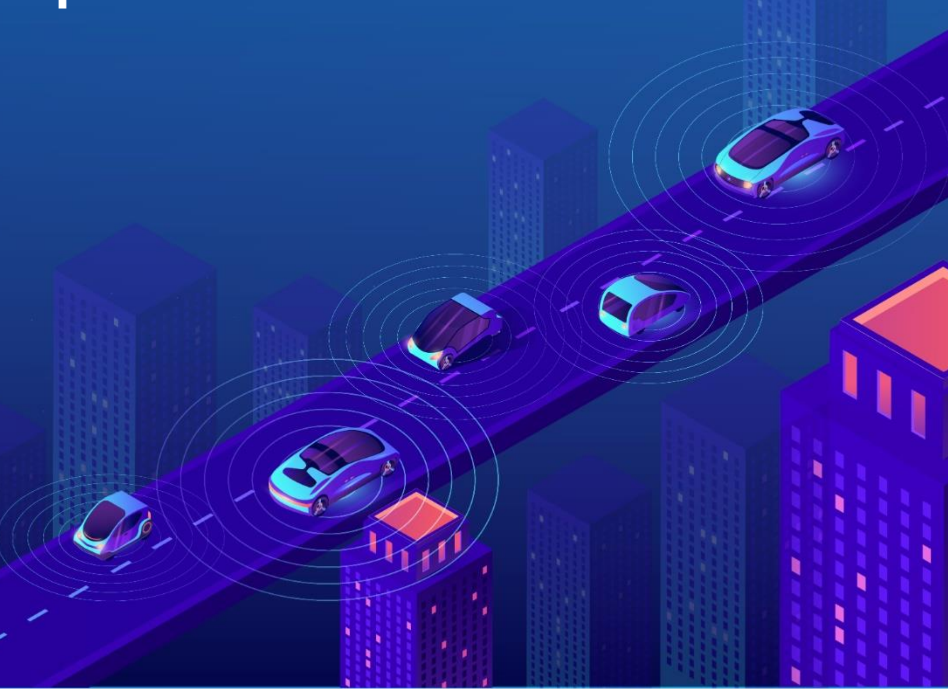
5GAA Automotive Association

Conclusions and Recommendations for Communications Service Providers Supporting Road Operator Priorities and Expectations



5GAA Automotive Association
Technical Report

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Introduction

The Bridge cross-Working Group work item (XWI) was established under the 5GAA 'Digital Roads' priority area. The concept of digital roads includes many elements, but Bridge addresses the business priorities of the Road Operators (RO) and how Co-operative Intelligent Transport Systems (C-ITS) and Vehicle to Everything (V2X) services, provided by Communications Service Providers (CSP), can support them directly. The primary objective of Bridge is to identify the levels of active co-operation required between Road Operators and CSPs, to highlight the need for co-operation, if any, and to encourage partnerships to accelerate the deployment of C-V2X.

Bridge's approach was to focus on C-ITS/V2X services that connect road users with Road Operators' infrastructure and information systems, since these use cases require collaboration between Road Operators and third parties, primarily CSPs, to deliver. In this context, CSPs comprise operators of mobile networks and/or road side unit (RSU)-based communications networks.

We have also considered the additional role of 'V2X service providers' that can work in conjunction with CSPs, since choices made by V2X service providers can affect the impact on mobile networks carrying V2X service-related data, although this is less applicable with RSU networks, where the service delivery configurations are well standardised.

Ultimately, we have focused on what CSPs can actively do to engage and work with ROs to encourage and accelerate V2X service deployment through C-V2X. By centring the work around Road Operators, we have limited the range of C-ITS services (or use cases) under consideration to Vehicle to Network (V2N) modes with emphasis on Vehicle to Network to Infrastructure (V2N2I) (i.e. including service information flows in both directions) as opposed to V2V-type services, which are enabled without support from CSPs. Similarly, V2N2V (or similar) use cases are not considered since they do not involve Road Operator systems.

Several 'Day 1' V2I/V2N use cases are already being operated today over public mobile networks, the primary examples being services enabled by 'Talking Traffic'[1] in the Netherlands and 'Travel Safely'[2] in the United States. Apps that connect to this service provide up-to-date traffic control and safety information to drivers, plus road usage data back to the Road Operator, and so appear to be very similar to the use cases analysed in Bridge[3]. Penetration of these apps is likely to be a fraction of total vehicles on the road, but they reportedly operate very well today over existing 4G mobile networks. In this particular case, it appears that while the mobile networks are fundamental to the service, the MNOs are not 'active' in supporting the service, which is likely a result of the high quality of existing mobile networks in the Netherlands. Active support like this is fundamental to Bridge because it enables mobile network operators (MNOs) to formulate policies – in their partnerships with Road Operators/Authorities – to cover the expected V2X use cases and to implement required network enhancements co-operatively. MNOs, like all companies, are required to justify investment by expected returns and so new ways of deriving revenue from supporting V2X services would be needed to enable investment in network capabilities that would otherwise not be necessary, or would be delivered at a later date. The basis for revenue extraction is out of scope here; this work aims to understand *whether* today's mobile networks would need active enhancements in order to address issues that may arise from the deployment of Road Operators' desired services and use cases, and *what they might be*.

To achieve the above, the Bridge WI needed to understand what the service priorities of the Road Operators are, in terms of the V2X use cases that they could see as most beneficial to their business and operations. This was achieved through a series of interviews with ROs. A set of V2X use cases was analysed to understand if CSPs would be required to implement any network strategies to support their deployment. Through Bridge, CSPs could then be aware of the appropriate strategies that would be necessary to satisfy generic RO V2X service deployment expectations. Bridge aims to highlight the positive aspect of a pro-active relationship between ROs and CSPs to deliver V2X services, which can result in targeted road coverage and optimised V2X data delivery strategies being devised.

1 Road Operator prioritised/expected use cases

The Bridge work item obtained high-level guidance on the expectations and priorities of Road Operators, through direct conversations with senior strategists within a number of European Road Operators.

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[1] Talking Traffic, available at link

[2] Travel Safely App, available at link /

[3] Smartphone-based apps include 'Onderweg', 'Flitsmeister' and 'Superroute'.

To support the discussions, a list of possible RO top-level business/operational areas was compiled in order to create a structure on which to base the conversation. The areas included road user safety (Vision Zero), road traffic control and optimisation, road network design and operation, autonomous vehicle support and environmental aspects (pollution, energy consumption). A number of V2X use cases, included on the 5GAA Roadmap were linked with potential RO business areas, to illustrate V2X support for RO operations and business priorities.

The Road Operator representatives that participated offered their views on the importance or priority of the business areas to their organisation and indicated which individual use cases were of interest. After a number of individual discussions, the Bridge team compiled a summary of the results, which is presented below:

The Annex in this document shows a single table representing the high-level outcomes and conclusions from Bridge interviews with Road Operators, on their priorities and expectations in terms of those C-ITS use cases that should be deployed to support their business objectives.

ROs agreed that the scope of their business and operational priorities could be represented by the following areas and discussed in terms of the associated C-ITS use cases taken from the 5GAA Roadmap:

- Vision Zero – reduction of road accidents and deaths
- CO2-free – energy/fuel consumption reduction by road users
- Digital Twin – data to support road traffic modelling and planning, provision of safety information to road users
- Co-operative, Connected and Automated Mobility – on-road service support for CCAM
- Digital Twin (Urban) – enhanced services for real-time support traffic monitoring and control in urban spaces

During the discussion process, use cases of service deployment – as described by the 5GAA Roadmap – were presented to RO strategy experts to determine their organisation's priorities and expectations. Specifically, the use cases that could be supported by co-operation between ROs and CSPs were discussed, since those would be the services enabling CSPs to achieve the Road Operators' priorities (one primary objective of Bridge).

Discussions with ROs were biased towards European highway operators, due to subject availability and resource issues, which undoubtedly resulted in the absence of some service types – e.g. vulnerable road user (VRU) protection – from subsequent analysis.

Qualitative analysis of the aggregated responses from ROs resulted in services from the priority areas Vision Zero and Digital Twin being taken forward for further analysis to determine how CSPs might enable accelerated deployment of RO priority V2X services, and help to develop co-operation between ROs and CSPs. A small set of exemplary services, representing the service type and communications mode, were selected and outlined below.

2 Mapping use cases to communications/V2X service provider network strategies

Network strategies can be required to optimise communications latency for critical safety or highly interactive transactions, or for ensuring good performance (quality of service) in congested networks.

In order to determine the network strategies that might need to be considered by the CSPs, enabling the deployment of V2X use cases to support the Road Operators' business priorities, an 'exemplary subset' of the use cases was selected for analysis (from those highlighted in Task 1).

In a qualitative exercise, the following four use cases were determined to be a good overall representation of the Road Operators' expectations, expressed during Bridge interviews. These use cases also represent those that can cause high data demands on the radio cell/sector and represent both uplink and downlink type information transfer modes. Additionally, both event-based and periodic information delivery is represented here.

- Local hazard and traffic information (LHTI)
- Green light optimal speed advisory (GLOSA)
- HD maps data collection and sharing (HD Maps)[4]

[4] The HD Maps collection and sharing is a use case that can only be implemented over wide-area mobile networks, as stated in the 5GAA Roadmap, 2020 version: 5GAA White Paper, A visionary roadmap for advanced driving use cases, connectivity technologies and radio spectrum needs, September 2020, available at link

- Probe vehicle data (PVD)

2.1 Network coverage

By definition, all V2X services require network coverage, however junction or intersection-based use cases (e.g. GLOSA) can operate using short-range systems (road side units) deployed near junction locations – they do not need contiguous network coverage of an entire area (i.e. city, state or territory). V2X use cases that demand comprehensive information delivery or collection anywhere that vehicles can be found (e.g. HD Maps, LHWI) ideally require the contiguous network coverage provided by most mobile networks. The PVD use case can be tolerant of coverage 'white spots', if PVD data is stored on-board the vehicle when it is outside wide-area overage, and then transmitted when coverage is restored or encountered.

The PVD V2X use case can, in theory, operate over short-range as well as mobile networks. With short range, the traffic information made available to the Road Operator will pertain only to the areas surrounding the RSUs deployed. Ideally, PVD will enable information for entire road networks, so operating it over mobile networks is the most likely path. (Note: We assume that most Road Operators are unlikely to deploy fully contiguous RSU networks covering whole road networks, due to the high cost.).

In summary, all of these use cases can operate over both connectivity types – cellular networks and short-range – however for LHTI, HD Maps and PVD contiguous coverage will be hugely advantageous, if not essential. It goes without saying that junction/intersection-based use cases can also be operated using contiguous network coverage.

2.2 Communications latency

Low latency as a connectivity characteristic for C-ITS/V2X services is required to support the communication of ephemeral information between ITS stations (e.g. V2V/V2N2V CAM or BSM Part 1) or safety critical event data (e.g. heavy braking DENM, BSM Part 2). In the example of safety critical events, the sooner the event is communicated to nearby receivers, the greater the chance there is to avoid on-road safety incidents.

However, none of the use cases highlighted by Road Operators (and by extension none of the exemplary use cases) qualify for the above categorisation, since events or information communicated there are either regular, predictable or not 'safety critical' as defined by 5GAA. In two of the use cases, data can be received and then stored for some time in the cloud (for periods greater than multiple seconds) before or while processing, and subsequent information value is extracted.

A communications systems such as PC5/C-V2X delivers low-latency radio communications by its nature as a direct, short-range radio communications solution. Modern mobile networks deliver relatively low latencies, albeit not as low as short-range, when they are operating under nominal conditions (i.e. not highly loaded).

In summary, network and radio techniques which minimise or control latency – such as active QoS, 5G-NR deployment, MEC-based application server deployment and network slicing – are not required to support the Road Operator business V2X priorities, as they see them today. Through qualitative analysis, it is clear to see that nominal 4G mobile network performance would be sufficient to deliver these services today, in terms of network latency.

Later in Section 3 we discuss the types of use cases that will require lower latencies.

2.3 Data throughput capacity

A network requirement that cannot be determined through qualitative analysis is the data throughput capacity required to support individual and multiple V2X use cases on mobile networks, since the associated data load depends on the use case signalling and messages, vehicle participation, and some on-road factors.

Highly loaded conditions in specific cells or sectors are sometimes experienced in densely crowded situations or venues. Control-plane overload can result from a large number of devices competing to access the cell/sector resources simultaneously, even if the expected data load of their individual active applications is relatively low. Often, additional, temporary capacity is installed for scheduled events like music festivals or large single-sited sports events, such as a Formula 1 race.

The scenario described above is by nature a short-lived issue, but if devices are often or regularly congregating in large numbers and continually uploading or downloading significant aggregated amounts of data then the sector/cell performance will degrade because the total data throughput capacity of the cell is close to being exceeded, resulting in higher radio network latencies or even failure to access the radio and ensuing connection timeouts. In practice, data latencies can begin to rise significantly even when the total data load is much lower than the theoretical capacity.

In V2X system scenarios, the numbers of vehicles accessing V2X services varies with the time of day, the road environment and often when accidents happen leading to road closures and subsequent traffic flow issues. Road Operators are keen to understand how their information/services will be carried under such circumstances, particularly if they are using public communications networks.

In a wide area cellular network, capacity can be increased by deploying additional frequency bands, site densification or with advanced techniques, such as massive MIMO[5]. Whereas capacity extension for short-range broadcast systems can only be addressed by additional spectrum and densification to a lesser extent.

2.4 Modelling data throughput load against radio sector capacity

Bridge undertook a qualitative analysis of the selected use cases in multiple road environments, using basic models of the service data transactions to determine the potential load on mobile networks resulting from the additional data that might be carried. For each model, a realistic scenario was sought, to set the inputs that would determine the level of data transmission activity. These included:

- Numbers of concurrent roadwork instances in dense urban environments (for LHTI)
- Numbers of traffic light controlling junctions and intersections in cities (for GLOSA)
- Levels of on-road object reporting required to support road mapping (for HD Maps)
- Data required in a highway obstruction scenario (for LHTI)
- Vehicle density on three-lane and dual carriageway highways (all, except GLOSA)

Other inputs, such as urban and dense urban vehicle density, were reused from a previous 5GAA study on 'Spectrum Needs'[6]. This work aimed to determine how much additional ITS spectrum would be required to support advanced V2X use cases in various road environments in the future.

Two different approaches to V2X message distribution by a V2X Service Provider (SP) were modelled, since each results in different data levels being transmitted in downlink-centric use cases (i.e. I2V, N2V). A Digital Twin approach assumes that the V2X SP has a real-time understanding of the location and velocity of each vehicle. A Geofenced approach assumes that the V2X SP only knows the approximate location of each vehicle, within defined areas.

The penetration of the V2X service, in terms of the proportion of vehicles on the road participating in the use case, was varied up to 100%, in order to determine when any stresses on the sector data throughput capacity might occur. Penetration typically starts at low levels, increasing with time, so this approach can determine whether CSPs might need to react on 'Day 1' or later in the lifetime of the service.

The capacity of the mobile network was modelled in the form of simple sector geometry (from Spectrum Needs) and modelling capacity using Shannon's Equation. Maximum load on the network is expected to occur in limited geographic areas, such as urban centres or accident locations, so individual sectors or cells could be loaded while the total network capacity is unchallenged. For each scenario the sector capacity was assessed by varying the available bandwidth, basing this on the concept of deploying multiple, aggregated 4G bands (up to 3 x 20MHx bandwidth).

Shannon's equation requires average signal-to-noise ratio (SNR) as an input, so in the absence of real data a range of values was selected as input (6dB to 8dB). The worst case would be when minimal available bandwidth is combined with lowest average SNR. However, this value assumes that a single radio cell/sector is present to support V2X. OEMs, VRUs and road users equipped with smartphones will naturally obtain V2X services using different MNOs and so the combination of multiple MNO networks will increase the overall capacity to carry V2X service data.

To complete the analysis, the amount of data generated by each use case with varying input parameters was compared with the sector capacity, also with varying input bandwidth parameters.

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[5] MIMO – communications systems using multiple-input, multiple-output antenna architectures to improve capacity through multipath recovery

[6] 5GAA Technical Report, Study of spectrum needs and safety related intelligent transportation systems – day 1 and advanced use cases,
October 2021, available at link.

2.5 Summary of mapping and modelling results

For the downlink-centric use cases (GLOSA, LHTI), the total V2X message data load (Mbit/s) resulting from the distribution of Road Operator service information (roadworks and junction signal phasing) was low or negligible in comparison with theoretical mobile network capacity (even for 100% vehicle participation), with the exception of two scenarios. The data load attributed to GLOSA using Geofence-based V2X message distribution in urban and dense urban areas is significant, particularly in the worst-case sector capacity scenario. The results show approximately 2-6% of sector capacity would be required by GLOSA in urban areas and 6.5-22% in dense urban areas. This is clearly resulting from the additional data sent by attributing a large area of 0.74km^2 in the Geofence approach. Smaller areas could be used, albeit resulting in a higher V2X service 'location update' rate.

The uplink-centric use-cases (PVD, HD Maps), provide road-originated information to Road Operators or third parties such as HD map service providers. In both of these uses cases it is possible that suitable information requirements can be attained with less than full vehicle participation. Some have stated that PVD, as it is currently understood, can work with only 3-5% participation from all vehicles on the road. However, increasing vehicle participation was modelled, from 10% to 100%[7]. However, for PVD and with 100% participation, data levels were low to negligible, even for the worst case: 1.78% additional data load for a highway closed lane environment, 100% vehicle participation, 6dB SNR, 20MHz available bandwidth. It should be noted that the frequency of transmission of vehicle location data modelled here was selected as 1Hz, rather than the maximum short-range value of 10Hz described in standards. This value reflects the reliable, access and resource controlled point-to-point nature of mobile connections, compared with short-range ITS systems.

The initial results of the HD Maps service model showed uplink data load values that on the face of it would be extremely challenging to support. This model used values taken from the Spectrum Needs work, which modelled a variation of the use case assuming short-range V2V communications. For the worst-case scenario, each vehicle would detect and upload over the mobile network 50 objects to the HD Maps server every second. With 100% participation, this amounts to 100Mbps per sector in the highway environment, dropping to 10Mbps with 10% participation. However, there is a widely held view that the value of 50 is high for several reasons, so reducing the number of uploadable objects to 10 per second reduces the uplink per-sector load by a fifth because it is a simple linear reduction. So with 10% participation and only 10 uploadable objects per second it offers a more manageable 2Mbps per sector, which in the worst-case 4G sector capacity model (112 Mbps from two separate MNOs) represents a load of 1.8% capacity.

It is worth noting that the HD Maps use case is designed to support vehicles with higher autonomy, since the HD map enables vehicles to better negotiate physical roads and ephemeral objects (supplementing their on-board sensor data), which does not normally present a problem for human drivers. So, the wide deployment of the full 'HD Maps data collection and sharing' as a crowd-sourced style use case is unlikely to happen in the next few years, until autonomous vehicles become much more widespread. Initial, less dynamic forms of HD maps will be available much earlier than the form considered in Bridge, so they are unlikely to pose an issue for mobile network capacity, as was seen in the LHTI example.

In summary, qualitative analysis of the various representative use cases showed that low latency is not essential to the correct operation of the use cases, so MNOs don't have to deploy strategies intended to minimise latency or latency variation. Network coverage is always a factor, and this is discussed in more depth in the next section. Additionally, quantitative modelling of selected use cases showed that during downlink, where information is sent to vehicles from Road Operators or other third parties, sector capacity is not impacted in the worst cases, although downlink V2X message distribution optimisation may be required in the Geofence approach. For the uplink cases the crowdsourcing nature of the service could seemingly challenge network capacity, but on further inspection the use cases – as deployed in terms of real levels of participation and net levels of data upload – suggest that any serious data upload levels will only occur in the future when we can expect the ongoing 5G rollout to have provided greater basic network capacity (e.g. densification and additional bandwidth) to urban and highway scenarios.

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[7] With the use of mobile networks and edge-based mass data processing capability, it is possible that new real-time traffic and incident/accident monitoring services could be created, leveraging higher levels of participation in V2X-based PVD, so it is worth knowing what the effect on sector capacity of participation up to 100% might be.

3 Discussion with recommendations for communications service providers and V2X service providers

We have seen that Road Operators today typically prioritise the deployment of C-ITS/V2X use cases that deliver road safety and traffic control information to vehicles. They also have an expectation that vehicle-originated data could be collected and used to support traffic monitoring and improved traffic efficiency.

Based on our discussions, ROs do not currently prioritise direct support for vehicle autonomy on their roads, nor do they prioritise C-ITS/V2X use cases aimed at reducing fuel/energy consumption by vehicles, possibly expecting that these activities sit within the OEMs' domain today.

Vulnerable Road User Protection use cases did not feature in the discussions, despite the area seemingly being of primary interest to both Road Operators and OEMs. The reason for this is likely to be due to the bias towards highway Road Operators over city ROs participating in discussions with Bridge, during the initial phase. Despite this, VRU Protection is likely to be a busy area for service development in the coming period and so a similar evaluation of the demands on CSP networks for VRU protection use cases is recommended for further work.

Those areas deemed to be a 'priority' by the ROs (represented by a range of 5GAA V2N/V2I-type use cases) were reviewed from the perspective of their potential demands or impacts on communications networks. Potential demands include network coverage scope (contiguous vs focused), low service connection latency, high radio data capacity and reliable information delivery. It became clear through the analysis that **advanced, active network capabilities are not a pre-requisite for deployment of these RO priorities** and that 4G networks can carry these services on the assumption that coverage exists and that there is sufficient available capacity to handle the additional data in those cells or sectors where the highest usage density will occur. The major remaining unknown for RO priority use cases was the effect on capacity of mobile networks due to the data levels that would be needed under high service adoption rates.

For short-range systems, the capacity depends on the available spectrum, which is determined by the local regulators, from within the range that has been allocated to C-ITS services. For wide-area mobile systems, capacity mainly depends on cell/sector design, base station site, density, and the how much licensed bandwidth is available. **We have shown that established, or mature 4G mobile networks (providing mobile broad band (MBB) services, ideally multiple aggregated bands) are capable of supporting the RO priorities even under the most demanding circumstances and with high service penetration**, primarily because those networks have suitable capacity to carry the data loads without active network support, in other words as 'over-the-top' service-level connections.

For those territories where 4G mobile networks are considered not yet mature enough in terms of coverage or capacity, network expansion will be required. As part of regular business operations, mobile network coverage and capacity is continually being upgraded by mobile operators, primarily according to well-established strategies handling coverage and functionality of the technology ('generation') under consideration. However, such strategies may not deliver in the timeframe or at locations desired by C-ITS service participants, and **with limited CSP budgets and with pressure to satisfy pre-existing licence requirements, it may not be possible to adapt or use coverage plans** beyond their primary objectives.

The current trend towards mobile network consolidation might address some issues around coverage gaps, since it can result in the coverage of MNOs being combined into a single service provider and singular, integrated network coverage, using combined licensed bands. 5GAA has written previously about possible strategies for Network Expansion[8], however **one important aspect that Bridge's work has identified is the potential for a business relationship between all ecosystem players, based on V2X and C-ITS service provision** and consumption, which can help to accelerate improvements to service delivery networks beyond the organically planned network extension. Specifically, **ROs anticipate being able to use information derived from vehicles on the road to meet some of their primary business objectives,** including traffic monitoring and control, and network design and planning.

The argument for an active three-way co-operation and business relationship can be made in the context of targeted expansion of 5G networks for road coverage and improving edge-service hosting performance for future C-ITS/V2X and vehicle autonomy support services over mobile networks, which will generate much higher levels of data communication

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[8] 5GAA White Paper, MNO Network Expansion Mechanisms to Fulfil Connected Vehicle Requirements, June 2020, available at https://5gaa.org/content/uploads/2020/06/5GAA_B-200044_WI-NetExp-White-Paper.pdf

and a need for low latency, interactive V2N2X communications covering urban roads and highways ubiquitously**. The potential that these future new services require extended, more road-focused contiguous network coverage, together with more active management of data carriage over mobile networks (e.g. QoS support or network slicing) is high.** Thus, in the lead up to the requirement, **it would be worthwhile establishing the business-based approach supporting the deployment of necessary systems**; in other words, a business case which involves all main participants in C-ITS and autonomy support services. This approach is more likely to result in appropriate networks provided in time to satisfy on-road requirements, as opposed to reliance on new/future regulation or binding conditions attached to the licensing of future mobile network generations. Those networks will also support OEM-specific or third-party on-road services, which will inevitably arise as vehicles' autonomous capability improves. To have the lack of suitable mobile network coverage and functionality hampering the rollout of more vehicle autonomy would be undesirable for OEMs, particularly given the huge investments that have been made.

Such business arrangements can be based around the following recognition: that road-originating data is provided by vehicles/OEMs and various V2X service provider apps (e.g. parking, navigation, VRU, etc.); that the data is actively carried, supported and processed by mobile networks and their partner V2X service providers (including OEMs themselves); and that it is consumed by road operators and other third-party service providers. Additionally, **the provision of high quality, real-time data from roads will enable Road Operators to monitor whole road networks in real time, while significantly reducing their reliance on expensive and often unreliable road surface embedded sensors and road side sensors**. **A robust exchange built around this three-party ecosystem can foster the generation and exchange of data at a fair price to the party creating, providing or supporting it** (i.e. OEMs, MNOs and their service providers).

Prior to the deployment of advanced C-ITS and autonomy support use cases, it is likely to be worthwhile for CSPs, particularly MNOs, to support the deployment of earlier C-ITS/V2X Day 1 and Day 1.5 use cases, such as those included in this study, in partnership with third-party V2X service providers or Tier-1 OEM providers developing V2X solutions and supporting use cases such as VRU protection. One way of helping the early deployment of such services, without requiring the complete redesign of existing services could be to provide detailed information around network coverage and performance related to geographic areas, so V2X service providers can be aware of existing challenges to the appropriate delivery of their data in some areas, and can be confident of good service in others.

In the long run, a greater level of integration between MNO service networks (e.g. including active QoS and MEC service hosting) will be required to support advanced C-ITS use cases covering higher, more predictable data throughput and with lower latencies. Demonstrating the performance of similar use cases with selected V2X service provider partners under such architectures can ensure that the C-ITS ecosystem understands the value of the full end-to-end support for V2X service hosting and delivery, compared with approaches that are fully over-the-top, without any active support.

Recommendations:

- **Road Operators can be confident that 4G networks are today capable of carrying Road Operator prioritised use cases similar to those elaborated in Bridge, and depending on sufficient existing network coverage. The presence of 5G network coverage on roads will improve the capacity and quality of C-ITS service support, including more advanced use cases. The exemplary use cases analysed in Bridge were**
    - **Local Hazard and Traffic Information**
    - **Green Light Optimised Speed Advisory**
    - **Probe Vehicle Data**
    - **Data Collection and Sharing for HD Maps**
- **As requirements for more advanced services and use cases arise, leading to the need for enhanced coverage and capability, ecosystem members should work towards establishing co-operative relationships and 'fair value' exchange mechanisms**
- **Road Operators should take the opportunity to shift future investments away from legacy ITS solutions (e.g. loops, roadside sensors, etc.) and towards gathering data from suitably equipped road users, to support their primary operational objectives**

Annex – Summary table of Bridge interactions with Road Operators

Bridge: High service-level requirements on information exchange

Public Road Authorities Highway Urban	Vision Zero	CO2-free	Digital Twin	CCAM (Co-operative, Connected and Automated Mobility)	Digital Twin (Urban)
Data Access	Safety (Data) is #1,#2,#3 Road worker safety Local hazard information Leverage SRTI (Safety-related traffic information)	Probe Vehicle Data Vehicle information on speed and direction	Data Exchange - Data exchange is needed for traffic simulation and digitalization (digital-road/twin of the road)- focus on efficiency	'What kind of data'? OEMs are responsible for introducing AD vehicle on the market. - No requirements from OEMs - OEM/RO sync required	Floating Data - Vehicle and VRU Information on speed and direction
Information Generation	Service Provider Leveraging geofences to offer dedicated Services Sensors (incl. RSU) on the road	Asset Management - Own sensors for dedicated road elements (tunnel, hard shoulder) Incl. traffic information gates	Data Operation - Data fusion/filtering and Service generation via Extended vehicle architectures	Digital AD Support - AD vehicle support by road sensors - Close linkage to Asset Management required	Mobility Data Space - Publish traffic light/intersection information (GLOSA/RLV)
Knowledge Distribution	Driver Warning Direct access to vehicle dashboard w/o disturbance of the driver - linkage to upcoming NCAP regulation	Travel Information - Optimization for road users - Freight in focus of government (vehicle density, average speed)	Information Channel Road operators' channel to the driver focusing on safety (ISAD C)	Dynamic Information Enable long term construction sites for AD level 3 vehicles by mapping of street lanes (ISAD B)	Infrastructure Information - VRU/micro-mobility protection - Priority for e.g., high emitters - Public (AD) Transport (MaaS) (ISAD A)
5GAA Roadmap Use Case Example	Local Hazard (2020)	Traffic Information (2020)	Informative Sensor Sharing (2025)	Sensor Sharing of dynamic Objects (2026)	Tele-Operated Driving (in-direct) Dynamic Intersection Management (2029)