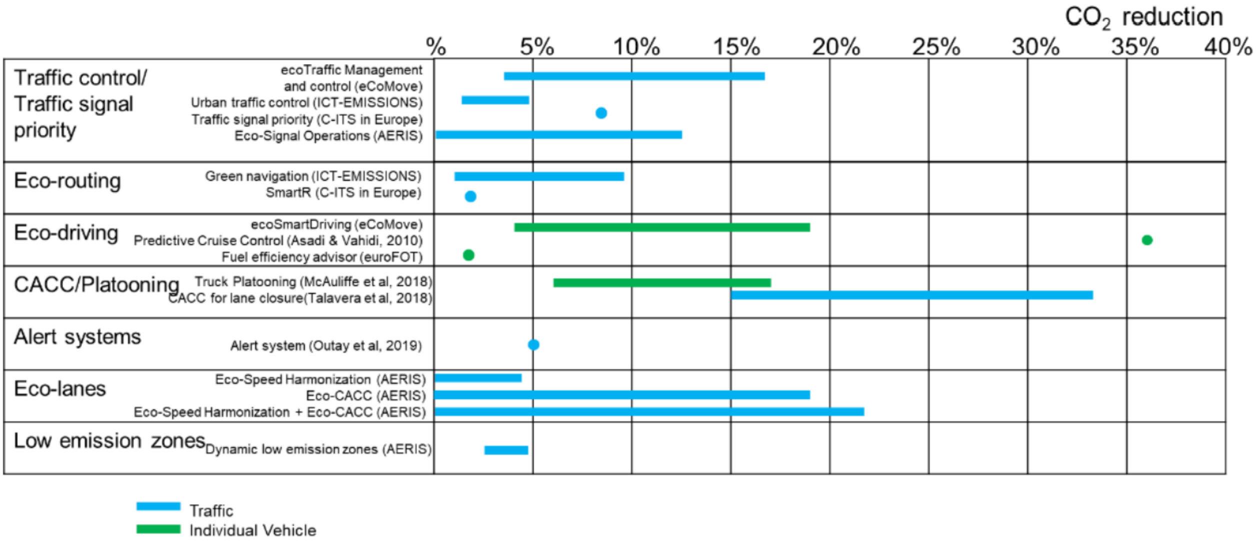


Figure 3-1: Impact of different applications on $CO_2$ reductions (source: TNO study[54])

The 5GAA white paper provides a long list of promising use cases and also includes a detailed analysis and modelling of a few use cases using different types of data sources for the impact assessment like pilot data, real-world data, data from microsimulations and synthetic data. The following 3 modelled use cases are particularly interesting:

- CACC (Cooperative Adaptive Cruise Control)
- Eco-driving on motorways (including avoiding congestion)
- Intelligent intersections

Using measured data from a real-world pilot on a rural road with controlled intersections showed that the move from ACC (Adaptive Cruise Control) to CACC reduces the vehicle dynamics and, consequently, the emissions about 6%.

Similarly, due to less vehicle dynamics, eco-driving systems that smoothen the driving pattern generate a potential $CO_2$ reduction from 3% - 7%, with the highest reduction for roads with speed limits between 50-80 km/h.

Intelligent intersections with interactions between infrastructure/traffic management and the vehicles have a much higher emission reduction potential by reducing the need to stop. Naturally, the impact on CO2 reduction from avoiding stops at intersections depends on the approaching speed, on the vehicle type and on the number of intersections. The white paper shows that in a large real-world pilot with trucks a reduction of 22% was measured on provincial intersections with a length of 2 km whereas the simulated potential for avoiding stops (1 stop per kilometre) for the average passenger car ranges from 13% - 21%.

Summarising, with C-V2X services supporting cooperative driving and interaction with road infrastructure and traffic management becoming available on a much larger scale to potential for emission reduction will grow substantially. As outlined earlier, these complex interactions will also drive the need for more advanced testing methodologies.

# 4 UK test capabilities

## 4.1 Why test in a controlled environment?

Production vehicles are already equipped with driver assistance technology, enabling them to keep in lane, keep a safe distance from the vehicle in front, monitor blind spots and more. At the same time, more and more vehicles are now equipped with communication devices that not only enhance the car occupants' experience by providing internet connectivity but also have the potential to become another source of vital information to the driver by providing warning signals as the vehicle approaches an area where a hazardous incident has taken place.

Connectivity and Autonomy are already here but as the systems become more mature, it is natural that the two will converge in the future, paving the way for self-driving cars. These vehicles will utilise the information from local sensors to understand their surroundings, and also communicate with road infrastructure and other cars around them to expand their field of view and even anticipate their movements.

As a result, the human driver is not going to be part of the control loop anymore whereas the vehicle itself will not be a separate entity, but it will be part of a wider ecosystem along with other vehicles, traffic infrastructure and other road users. As the scope and complexity of the systems under test increases, new challenges emerge that the automotive industry has never faced before: The effects of system integration should not only be studied in vehicle level, but also in a system-of-systems level, testing the interactions with other vehicles, road infrastructure and external services.

### 4.1.1 CAV verification and Validation – Multi pillar approach

Compared to conventional vehicles, the introduction of CAVs introduces strict safety requirements and diverse operating scenarios, therefore the limited number of bench and proving ground tests will not be sufficient to fully assess the safety and robustness of CAVs. In addition, validating these capabilities is a very complex task which cannot be completed by utilising one validation methodology alone. As a result, the industry is moving towards an updated Verification and Validation (V&V) model for CAVs which will extend and augment the current V&V procedures[55], which utilises a combination of different validation methodologies (pillars) to collect evidence. A number of variations of the model do exist, based on the perspective of different stakeholders, but the main validation methodologies used in all variations are as follows:

**Simulation / Virtual testing**

Virtual testing is used to assess the performance of a CAV under conditions that are prohibitive for conventional physical testing. It is enabled by using simulation toolchains to reproduce the driving environment and the objects operating in it, that interact with the driving system.

[55] https://unece.org/sites/default/files/2021-04/ECE-TRANS-WP29-2021-61e.pdf

This method is utilised to provide the main body of evidence for the validation strategy as it can be the most efficient and cost-effective way of collecting data while covering a wide scenario and parameter space. In addition, as every parameter of the simulation is captured, it allows for execution of the same virtual test without deviations.

At the same time though, this method cannot be used exclusively as it is almost impossible for computer models to reproduce the physical environment and the vehicles' behaviour. Therefore, this method needs to work alongside physical testing to prove the validity of the models used. This is achieved by executing a sufficient number of simulated scenarios in a controlled environment and correlating the physical and simulated results.

**Real world testing**

Real world testing uses public roads to test the capabilities of a system in real world traffic. It exposes the CAV to a large variety of real-world conditions and can be used to assess the capability of the CAV handling all the aspects of everyday driving (maintaining flow of traffic, interactions with human drivers and other road users etc.) as well as the performance at some ODD boundaries. Finally, real world testing can reveal issues that might not have been captured in simulation and controlled environment testing.

Real world testing is considered a "Driving license test" for CAVs. It provides an opportunity to test features that are not available in a controlled environment, such as bridges, tunnels, railway tracks etc. It can be used to further correlate test results from the simulation and testbed validation activities and it also provides an overall impression of the system behaviour.

On the other hand, real world testing cannot stand as an isolated validation activity. There is no control over the parameters of a drive cycle and therefore the results of the activity cannot be sufficiently replicated or repeated. In addition, the safety risks for the safety driver and the other road users could be significant as the evidence for the system's performance will be limited. Finally, any failure of the system in public will most certainly have a huge effect in the system designer's credibility.

**Controlled environment testing**

Controlled environment testing takes place in testbeds, closed access testing facilities that are purpose-built to support the validation activity by providing real environments and obstacles to create a limited set of realistic scenarios.

This method is essential to the multi-pillar approach as it bridges the gap between virtual and real-world testing. It allows for a physical vehicle to be tested in a safe environment, where exists a strict risk assessment process for all activities. In addition, the facilities are designed with runoff areas and prevent unnecessary interactions between vehicles. Finally, the equipment used during testing is safe for vehicle impact, further protecting the prototype vehicle in case of a failed test.

Furthermore, all the relevant test elements can be controlled, repeated, and even replicated in different locations by different entities. This allows for multiple iterations of tests to be run in the same way, with the same initial condition and inputs.

 

Finally, compared to real world testing, testing in a controlled environment can be more efficient by accelerating exposure to known rare events and safety-critical scenarios and also ensure the results of the validation activity remain private to the entity running the test.

Control environment testing on the other hand provides limited variability of features as the testbeds are restricted to their geometries, dimensions. In addition, certain aspects of the ODD cannot be controlled (weather, ambient illumination, road temperature etc.). Finally, setting up and executing a test activity can take a significant amount of time, utilizing a substantial number of test engineers and specialized test equipment, which has an effect on total cost and therefore on the number of tests that can be realistically order per validation program.

### 4.1.2 Connectivity Use cases

Focusing on V2X communications, two high level use cases are identified for customers using controlled environments to complement public road testing:

**Verification activities**

This use case includes all the activities needed to collect evidence for the system validation. In addition, supporting activities like pre-testing interoperability, performance characterisation and general pre-trial shakedown are also expected to take place in a controlled environment prior to public road testing.

**Issue investigation and resolution**

This use case is exercised when the system underperforms during public road trials. The customer has the ability to recreate the failure modes and the behaviours observed during the trials and initiate an investigation activity to resolve identified issues before returning to public roads for further testing.

More specifically, the following applications have been identified:

- Real time data analysis from test vehicles
- Cyber Security testing
- Software Development
- Hardware Development
- Smart Infrastructure Development and testing
- Connected vehicle testing
- Autonomous vehicle testing
- Mobile Network Operator testing
- High speed data transfer testing
- Internet into high-speed train testing
- Platooning
- Developers of smart city infrastructure
- Connected Events and demonstrations

### 4.1.3 Testbed Requirements

To exercise the use cases identified in Section 4.1.2, testbeds need to meet the following requirements:

- **<u>A testbed should be equipped with infrastructure representative of the public road network</u>**

A testbed needs to be able to replicate the public road environment. As a result, the communication infrastructure found in public roads should also be available in a controlled environment and configured in a way that the vehicle under test can seamlessly drive from the testbed to the public road network. In addition, the road infrastructure should be diverse, able to represent all driving environments (urban, inter-urban, rural etc.)

- **<u>A testbed should be reconfigurable</u>**

A testbed is designed to offer prescribed test scenarios, should therefore be modular and capable to accommodate different levels of scenarios, from simple proof of concept setups to more challenging scenarios. In addition, a controlled environment should be capable of recreating failure modes and behaviours observed during trials.

- **A testbed should provide test measuring capabilities**

In a testbed all the parameters relevant to the test should be logged. Test measuring not only allows the replication of interesting test cases, but it also enables post processing of data.

## 4.2 CAM Testbed UK – Physical facilities

The UK is a global centre for the innovation and development of connected and self-driving vehicle technologies. It is the only place worldwide with the capability to take ideas from concept to development both virtually and physically, all within a 3-hour drive.

UK regulation allows self-driving vehicle testing on any UK road, and CAM Testbed UK[56] testing facilities work collaboratively to provide a uniquely comprehensive offering. This collaboration, led by Zenzic, is building a complementary, world-leading ecosystem from the heart of the UK.

The physical facilities comprising CAM testbed UK are presented in the following sections.

### 4.2.1 UTAC Millbrook Private Hyper Dense Small Cell Network

**Overview**

UTAC Millbrook has a private hyper dense small cell network supported by Dense Air that can provide cellular connectivity across the site.

The network consists of 4G and 5G Cores, 4G and 5G Stand Alone RAN, mmWave 70GHz, high speed internet connectivity, pervasive coverage around 70km of test tracks and deep indoor coverage into the majority of buildings.

This allows customers to stream live data from a vehicle to an engineer or test a huge range of solutions and applications, as an initial controlled test environment or as a final location for application testing.

Each mast has a cabinet which has power and spare ports on the switches to access the network if required.

UTAC Millbrook has a range of Mi-Wi routers SIM cards and handsets to connect to the network.

[56] https://zenzic.io/testbed-uk/

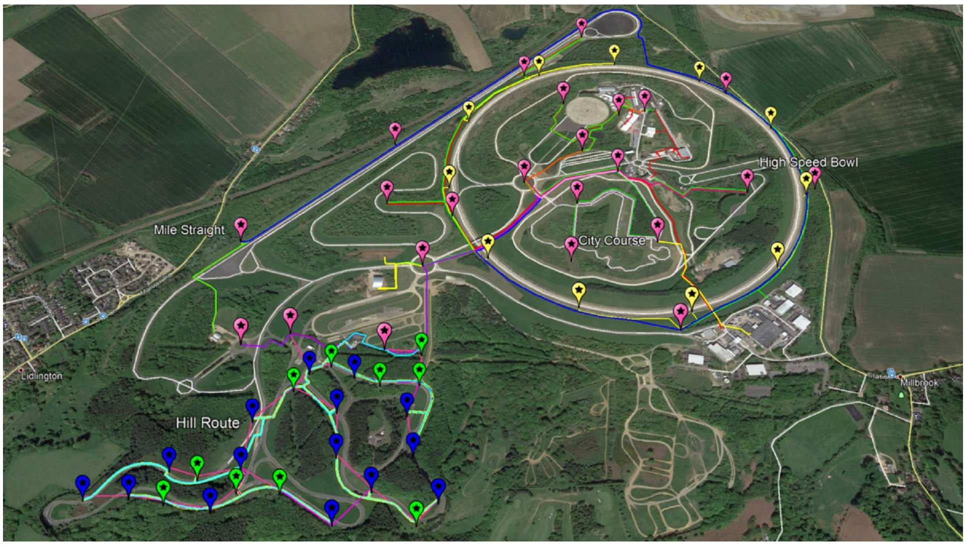


Figure 4-1: UTAC Millbrook test track

**V2X High Speed Bowl 70GHz mmWave**

The High Speed Bowl has 11 short masts evenly spaced around its 2 mile diameter, each mast has two 70GHz mmWave units aligned toward and away from the direction of traffic flow.

10Gbps fibre backhaul over the newly installed fibre network to the McLaren ATLAS server located in server room in the Autonomous Village building.

Data transfer rates in excess of 2Gbps.

**V2X DSRC 802.11p Wi-Fi**

All paved tracks both flat and hilly areas are covered by 40 Cohda MK5 Dedicated Short Range Communication (DSRC) roadside units.

The units are an 802.11p-based wireless communication technology that enables highly secure, high-speed direct communication between vehicles and the surrounding infrastructure, without involving any cellular infrastructure.

This allows small packets of data to be sent to a vehicle with an on-board unit to warn the driver of dangerous situations (road obstacles and potential collisions with other road users) even before they are in line of sight.

Magnetic mount On-board units are available if required.

**CCTV**

32 tilt pan zoom 2MP cameras have been installed to cover most of the paved tracks, they are used by Track Control for customer safety and for customers who want to watch a test from a remote location, an example of this could be witnessing a drive by noise test where the test data and CCTV footage could be shared with the customer over a secure connection.

### 4.2.2 ASSURED CAV - HORIBA-MIRA

ASSURED CAV[57] is a world-leading connected and automated vehicle test ecosystem. Extending over an 850 acre / 350-hectare site at the HORIBA MIRA campus, ASSURED CAV provides the latest facilities to support mobility companies in the design, development and testing of self-driving technology.

It consists of:

**ASSURED CAV Highway**

A completely level facility with a 300m diameter dynamic platform, allowing vehicles to be tested at the limit of controllability. Fully configurable lane and junction markings permit customisable scenario-based testing of merging, lane assist, and evasive manoeuvres to be conducted to international regulatory protocols. It enables high-speed vehicle interactions, Motorway scenarios and on-demand urban/suburban road layout design.

**ASSURED CAV City**

A fully controllable and configurable, connected urban and sub-urban driving environment. A mix of urban junction types and street furniture frequently experienced in cities, enables validation of complex automated driving systems and traffic scenarios under safe and repeatable test conditions. The facility is also equipped with two signalised intersections. The South (Master) junction is the main signal-controlled intersection and comprises of 4 different approaches to the intersection, 7 different traffic light types, pedestrian traffic lights, multiple repeater light configurations, and 5-phase traffic signal cycle with a mixture of protected and permitted vehicle movements. The North junction is not representative of a standard UK signalised intersection but can be used to create more complex use cases where vehicles must distinguish visually, and from V2X data, between two intersections in close proximity.

**ASSURED CAV Parking**

A dedicated multi-storey car park located within ASSURED CITY, replicating real-world situations to support the development of self-parking solutions. Restricted visibility, constricted manoeuvres, and GPS drop-out in covered locations can be tested in a fully configurable and safe, controlled environment. It enables indoor and outdoor automated parking scenarios.

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57 https://www.horiba-mira.com/assured-cav/

Figure 4-2: ASSURED CAV facilities in HORIBA-MIRA Proving Ground

All physical facilities are fully equipped with the latest V2x technologies:

**Cellular**

HORIBA MIRA have partnered with Vodafone and have jointly deployed one of the UK's first private 5G networks, using Nokia equipment along with Vodafone 4G/5G spectrum.

The LTE network is an 4G/ 5G NSA private mobile network operating on LTE band n38 (2600 TDD) and 5G band n78 (3400 TDD). The allocated bandwidth in each band is 20 MHz and 50 MHz respectively. Coverage is achieved by using a combination of micro, mini-macro, and macro access point kits and a georedundant server setup from Nokia. The network is supported by 10Gbps of single mode fibre backhaul.

In addition, a number of Cohda MK6c OBUs is available to test the LTE-based C-V2x PC5 sidelink interface.

**DSRC**

A combination of Cohda MK5 RSUs and OBUs, fully compatible with the latest ETSI standards, are used to broadcast ITS messages to equipped vehicles and/or log broadcasted messages to provide ground truth during testing. In addition, the intersections in ASSURED CAV City are V2x (ITS-G5) enabled, each with its own dedicated RSU, capable of broadcasting SPATEM & MAPEM messages.

### 4.2.3 Midlands Future Mobility

Midlands Future Mobility (MFM)[58] is installing infrastructure on 200+ miles of West Midland's roads to enable trials of Connected and Automated Mobility (CAM) solutions. This includes CCTV, weather stations, communications units, and highly accurate GPS coverage. The technology developed on the route will make UK roads safer and allow for more predictable goods delivery and journey times.


Figure 4-3: The Midlands Future Mobility (MFM) route

The testbed user is able to:

- Utilise remotely configurable RSUs along the route, supporting various C-ITS services (for example in-vehicle signage, roadworks warnings and Green Light Optimized Speed Advisory (GLOSA)) via DSRC (ITS-G5). DSRC communications are supported by PKI security management and authentication
- User configurable C-ITS services via LTE communications technologies (3G/4G/5G)
- Record and review the trial alongside a trace of the route used via the MFM Data Hub, which collates data from geo-fenced Closed-Circuit TV (anonymized), Real-Time Kinematic GPS (correction signal broadcast over route), programmable roadside units and environmental monitoring stations. Additional services, such as data analytics, can provide further insight on test performance and network state during trials using reliable, secure and resilient data and video management tools
- Develop and test own infrastructure using MFM's plug-and-play environment and mobile CCTV and RSUs

[58] https://midlandsfuturemobility.co.uk/

- Utilise the MFM Playbook Transport Data Services for advice on traffic data available across the region, local data sets for testbed routes, precise environmental data and APIs, as well as downloads of traffic and travel data
- Utilize the University of Warwick campus (including designated shared space routes for low-speed autonomous vehicles) and MFM's development pod platforms as a mini city for logistics and CAM service development
- Access the MFM Participant Database to test public acceptance of new MaaS (Mobility as a Service) business models, vehicle ownership models or new CAM features
- Develop and plan CAM tests using the MFM Data Hub to identify locations on the route with specific static or dynamic features (e.g., road layouts; traffic flows) to ensure precise test conditions.

In addition, the testbed offers 5G Research Services and can provide support in solution development for 5G and beyond communication networks. Some Illustrative cases include:

- 5G FR1 (Frequency Range 1 – sub 6 GHz) link performance, including Error Vector Magnitude (EVM) analysis and Power Delay Profile (PDP) analysis up to bandwidth of 240 MHz
- 5G FR2 (Frequency Range 2 – mmWave) link performance, including EVM and achieved throughput analysis / PDP analysis up to a bandwidth of 2 GHz
- 5G Core, including resilience tests against core functions failure (Session Management Function – SMF, Access & Mobility Management Function – AMF, User Plane Function - UPF), end-to-end latency evaluation, evaluation of custom SIM card authentication, data governance compliance, network traffic load dependent performance test
- 5G Network Slicing evaluation, which includes Quality of Service (QoS) against Service Level Agreement (SLA)
- Complete 5G End-to-End evaluation (User to Core to Cloud/MEC) in controlled and real-world contexts
- 4G/5G/IEEE 802.3 Interoperability Testing

#### 4.2.4 SMLL CAM testbed

Smart Mobility Living Lab London (SMLL)[59] is one of the key public environment testbeds withing the CAM Testbed UK community. Based in Greenwich and the Queen Elizbeth Olympic Park it has extensive monitored infrastructure across the test environment.

The SMLL Testbed infrastructure features 196 fixed monitoring and roadside communication sites across 24km of real-world public roads in London. This network is split across the Royal Borough of Greenwich, and Queen Elizabeth Olympic Park, enabling our customers to test their solutions, trial services and undertake research in a wide range of road environments. Supported by a 10gbps private fibre network the infrastructure provides feeds into our dedicated-on premises data centres at both the Woolwich HQ and the Plexal office on the QEOP. These feeds are available

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[59] https://static1.squarespace.com/static/5e440b36f686ae560a571ed4/t/5fe0e4a20397b117f6ae42f0/1608574116687/SMLL+Datasheet+Roadside+Infrastructure.pdf

to clients to support testing, validation activities and any other video analytics they may want to perform when testing their technologies. The network has the capability to integrate client provided infrastructure at the roadside and the data centre to support their development.


Figure 4-4: Smart Mobility Living Lab London (SMLL)

**Roadside Monitoring Equipment**

SMLL is equipped with 35 permanently installed V2X ITS-G5 roadside units but also offers flexibly deployed monitoring infrastructure (10 pop-up monitoring sites). In total 36 connected traffic lights are located within SMLL testbed. In terms of test monitoring, SMLL is also equipped with 276 CCTV cameras which are infra-red enabled to support both day and night testing. Internet connectivity is provided using 196 Wireless Access Points.

The testbed also offers environmental monitoring as well as the ability to incorporate additional equipment onto the infrastructure.

**Connectivity**

In terms of connectivity, the following technologies are enabled in SMLL:

- WLAN (ETSI G5, IEEE 802.11p, 802.11ac), supported by 10gbps private fiber backhaul
- LoRaWAN
- LTE (4G backhaul / 5G-ready)
- Support for IoT devices

### 4.2.5 CAVWAY

CAVWAY[60] is a test site for the automotive and mobility industries part-funded by the UK government to aid the development and testing of Connected & Autonomous Vehicles (CAVs). It will soon start to be built near Oxford in the UK. What makes CAVWAY special is that it will include a comprehensive set of highway junctions, all within a fully connected, controlled, repeatable and safe environment to perform all required development and validation testing programs for ADAS and CAV development, and according to the latest Euro NCAP and regulation requirements.

Figure 4-5: Draft version of CAVWAY testing facility

A wide variety of testing possibilities for development and validation projects will be possible thanks to fully configurable V2X, C-V2X, 4G / 5G network coverage. At CAVWAY proving ground, it will be possible to control everything the vehicle "hears" and "sees" in a coordinated way to set up all kinds of tricky edge-case traffic scenarios, facilitating seamless integration between experimental and virtual development work. Additionally, CAVWAY will also offer vehicle simulation and cyber security testing in normal and abnormal conditions, as well as connectivity testing and benchmarking, among other services.

## 4.3 Public road trials

### 4.3.1 A2/M2 trial – 2017

In support of the Government's commitment to research, development and demonstration of CAVs, in 2017 a UK partnership between the DfT, Highways

[60] https://www.cavway.co.uk/

England, TfL and Kent CC embarked upon the A2M2 Connected Corridor project[61] [62] to deliver an urban and interurban 'connected' road corridor.

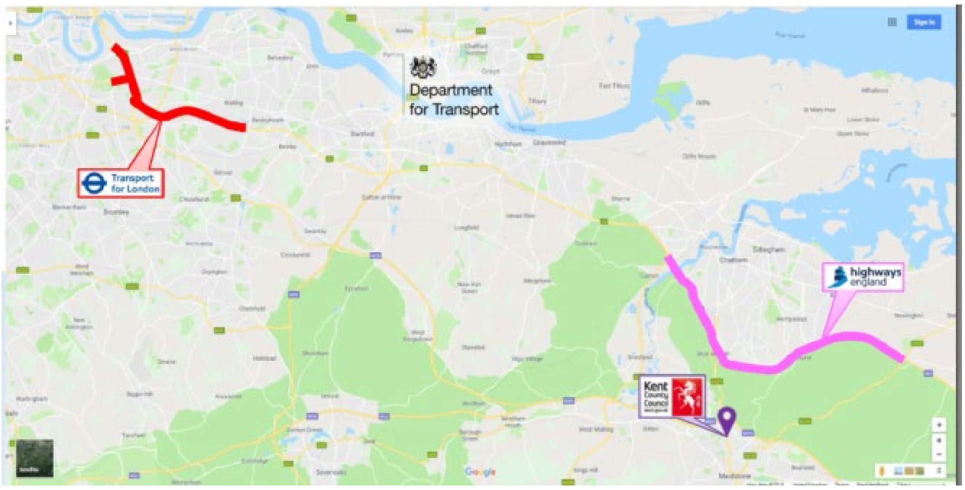


Figure 4-6: A2/M2 trial – 2017

The development of a shared Cooperative Intelligent Transport Systems (C-ITS) platform, allowed the testing of connected vehicle services during a series of test events on live roads in London, Kent and Europe.

Hybrid communications (cellular and ITS-G5 'wifi') were tested and four services demonstrated with real users, using existing traffic data:

- In-Vehicle Signage (IVS) – reproducing roadside Variable Message Sign (VMS) messages on in-vehicle displays
- Road Works Warning (RWW) – providing accurate location-based hazard warning messages about road works
- Probe Vehicle Data (PVD) – testing the ability to securely receive data from vehicles
- Green Light Optimised Speed Advice (GLOSA) – provides speed advice and countdown timer on approach to traffic lights

As part of the wider European InterCor project, the UK deployed the system in line with shared specifications and was able to demonstrate interoperability with corridors in Belgium, France and the Netherlands.

The A2M2 Connected Corridor project successfully demonstrated real time connected vehicle services on live urban and interurban roads.

Using existing live traffic data sources the project provided drivers with in-vehicle services that the users liked and indicated they would use in the future.

It demonstrated that:

[61] https://www.gov.uk/government/news/signs-of-the-future-new-technology-testbed-on-the-a2-and-m2-in-kent
[62] https://publications.ergonomics.org.uk/uploads/A2-M2-Connected-Corridor-Connected-Autonomous-Vehicle-Testbed.pdf

- C-ITS technology works and that through the implementation of common specifications interoperability of services can be achieved across regional and international borders.
- Cellular communication performs well in a ‘hybrid’ environment (ITS- G5 and cellular communications).
- All services deployed on the project were effective, but require improvement before wide scale rollout, with the IVS most ready.
- GLOSA could provide real world benefits but is challenging to implement when used in conjunction with existing highly optimised and adaptive traffic signals.
- The in-vehicle information display (HMI) has a significant impact on the user acceptance of services, it also has the potential to cause distraction. The safety planning and collaboration through the HMI design and pilot operations during this project provides for best practice that can be taken into future trials.
- Impact assessments and wider benefits analysis were difficult due to the scale and duration of the project; larger fleets and naked roads would allow for a clearer result.  Data logging (common or not) is key to obtaining good results and can take significant effort to implement.
- The architecture of the shared C-ITS platform, performance of cellular communications and advances in service development (IVS in particular) mean that a wide scale roll out of connected vehicle services in the short term is attainable.

#### 4.3.2 Compass4D

The Compass4D[63] program run between 2013-2015 and was funded by the European Union’s Competitiveness and Innovation (CIP) Framework Programme . It focused on three services which would increase drivers’ safety and comfort by reducing the number and severity of road accidents as well as avoiding queues and traffic jams. Compass4D also had a positive impact on the local environment by reducing vehicles’ CO2 emissions and fuel consumption. It had the following objectives:

- Specification of a methodology for the evaluation of the Compass4D services: road hazard warning systems, red light violation warning and energy efficiency intersection service.
- Development of measurement and assessment tools for safety, efficiency, sustainability, maintenance, traffic management, and driver-specific metrics;
- Evaluation of services’ contribution to improved journey time reliability, reduced accident rates, improved energy efficiency, support for reductions in carbon emissions, and user acceptance/experience.

The project piloted 3 C-ITS systems in seven cities across Europe. The cities were Bordeaux (France), Copenhagen (Denmark), Helmond (The Netherlands), Newcastle (UK), Thessaloniki (Greece), Verona (Italy), Vigo (Spain). The 3 systems that were tested were:

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[63] https://trimis.ec.europa.eu/project/compass4d

- The Red Light Violation Warning (RLVW) service, which sends messages that will increase drivers' alertness at signalised intersections in order to reduce the number of collisions or the severity of collisions should they still happen. This service also addresses exceptional situations such as alerting other vehicles that an emergency vehicle is approaching or violating a red light.
- The Road Hazard Warning (RHW) service, which reduces the number and the severity of road collisions by sending warning messages to drivers approaching a hazard (obstacles, road accident, etc). The messages sent will raise drivers' attention level and inform them about appropriate behaviour in specific situations such as queues after a blind spot.
- The Energy Efficient Intersection (EEI) service, which reduces energy consumption and vehicle emissions at signalized intersections. Selected vehicles (Heavy Goods Vehicles, Emergency Vehicles, Public Transport) were granted a green light when approaching the intersection, thus avoiding stops and delays. This service also provides information to other drivers to anticipate current and upcoming traffic light phases and adapt their speed accordingly (GLOSA).

# 5 Transport Data services and portals

The collection, processing, correlation and exchange of data become an essential element of the mobility ecosystem to enable new cooperation relationships and business models. The European Urban Data Platform initiative[64] wants to accelerate the adoption of common open urban data platforms. Many C-ITS use cases can rely on data and interfaces provided by urban data platforms which typically include safety related data. The following section focuses on national platforms and National Access Points (NAP), in particular.

## 5.1 UK National Access Point (UK NAP)

The EU ITS directive 2010/40/EU[65] outlined the need to provide road, traffic and travel data and information services and to link the vehicles with the transport infrastructure. Implementing the ITS directive many member states have established NAPs[66], a digital interface that constitutes a single point of access to data. The NAPs organise the access to and reuse of transport related data to help support the provision of EU-wide interoperable travel and traffic ITS services to end users. In line with the Commission Delegated Regulations the following data categories are in focus:

- safe and secure truck parking areas (SSTPA) – see No 885/2013[67]
- road safety-related traffic information (SRTI) – see No 886/2013[68]
- real-time traffic information (RTTI) – see No 2015/962[69]
- Multimodal Travel Information services (MMTIS) – see No 2017/1926[70]

In 2018 the UK Department for Transport (DfT) decided to extend the European regulatory framework which covers the TEN-T strategic road network only to consider the potential for cataloguing all data relating to infrastructure, attributes and operations for all roads in England[71].

A feasibility study demonstrated a clear user-need for a UK NAP.

In Q1 2019/20 DfT decided to proceed with the detailed design of a data catalogue, for all roads and all roads-based data, and which will far exceed the requirements of the EU ITS delegated acts for the TEN-T road-based NAP.

**Devolved Administrations**

In parallel with the above work, we have established a STREETWISE sub-group to coordinate the UK national road authorities for meeting the EU ITS Directive delegated act requirements and coordinate the NAP developments. The group is

[64] https://smart-cities-marketplace.ec.europa.eu/action-clusters-and-initiatives/action-clusters/integrated-infrastructures-and-processes/urban-data#documents
[65] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32010L0040
[66] https://transport.ec.europa.eu/transport-themes/intelligent-transport-systems/road/action-plan-and-directive/national-access-points_en
[67] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32013R0885
[68] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32013R0886
[69] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32015R0962
[70] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32017R1926
[71] https://transport.ec.europa.eu/system/files/2020-02/2019-its-national-report-uk.pdf

mapping what road data services the devolved administrations collect and publish and this will be developed to show UK compliance with the with the EU ITS Directive delegated regulations and the NAP. The Group will also become the focus for coordinating the UK national roads deployment of C-ITS and the requirements for the C-ITS Delegated Regulation, recently adopted by the European Commission.

**Multi-modal travel information**

The English roads-based data catalogue is potentially the first stage development towards a national transport data catalogue. The design specification will ensure that the design specification meets the capability for the EU ITS Directive including the multi-modal travel information delegated act. In doing so, the specification will give consideration to related workstreams currently being undertaken by the DfT.

In 2020, the UK had:

- Made operational the NAP for Safety-related Traffic Information:
- Made operational the NAP for Real Time Traffic Information (RTTI), with all static road data, dynamic road status data and traffic data.

## 5.2 European National Access Points (NAP) activities

Since the publication of the EU ITS directive[65] in 2010 most member states have implemented National Access Points (NAPs) as listed[66] and also shown on Figure 5-1.


Figure 5-1: Overview about National Access Points (NAP) in Europe[72] - see also note[73]

The proposed amendment to the EU ITS directive[74] expresses the need for a stronger coordination mechanism for NAPs. It stipulates that member states shall ensure the availability and accessibility of a comprehensive list of data types latest until 2025 – 2028 (depending on data type).

This list of data [75] includes, for example:

- Static and dynamic traffic regulations like access conditions for tunnels & bridges, speed limits, permanent access restrictions, …
- Data on the state of the network road & lane closures, roadworks, …
- Data on safe and secure parking places for trucks and commercial vehicles
- Data on detected road safety-related events or conditions like temporary slippery road, obstacles on the road, unprotected accident area, reduced visibility, wrong-way driver, exceptional weather conditions, …

Data can be generated by vehicles (e.g. slippery road warning[76]) and transferred via long or short range communications or they are generated by the traffic

[72] https://andnet.ro/nap_eueip/naps.php
[73] Green: Countries that have all topic related NAPs in operation; yellow: countries that have at least one NAP; red: countries that don't have any NAP
[74] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=COM:2021:813:FIN
[75] Annex III of https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=COM:2021:813:FIN
[76] https://www.volkswagenag.com/en/news/2021/03/precise-data-for-greater-safety--audi-warns-its-drivers-about-sl.html

management centre (e.g. speed limits, lane closures) or derived from sensor data of the road infrastructure (e.g. exceptional weather conditions). Some of those use cases can also be tested on test tracks to verify the end-2-end chain.

NAPs also play an important role in the Data for Road Safety[77] ecosystem as described in the overview[78] and technical documentation[79].

Given the need for stronger coordination between NAPs, a National Access Point Coordination Organisation for Europe (NAPCORE)[80] has been founded. It is expected to coordinate and harmonise more than 30 mobility data platforms in European countries. Currently, NAPs are quite different in their setup and data access interfaces with respect to formats and standards. The organization of 36 partners (including 3 associated partners) received €14 million funding until end of 2024 and is targeted to improve interoperability of the NAPs as a backbone of European mobility data exchange and to establish a long-lasting and future-oriented platform organization across Europe.

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[77] https://www.dataforroadsafety.eu/
[78] https://www.dataforroadsafety.eu/images/Documenten/Data_for_Road_Safety_overview_-_guiding_slides.pdf
[79] https://www.dataforroadsafety.eu/images/Documenten/Annex_1_-_Data_For_Road_Safety__Technical_Documentation_Version_1.01.pdf
[80] https://www.uitp.org/projects/napcore/

# 6 Conclusions

This report examines the current UK V2X test fields, capabilities and activities, government and industry roadmaps. It also describes the market needs, opportunities and roles V2X plays for increasing traffic safety, efficiency and paving the way to wider deployment of automated driving which, ultimately, is expected to contribute to protecting the environment and achieving the emission reduction targets as one of the global challenges society faces.

It is shown that evolving connected mobility involves a complex ecosystem of different public and private market players from domains like automotive, telecommunications, road operators and various service providers. Acting in a global automotive and transport market, this ecosystem needs to address several challenges, for example:

- Evolve the relevant technologies (e.g. communications, sensors, …), message formats and exchange protocols in order to enable new advanced use cases
- Design and implement new test and certification approaches including for safety relevant functionalities to address the interworking of various solution components and to address the increasing frequency of software changes in vehicles and other elements of the e2e solution
- Digitalise road infrastructure and important elements of vehicles and other traffic participants, i.e. create digital twins
- Create means to provide, aggregate and exchange data to fair conditions in line with regulation
- Identify and verify new business and cooperation models which enable a sustainable long-term deployment of the ecosystem

Given the important role of testing and certification, optimal CAM Testbed UK V2X test and validation services need to be defined with a particular focus on:

- Developing a scalable V2X architecture template which can interface with multiple V2X standards, stakeholders and test activities and on and off-roads
- Implementing this architecture into a comprehensive CAM Testbed UK ready for commercial operation for various customers
- The commercial operation should include not only technology testing but also conformance assessment testing and certification
- Enabling interoperability testing across the ecosystem – involving new technologies like precise positioning or road-side sensors and involving different OEMs, bikes, pedestrians as well as various types of road infrastructure and related data environments.

This will provide a UK-based platform for all stakeholders to test V2X methodologies safely and in private. It will also encourage investment into the ecosystem and make the UK the place to come for V2X development.

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