ZENZIC

UK CAM Roadmap to 2035 – Infrastructure and Data Services

April 2024

zenzic.io

United Kingdom

Contents /

Delivery Team /

For further information on this Roadmap please contact the Zenzic team
info@zenzic.io   zenzic.io

Authors

Mili Naik
Technical Delivery Lead
Zenzic

Francis McKinney
Head of Technology and Insights
Zenzic

Acknowledgements

Thanks to CCAV and the CAM Creators for guiding and shaping this work since the start of the first roadmap and through the workshop with a special thanks to Stantec for hosting the workshop and Gareth Bathers for his detailed feedback on this topic roadmap.

Acronyms

Abbreviation	Definition
AI	Artificial Intelligence
AV	Automated Vehicle
CAM	Connected and Automated Mobility
CAV	Connected and Automated Vehicle
DoIP	Diagnostics over Internet Protocol
ML	Machine Learning
OEM	Original Equipment Manufacturer
OTA	Over the Air
SoS	System of System
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
V2X	Vehicle to Everything

1.0 / Executive summary

An update to the UK Connected and Automated Mobility (CAM) Roadmap 2035 (Zenzic, 2023) was published in early 2023. In that update the Roadmap took the first CAM Roadmap to 2030 data, restructured and updated it into a three-layer model of 'Why', 'What' and 'How'.

In that roadmap update six topic roadmaps were identified, four applications of CAM and two enablers of CAM:

CAM Applications

- Freight and logistics vehicles and services
- Public transport vehicles and services
- Personal mobility vehicles and services
- Off-highway (without public access) vehicles and services

CAM Enablers

- Infrastructure and data services
- Verification, validation, and assurance services

This topic roadmap is focussed on the details of the key area – 'Infrastructure and data services'.

Data services are seen to be a foundation element of CAM services and have the potential to enable CAM to deliver improvements to transport accessibility, efficiency and productivity.

In the near future, Automated Vehicle (AV) systems will need to work independently of connectivity in "real time", but connectivity can augment these systems. There is, however, potentially a future where connectivity starts to assist the AV in real-time.

This topic roadmap is based on a similar approach with answering the questions Why, What and How? from the infrastructure and data services perspective.

The topic roadmap then details a timeline of activities and milestones which realise the development of these themes up to 2035.

Figure 1.2: The 'Why?', 'What?', 'How?', layer for infrastructure and data services

1 Why?

Even beyond CAM V2X communications is an emerging technology. For CAM services to run efficiently and be able to provide the benefits of CAM, enabling data communication is a key behind these services.

In order to benefit from the emergent properties for societal, economic and environmental gain as defined in the UK CAM Roadmap 2035 Executive Summary (Zenzic, 2023), the communication interfaces between geographically dispersed elements of the system are vital to delivering the following areas of benefit:

- Real-time decision making
- V2V and V2I communication
- Mapping and navigation
  Monitoring and maintenance
- Fleet management and optimisation
- Data sharing and collaboration

2 What?

The 'What' Layer defines the products, services and solution that link to the benefits defined in the 'Why'.

To enable the data conjunction, physical and digital infrastructure are key products and the elements that associate with the end-to-end delivery of services, the most significant elen1ents a re listed below:

- Data collection and sensing
- Data processing and analysis
- Communication and connectivity
- Web services and cloud computing
- Data and Cyber security
- Service delivery and usage
- Decision-making and control systems
- Maintenance and Support

3 How?

Through identification of the value-chain in data services, the third key question of how to enable the data services is to be answered. This is detailed later in this Roadmap but following are key themes to enable infrastructure and data services:

- Data standards and cooperative data sharing
- Federated data architecture
- National coverage plan
- Digital infrastructure
- Physical infrastructure
- Skills and education

Source: Author generated

1.1 Recommendations

An analysis of the themes and activities in the 'how' layer then yields the recommendations captured below.

Use cases and stakeholders for data packages

Define clear, concise use-cases for the data requirements and subsequent infrastructure requirements.

Data standards and sharing frameworks

A package of work to understand which data standards and formats, including security requirements, apply to which use case of CAM services.

National coverage and infrastructure strategy

Integration of CAM into the future of transport and specifically integration with the future infrastructure update is key to enable CAM. Understand the current national coverage for the data requirements and identify where the infrastructure are not able to meet the needs derived from the use-cases.

CAM inclusion in the National Digital Twin Programme

A programme of integrating the CAM sector into the development of federated digital twins for the wider transport network.

Standardisation and maintaining of HD-maps

A dedicated programme of work is required to understand the responsibilities and processes for the wider-scale development of HD maps. This exercise can then help inform the longer-term vision of included HD maps.

Collaboration with different stakeholder groups

A concerted effort is required to bring all the different groups looking at data services and infrastructure in transport, to ensure there is clear and joint understanding of requirements and commercial needs.

Skills and Education

A cross industry and governmental initiative to address the gaps in skills is required around data analysis, synthesis, cyber-security and cyber-resilience.

Source: Author generated

2.0 / Overview

2.1 Background

An update to the UK Connected and Automated Mobility (CAM) Roadmap 2035 was published in early 2023. In that update the Roadmap took the first CAM Roadmap to 2030 data, restructured and updated it into a three-layer model of 'Why', 'What' and 'How' shown in figure 2.1.

Figure 2.1: Overview of the integrated UK CAM Roadmap 2035

Why?
Trends and drivers

- Rising expectations and the need for easy access and convenient options
- A more sustainable, environment-friendly transport solution
- Public transport options and requirements for rural areas
- Government agenda for Levelling Up and growing the CAM supply chain in the UK, with development or new technologies
- Labour shortages creating a shortage in the availability of drivers for vehicles
- Developing and maintaining skills in the UK
- Strong international competition to stay on the forefront of driving innovation
- Safer and securer travel options

What?
Products, services and solutions (Key CAM areas)

- Off-highway (without public access) vehicles and services
- Freight and logistics vehicles and services
- Personal mobility vehicles and services
- Public transport vehicles and services
- Verification, validation and assurance services
- **Infrastructure and data services**

How?
Capabilities and enablers

- Early commercial service models ready for investment
- Commercial deployment pilots
- Commercial service models ready for investment
- Monitoring and refinement followed by expansion in CAM deployment areas
- Connected and automated vehicles (CAVs) framework in place
- Framework for the life cycle of CAM services
- Framework for the federated data architectures
- Vehicle-to-everything (V2X) connectivity and data availability
- Creation of integrated systems and services
- Seamless passenger connectivity
- Identification of training and skills required for the CAM sector
- Cost-effective technology/product solutions (e.g. for sensors, HD mapping, road infrastructure)

Source: Executive summary to UK CAM Roadmap 2035 (Zenzic, 2023)

UK CAM Roadmap to 2035 – Infrastructure and Data Services / **Zenzic**

The 'Why' layer setting the context of the market and opportunities of CAM, and how CAM can support delivering the economical, societal and environmental benefits to the UK.

The 'What' layer of the Roadmap is concerned with identifying which product services and solutions the UK can collaboratively develop which will in turn create value and deliver economic, environmental or social benefits.

Lastly, the 'How' layer, defining the requirements on that enable the realisation of the products and services

Within the 6 key areas identified under the 'What' layer shown in figure 2.1. This topic roadmap is focussed on the detail of the key area – 'Infrastructure and data services'.

Data services are seen to be foundation element of CAM services and have the potential to enable CAM to deliver improvements to transport efficiency, accessibility and productivity.

Connectivity also has the potential to support the delivery of safety benefits both through remote operation and monitoring of Connected and Automated Vehicles (CAVs) and improved data services supporting CAVs in the wider transport network. The delivery of these benefits is reliant on having high quality and low latency communications infrastructure where applicable.

To realise the potential of the data services, the foundation is based in the infrastructure. The term infrastructure is more than just the physical infrastructure i.e. roads, Vehicle-to-Everything (V2X) units, sensors etc but also include digital infrastructure such as the digital and data components that support the automation of the vehicles in safely and efficiently.

These data services and better connectivity could also have a significant impact on other sectors in the UK, but this topic roadmap focuses only on the role it would have in the context of CAM.

2.2 Purpose

The purpose of this Roadmap is to present the analysis from the original Roadmap update workshops in November and December 2022 and then the subsequent detailed workshop on the topic of Data and Infrastructure in August 2023.

The overall aim is to show how this topic can develop over the period to 2035 and how stakeholders and developers of CAM services and government can support achieving many of the critical drivers and benefits of CAM.

Through the workshop data analysis, the challenges and opportunities for the UK are drawn out and distilled into a series of critical actions for the topic of data and infrastructure in CAM.

3.0 / Why

The Importance of Infrastructure and Data Services in CAM

V2X features are emerging on current vehicles, and from 2027, V2X are set to become part of the EU NCAP assessment. The richness of the features being offered is developing over time with the increasing emergence of software defined vehicles. There is a rise in the use of Diagnostics over Internet Protocol (DoIP) and Over the Air (OTA) updates driven by regulation with regards to software updates and their management system (UNECE 156, 2021). These capabilities will develop and be a standard part of Connected and Automated Vehicles (CAVs) as the sector moves from the current small (1-3) vehicle type trials and deployments to larger scale CAM deployments.

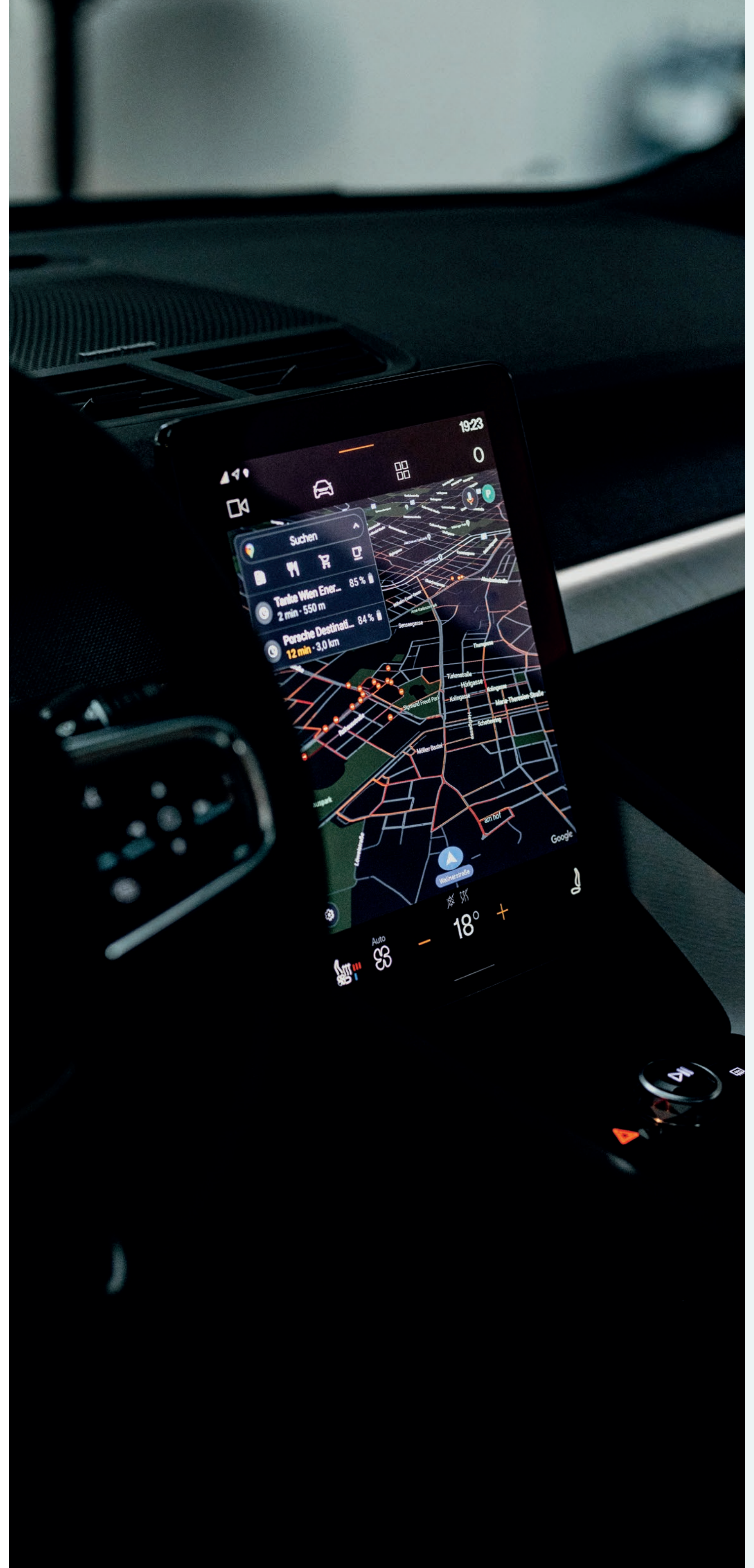
Increasingly developers are looking at remote monitoring and teleoperation to augment the fully automated operations of the vehicle either to assist the vehicle when it comes to a halt or if it has encountered conditions which are outside of those defined by the Operational Design Domain (ODD)

In the longer-term, CAM solutions are intended to become an integrated part of the wider transport 'System-of-Systems' (SoS). The wide societal and economic benefits that are sought from transport are driving properties of that shape the emergent branches of the SoS. Essential to the SoS's operation is the necessity for sub-system communications and therefore data and connectivity provide a major interface between geographically dispersed elements of the system.

These developments are reflected in the issuing of Remote Driving guidance from the law commission in February 2023 (Law Commission, 2023).

Furthermore, the British Standards Institute produced a flex standard (BSI Flex 1886 v1.0 2023-08) in August 2023.

It is important to distinguish between the automated operation of a vehicle and the connected and automated operation of a vehicle. The automated operation needs to be able to comply with safety requirements without the need of external connection providing supervision or monitoring, whilst the connected and automated operation can aid the operation of the vehicle by presenting it information beyond the range of its sensors and connecting the vehicle into the wider transport network.



UK CAM Roadmap to 2035 – Infrastructure and Data Services / **Zenzic**

The enhanced operation of the vehicle and CAM services through connectivity is realised in the following ways:

Real-time decision making

Self-Driving vehicles rely on data to make split-second decisions on the road. This includes information on traffic patterns, weather conditions, road closures, and other vehicles' movements. Access to connectivity and real-time data can support plugging the existing gaps in safety and efficiency of decision making of an ADS which impacts not only the CAV but also the wider transport network.

Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communication

Data and connectivity allow CAVs to communicate with each other, other vehicles and infrastructure such as traffic lights and road signs. This communication can facilitate coordinating the movements, anticipate potential hazards, and improve overall traffic flow.

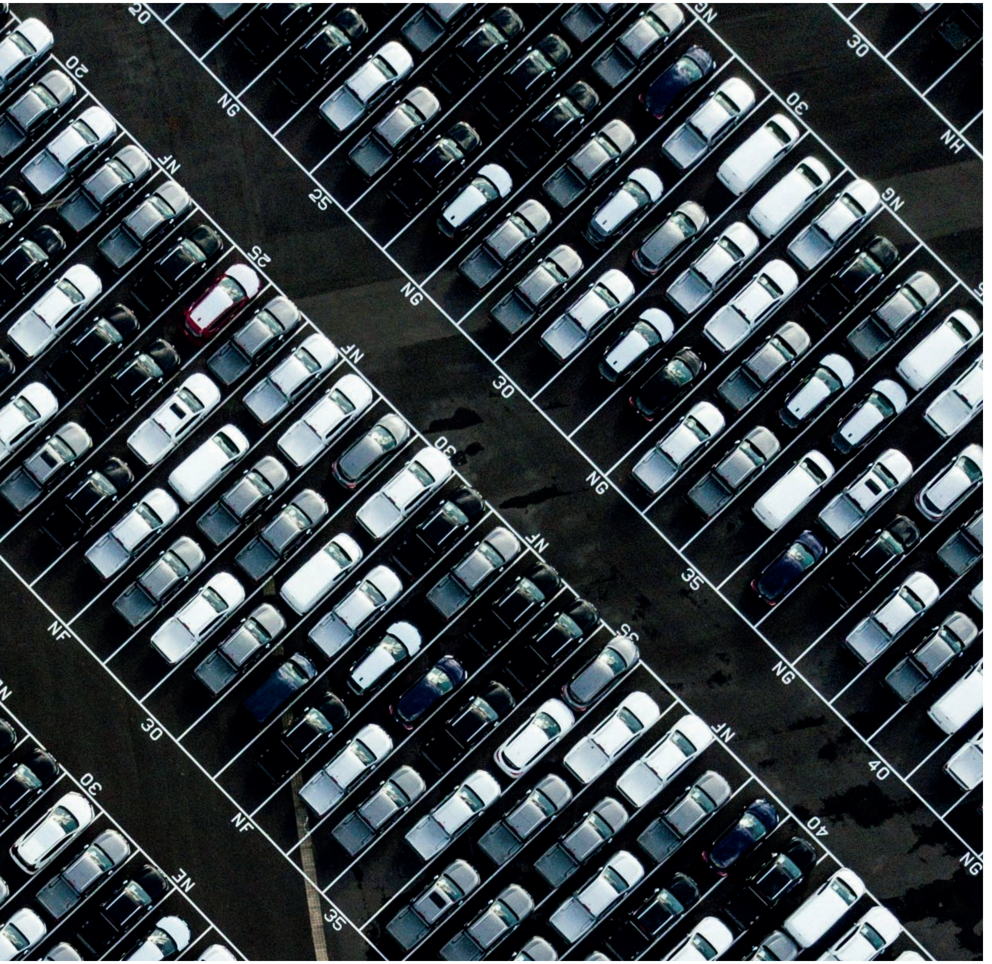
Example: *Vehicles will alert each other of the presence and precise location of hazards (this may be presented as a warning but will also change the vehicle's behaviour on approach to the hazard). Incidents and road closures will be fed to the vehicle in real-time so that it can safely reroute itself.*

Mapping and navigation

CAVs can use data from mapping and navigation systems to navigate roads and find the most efficient routes. This data is constantly updated to account for new construction, closures, and other changes to the road network including real time changes. There is a sub-group of CAVs which utilise HD maps of a prescribed route to help them know what they will encounter as features of that route. They then use the sensors for the detection of hazards on their path. HD maps are a critical asset to this type of CAV – which is typically used for fixed route for example shuttle buses. Not all manufacturers use this method to navigate as vehicles with variable routes rely more on full environmental sensing.

Monitoring and maintenance

Data can also be used to monitor the performance and condition of CAVs, enabling proactive maintenance and ensuring the safety and reliability of the vehicles. Some of these data requirements could be covered under legal requirements but there are also other stakeholders who may be interested in accessing data provided by connectivity such as insurance, emergency services, transport planners and managers.



Fleet management and optimisation

Providing tools to monitor and manage a fleet of CAVs, including routing, scheduling, and real-time tracking is important. Having access to data from the wider fleet can help the optimise the decisions about routing and planning.

Example: *Hybrid vehicles will be able to select low-emission settings when travelling in areas with schools or high population densities.*

Data sharing and collaboration

Enabling the sharing of anonymised data between wider stakeholders in the sector, such as transportation agencies, private companies, and research institutions, to improve overall mobility solutions. For example, advertisers can change roadside billboards based on real-time traffic demographics – in-car offers, and advertising will be more interactive and linked more lightly to local businesses and events (i.e. allowing for dynamic pricing/offers). With data sharing there is a big potential to improve the user (consumer) experience as well, for example a shuttle taking people to a train station or transport hub giving information on times and platforms etc., seamless journey experience.

UK CAM Roadmap to 2035 – Infrastructure and Data Services / **Zenzic**

4.0 / What

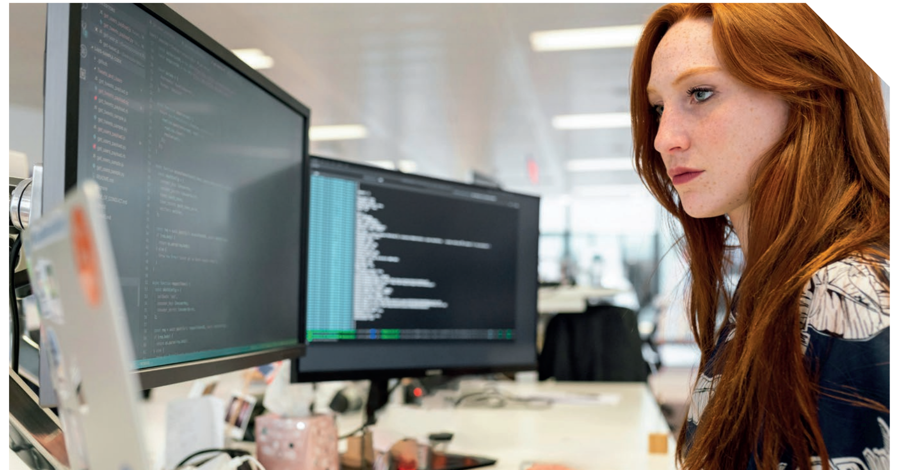
Identifying CAM Infrastructure and Data Services

4.1 Data services

Data in CAM generally refers to the information collected and used by the vehicle's systems to navigate, make decisions, and communicate with other vehicles and infrastructure. This data can include information about the vehicle's surroundings, such as road conditions, traffic patterns, and the location of other vehicles.

Infrastructure in CAM refers to the physical and digital network of communication and support systems that enable the vehicles to operate effectively. This can include things like roadside sensors, communication networks, data centres and digital twins that collect and process information to support the safe and efficient operation of connected and automated vehicles.

The major elements of the value-chain for CAM data and infrastructure are:



Data collection and sensing

This involves the deployment of sensors, cameras, LiDAR, radar, and other devices to capture data about the vehicle's surroundings, as well as information about the vehicle's performance and status.

Data processing and analysis

Once the data is collected, it needs to be processed and analysed to extract useful insights and information. This may involve the use of machine learning algorithms, artificial intelligence, and other advanced analytics techniques to gain insights from the massive amounts of data generated by CAVs.

Communication and connectivity

CAVs rely on communication infrastructure i.e. high-speed, reliable communication networks to transmit and receive data in real time. This includes V2V and V2I communication, as well as connections to cloud-based platforms and other external systems.

Web services and cloud computing

The data generated by CAVs needs to be stored, managed, and processed in cloud-based platforms and data centres. This requires robust and scalable physical infrastructure, as well as secure and resilient cloud computing resources supported by scalable digital infrastructure.

Data and Cybersecurity

Protecting the data and communications of CAVs is critical to ensure the safety and security of the overall system. This includes implementing robust cybersecurity measures and mechanisms to protect against potential threats and unauthorised access.

Service delivery and usage

The insights derived from the data are utilised to deliver various services, such as real-time traffic information, predictive maintenance, fleet management, and other mobility solutions. These services are then delivered to end-users, such as passengers, fleet operators, and transportation authorities.

Decision-making and control systems

The data and infrastructure elements support the development of advanced decision-making algorithms and control systems that enable autonomous vehicles to operate safely and efficiently in complex environments.

Maintenance and support

The value chain includes the necessary maintenance and support systems to ensure that the data and infrastructure elements remain operational and effective over time.

In-vehicle Infotainment

Finally, with CAVs there is a possibility for vehicles to become mobile entertainment/infotainment pods. There is endless possibility for the interaction and entertainment of the consumer with availability of internet. They could also access productivity apps.

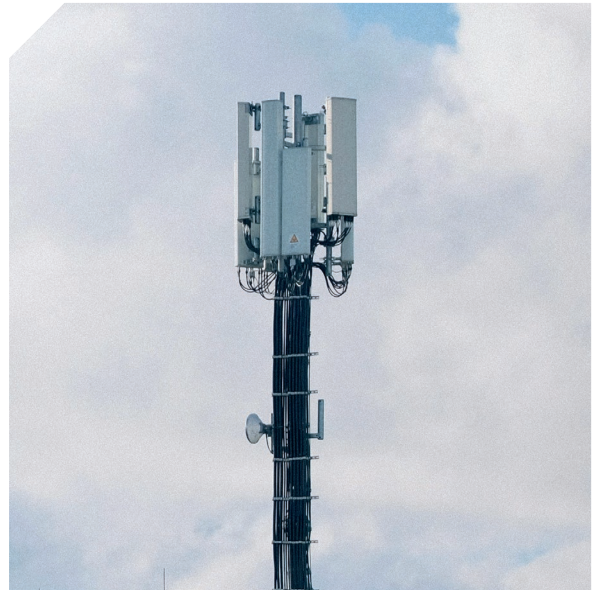
The above elements form a comprehensive value chain for data and infrastructure related to CAM, supporting the development and operation of advanced mobility solutions.

4.2 Network Infrastructure

The data services identified have different requirements of when and how they are needed, and also the data latency which determine the type of network and infrastructure that might be utilised. There are many sorts of network infrastructure currently available and future possibilities. Some of them are listed below:

Telecom Network (5G, 6G)

5th and 6th generation cellular communications, 5G is in the process of being rolled out across the UK, 6G is still in the concept stage. These both provide progressively lower latency and increased overall network bandwidth.



Satellite Communications (non GNSS/GPS)

Enabling vehicles to communicate with each other and with the infrastructure through satellite links. Global coverage means deployments can be made across large geographies. Can provide redundancy and resilience as back-up to terrestrial communication systems.

GNSS

Enables accurate positioning, navigation and timing services to vehicles and infrastructure. Very good in applications where time synchronisation is required.

Mesh Systems (V2V/V2X)

Nodes within a network are directly connected to each other in mesh-like structure. The offer the possibility of ad-hoc networks which means vehicles or users can connect and disconnect based on needs and location. Offer flexible, resilient and scalable network architectures which in turn can enable technologies such as edge computing and so lower the overall data transmission requirements.

These network infrastructure solutions are likely to support a mix of the data services listed in the section 4.1 and one of the primary determinants of this is the timing and the quality of the data needed.

The timing of the data is generally referred in terms of the data latency which indicates the time it takes for data to become available after an event occurs. At high level these can be categorised in four categories.

Between the real time and passive data the key differences can also be the criticality of the data and the purpose of the data.

Figure 4.2 shows how the mix of network can support CAM and shows the general understanding that 5G infrastructure is a must for CAVs is a myth.

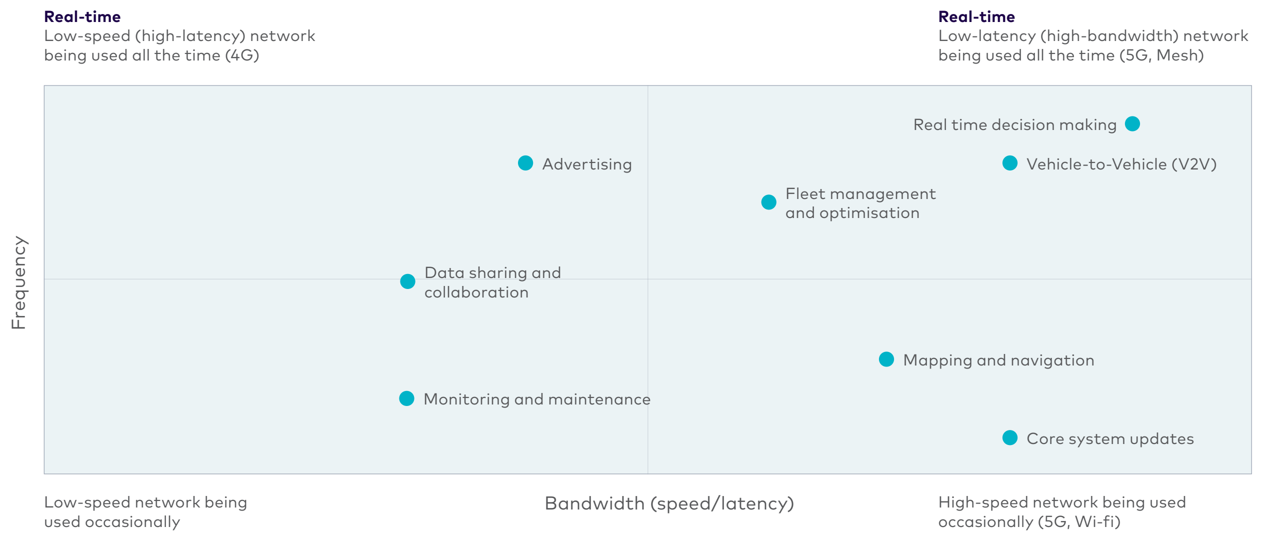
1. **Real-time data**
   Data required dynamically, generally identified as low latency and high bandwidth.
   Examples: *collision avoidance, remote operation*

2. **Near real-time data**
   Data required dynamically, but may not require the same latency as real-time data.
   Examples: *communicating information between vehicle and control centre like battery status, tyre pressures, weather updates affecting ODD*

3. **Passive data**
   Data generally identified as higher latency (compared to real time data) and high bandwidth.
   Examples: *in-vehicle entertainment like streaming music*

4. **One-time/irregular/batch data**
   Data in this category are generally associated with post-processing analysis and data that is not required on the move.
   Examples: *software updates, early warning identification.*

Figure 4.2: Data vs infrastructure network



4.3 Who: the key stakeholders and their elements in the value-chain

These elements of the value chain are designed, delivered and operated by several different stakeholders and it is important to understand what and how their roles relate to the infrastructure and data services in CAM and how their collaboration can enable the elements in the value chain.

The usage of data and data requirements were explored in the workshop hosted by Zenzic in August 2023. There were some similar data requirements from different stakeholders but with a different intention of how to utilise the same data and how they support the CAM services. particularly with regard to sharing of data and what will be the minimum requirements for each of these stakeholders.

The major stakeholders representing the value-chain:

Original Equipment Manufacturers (OEMs)

Organisations that design, manufacture, and sell CAVs are significant stakeholders these include both traditional OEMs and the new manufacturers for CAM specific vehicles. They rely on data services to improve vehicle performance, safety, and user experience.

Infrastructure operators

Stakeholders responsible for managing and maintaining physical transportation infrastructure, such as roads, traffic signals, and toll systems generally sit under the remit of Highway authorities. They utilise data services to optimise infrastructure utilisation, improve traffic flow, and enhance overall transportation efficiency.

Data service providers

Third-party companies that offer data collection, analysis, cyber security and management services for CAM. They play a crucial role in ensuring the availability of high-quality, reliable, and timely data for various mobility applications.

Regulatory bodies

Regulatory bodies oversee transportation policies, standards, and regulations. They are key stakeholders in advocating for and implementing data services to improve safety, efficiency, and sustainability in transportation systems.

UK CAM Roadmap to 2035 – Infrastructure and Data Services / **Zenzic**

Insurance organisations

Insurance organisations provide insurance for vehicles, infrastructure and their usage for CAM services. Data is the core element for them to understand the risks, relay the liabilities and thereby create informed insurance policies and viable business case.

Service Operators

Providers of mobility services, such as ride-sharing, car-sharing, and shuttle operators, rely on data services to optimise their operations, provide predictive maintenance, and improve the overall customer experience.

Transport Bodies

Organisations responsible for planning, managing, and regulating transportation systems at regional and local levels. They use data services to make informed decisions, optimise traffic flow, and enhance safety in their jurisdictions.

Technology providers

Technology providers are organisations that develop and supply technologies like hardware, tools e.g. sensors, communication systems, and data analytics tools for connected and automated mobility are essential stakeholders in the ecosystem. These also include organisations involved in the innovation and development of areas like cyber resilience, simulation and digital twin.

End users

This category includes passengers, fleet operators, and businesses that benefit from the data-driven services and applications, relying on the data services to access real-time traffic information, navigation, and other mobility solutions.

By collaborating and ensuring interoperability, these stakeholders can work together to advance CAM through data services.

5.0 / How

Enabling the delivery of Infrastructure and Data Services

The vision for infrastructure and data services as identified in the UK CAM Roadmap 2035 is:

'To enable the design, operation, maintenance and widespread utilisation of the network so that it can support the safe, secure and efficient movement of people and goods, and provide an environment in which commercial services will develop and grow.'

One of the underpinning areas of CAM development is collaboration across different sectors creating a fully functional supportive ecosystem.

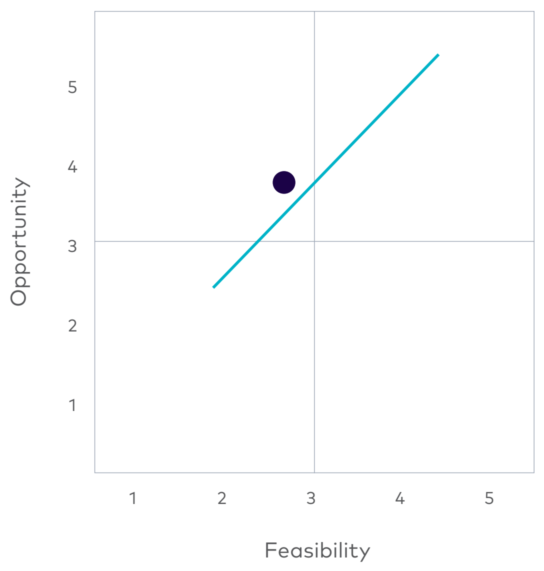
Developing partnerships across the sectors, including infrastructure and data services, is critical for the next few years to realise the commercialisation of CAM. How these partnerships evolve depends on understanding the opportunities and actions that can deliver the areas identified in section 4 and represented these with a Roadmap in section 5.2.

5.1 Assessment of Infrastructure and Data Services

The topic of infrastructure and data has been explored by many CAM stakeholders in the past couple of years. Zenzic hosted a workshop with industry stakeholders where an exercise had been carried out to explore and better understand the opportunity for this key area and its feasibility within the UK from the perspective of CAM stakeholders.

'Opportunity' represents the impact and improvement that infrastructure and data services can bring to the UK's competitiveness in CAM and the feasibility representing the current capability of this opportunity in the UK. The output from the workshop is depicted in Figure 5.1

Figure 5.1: Opportunity vs Feasibility in Infrastructure and Data Services



Source: Author generated

Opportunity assessment

5 Very substantial and persistent improvement in UK global self driving competitiveness

4 Substantial medium term improvement in UK global self driving competitiveness

3 Short term improvement in UK global self driving competitiveness

2 Minor and temporary improvement in UK global self driving competitiveness

1 No improvement in UK global self driving competitiveness or negative impact

Feasibility assessment

5 Capability already exists and in widespread use

4 Capability already exists and can be readily adopted by the supply chain

3 Capability required is available and can be adopted with concerted investment by government and industry

2 Capability required is identified but it is uncertain whether concerted investment by government and industry will realise

1 Capability required is unavailable in UK and no means is identified to obtain it

The output from the exercise indicated that with an improvement in infrastructure and data there is a high opportunity in the UK's competitiveness in the CAM sector but a lower feasibility indicated that there is a lack of capability in infrastructure and data presently in the UK.

Following further research and conversations with CAM stakeholders the following areas were uncovered for further actions and interventions:

- Better understanding of the connectivity and infrastructure needs vs the use cases against timescales
- Improved understanding of the true linkage between 5G and associated equivalents roll out and CAM capability for safety critical decision making in real time, for example in the use of remote monitoring and teleoperation.
- A clear understanding of the wider drivers and motivations for connectivity requirements and how these link to regulatory requirements of data when the vehicle is in use.
- Clarification of the data requirements and its usage and implications across a range of stakeholders.
- Having a clear recognition of any need for infrastructure digital twins and their implications on CAM deployment.

The following section will explore how these interventions could be exploited to build the future of the CAM in the UK.

5.2 Infrastructure and Data Services – Roadmap

In the executive summary of the UK CAM Roadmap 2035 (Zenzic, 2023), the top layer of what the Roadmap for CAM infrastructure and data services looks like was highlighted. In this roadmap, it is detailed further from a strategic point of view.

Note the key categories identified in delivering the infrastructure and data services are not isolated. There are dependencies on other CAM enablers and applications being developed as well but to keep the topic concise, here only infrastructure and data related to CAM is explored.

	Short Term (2023-26)	Medium Term (2027-30)	Long term (2031+)
Executive summary Roadmap – Infrastructure and Data Services	**Framework for the federated data architecture**	**V2X (vehicle to everything) connectivity and data availability**	**Seamless passenger connectivity**
	Defining the data requirements	Regulatory information digitised with agreements in place to share the required data	Connectivity with electric charging infrastructure
	Compiling, developing and building the federated data architecture	Vehicle to vehicle connectivity between different vehicles (owned by different providers)	Ubiquitous connectivity for the services enabled with connectivity
	Real time digital twins of the operating environment, including HD mapping	Vehicle to infrastructure connectivity between roadside infrastructure, vehicles and applications utilised to run services	Geographic information system (GIS)/ digital/data platforms driving services (public and commercial)

	Short Term (2023-26)	Medium Term (2027-30)	Long term (2031+)
	VISION – Sharing Data in CAM is legislated		
Data Standards and Cooperative Data Sharing	Establishing safety critical data and data packages for different stakeholders	Establishing data packages for cross sector organisations for different use cases	
	Defining and creating data standards and minimum legal requirements for safety critical measures for usage of CAVs	Defining and creating data standards and requirements across different usage of data	
	Definition of current best practice principles for cyber-secure vehicles and systems		
	R&D into cyber resilience capability throughout the vehicle lifecycle		
	UNECE CAV and cyber security regulations development		
		Create a national operational data hub	
			Research into cryptography for safety data
		Cyber Centre of Excellence	

	Short Term (2023-26)	Medium Term (2027-30)	Long term (2031+)
	VISION – Standardisation and interoperability of data architecture is achieved		
Federated Data Architecture	Review and consolidation of unified data exchange formats and interfaces.		
	Identification of data sources such as vehicles, infrastructure and environment		
		Data governance frameworks	
		Collaboration and partnerships with major stakeholders in ecosystem.	
			Local and national authority access and use of the architecture
		Security and privacy enhancements	
		Ai and ML integration to derive actionable insights from data gathered	
		Consumer education and acceptance	

	Short Term (2023-26)	Medium Term (2027-30)	Long term (2031+)
	VISION – Connectivity does not prevent CAM scale deployments		
National Coverage Plan	Understand use cases and requirements for CAM connectivity		
	Assess CAM requirements against current network coverage and capacity		
		Legacy fleet connectivity	
		80% of SRN enable with CAM connectivity	
	Define new operational models	Deploy new operational models	Increase network efficiency
	New planning and investment guidance		
	Agree communications approach at a national level	Repurpose infrastructure	

	Short Term (2023-26)	Medium Term (2027-30)	Long term (2031+)
	VISION – Digital assets in place for the testing and operation of CAM services		
Digital Infrastructure	Identification of data required from assets	Data collected from assets	Access to the data for public and private
		Security and privacy enhancements	
	Early virtual test environments deployed (testbeds)	Wider road virtual test environments developed	Develop automated validation
	Digitisation of road rules		
	Digitisation of signage assets	Phase out plan for fixed signs in place	

	Short Term (2023-26)	Medium Term (2027-30)	Long term (2031+)
	VISION – Infrastructure is ready for deployment of CAM with highly connected roads		
Physical Infrastructure	Identify gaps in the current infrastructure that need update to support CAVs		
	Develop business case for the physical infrastructure	Deploy CAM road infrastructure	
	Develop and deploy CAM road safety infrastructure		
		Planning for waste and redundant infrastructure	
			Repurpose infrastructure
	New planning and investment guidance for physical infrastructure to support CAM		
	Identify the overlap with other future transport solutions and their infrastructure needs		

	Short Term (2023-26)	Medium Term (2027-30)	Long term (2031+)
	VISION –Operational skills supporting development of infrastructure and data services in place		
Skills and Education	Gap analysis of skills and capabilities		
	Investing with industries in CAM skills		
		Strategic links with providers and centres of excellence	

Source: Author generated

Here the key categories identified are explored:

1. Data standards and cooperative data sharing
2. Federated data architecture
3. National coverage plan
4. Digital infrastructure
5. Physical infrastructure
6. Skills and education

Data standards and cooperative data sharing

One of the key benefits of connectivity is the ability to improve the efficiency and productivity. Due to the connected nature of CAM, this also involves the need for standardising the data. Cryptography research, specifying the safety critical data use cases and establishing common data formats for communications will be essential requirements in establishing these standards. This will ensure that the wide benefits connectivity brings to CAM start with safety at their core.

Foundational to the delivery of free-flowing roads, delivering safe, inclusive and desirable mobility, is the ability for vehicles to cooperate, for the time period of this roadmap there will be mixed fleets of vehicles and so cooperation between them is vital.. This is enabled by data sharing that will enable the vehicle population to make collective decisions about the CAM network operation. This will require the sharing of sensor data, regular uploads of journey information across vehicles as well as appropriate interfaces for data to be communicated to the driver.

The emerging themes for data standards and data sharing are safety, security, sharing data, ownership which can be regulated with having established standards and common data.

These data standards can be achieved with early investment from government and industry. This would not only ensure more resilient and trusted services but could also be a significant export strength for the UK in years to come.

Enabling cross organisational data sharing is a crucial first step. This includes agreeing what data must be shared between vehicles and infrastructure, specifying its accuracy and the mechanisms by which is will be both transferred and stored. This also provides us with vital information for the requirements of connectivity.

Federated data architecture

A federated data architecture refers to a system in which data is distributed across multiple interconnected entities, such as vehicles, infrastructure, and cloud-based platforms. This architecture allows for the sharing and processing of data from various sources to enable connected and automated mobility services.

In a federated data architecture, each entity within the mobility ecosystem retains control and ownership of its own data, while also sharing relevant information with other entities as needed. This can include data related to vehicle location, traffic conditions, weather, and other environmental factors. The architecture supports the integration of data from disparate sources, enabling more comprehensive and real-time insights for mobility services and applications.

By leveraging a federated data architecture, CAM systems can benefit from enhanced data quality, increased scalability, and improved privacy and security measures. This allows for the development of more efficient and intelligent mobility solutions that can better adapt to changing conditions and provide a safer and more seamless experience for users.

National coverage plan

To realise the benefits of ubiquitous CAM connectivity, incentivising cooperative protocols across the CAM services vehicle fleet is a key to maximising the intelligence and safety of the network. This will ensure that all vehicles meet minimum cooperative connectivity standards as defined by the rules of the architecture.

To have the seamless connectivity for CAM services there needs to be appropriate level of network coverage in the correct places to meet user requirements and demand. This is an area which is a critical enabler to CAM services being deployable at scale. This requires a clear understanding of the requirements imposed by CAM on the network and an understanding of where the gaps are to meeting those requirements.

Digital infrastructure

Simulation of the ODD and other digital infrastructure will allow both testing and development activities to be undertaken to provide testing activities and assist the operational deployment of CAM services. Virtual road environments will provide accurate proxies of the road network for testing which accelerates the progress of maturing connected and self-driving vehicles.

A real-time and dynamic digital twin of the physical environment that utilises 100% seamless connectivity to enable the design, maintenance, and exploitation of the network so that it supports the safe and efficient movement of people and goods and facilitates commercialisation of services.

Physical infrastructure

As vehicles become more connected and the driving task more automated, road infrastructure requirements are likely to change to support this transition. As such, new business models for different types of road infrastructure will be developed as new planning guidance is produced with CAM requirements in mind.

Having specific infrastructure in place to facilitate the development and testing of technologies and services is key to unlocking insights that inform regulation, service design and technology requirements. Research is required to obtain the probable impacts of CAM on physical infrastructures and find the way out of these limitations.

Skills and education

Bolstering the UK's supply chain capabilities and responding to the skills needed by industry to manage data and new infrastructure is critical. It is well recognised there are economy-wide skills shortages across emerging technology sectors. Cross-industry collaboration is critical to creating and filling a skills pipeline particularly for data and infrastructure services. A comprehensive review of current skills capability will inform and help to establish the necessary skills pipeline. Data analysis and cyber security are a strength in the UK and building upon these skills however there is strong competition beyond CAM. Sectors such as fintech, gaming and traditional IT are all working to fill gaps for these same skillsets. Furthermore, developing these skills can become one of the key exports for the UK CAM supply chain as detailed in the Zenzic's supply chain report (Zenzic, 2024).

6.0 / Key Messages and Priorities

Across the globe, progress has been made in the building towards CAM services. However, many of the current solutions are bespoke to the developers and environment in which they operate. There are few standardised solutions developing where there is clear collaboration between the OEM, ADS developer and the infrastructure operators that can yield a scalable solution.

Trials with AVs including V2X services are generally advisory in their capacity and not developed as safety systems.

There are deployments within the UK running until 2025 and possibly beyond with which important lessons can be learned around the role of data in the integration of these CAM services into the transport network.

There remain challenges when building on these early trial and deployments to a point where they can be scaled. What data is required to be sent and received by which stakeholders and who should have oversight of how that system is managed for safety and security purposes. How can improved connectivity and data support important stakeholders like insurance and what are going to be the regulatory obligations around the creation and storage of data for CAM services?

Furthermore, which other organisations are involved in the process once CAM is commercialised. CAM is a very complex sector involving multiple industries to come together and collaborate whilst still holding their unique value and knowledge.

UK CAM Roadmap to 2035 – Infrastructure and Data Services / Zenzic

Engagement sessions with specific stakeholder groups and further analysis identified the following actions as they key priorities and opportunities to address the gaps in feasibility:

Identify use cases and stakeholders for data packages

Require clear, concise use-cases to define the data requirements and subsequent infrastructure requirements to be defined. Creating clusters of the data for different stakeholders and building them into solutions and where applicable into regulations can be key to build the future of CAM in the UK.

Creation of data standards and data sharing frameworks

A package of work to understand which data standards and formats including security requirements apply to which use case of CAM services. This action can only be completed when there is a comprehensive understanding of the use cases and the requirements on the data in terms of quality, latency and security. The selection and consolidation of standards must be harmonious with applicable European and international standards.

Understand the current planned coverage and infrastructure strategy

Without infrastructure, certain functions of CAM services could still be deployed but integration into the wider transport system would be poor, thereby not providing the potential benefits being sought with CAM services. It is critical to understand the requirements of infrastructure in other future transport solutions particularly of how well areas like connected vehicles are linked to CAM. Furthermore, understanding the true capabilities of 5G and similar connectivity providing a true understanding with the linkage to safety critical aspects of CAM.

CAM inclusion in the National Digital Twin programme

A programme of work, integrating the CAM sector into the development of federated digital twins for the wider transport network. Key CAM stakeholders need to be involved in the national digital twin programme to feed in the specific requirements around CAM for operational digital twin of the infrastructure. A dedicated programme of work across transport and regional authorities to educate and inform on the vision of a federated digital twin and ensure user requirements for CAM are captured is needed.

Standardisation and maintaining HD-maps in real-time

Currently the HD maps being developed by OEMs/ADS developers are for the purpose of research and development , such as running pilots. To maintain these HD-maps in real-time and to achieve standardisation is not realistic if they are held by OEM/ADS developers. In the near term, a short programme of work is required to understand the responsibilities and processes for the wider-scale development of HD maps. This exercise can then inform the longer-term vision of included HD maps with the federated digital twins of the infrastructure.

Collaboration with different stakeholder groups

A number of notable stakeholder groups are associated with development in these areas including UKTIN, Work Stream 6 of the CAVPASS programme, Automotive council, and the National Infrastructure Commission.

A call for a unifying effort around stakeholders' collaboration to understand the demand of infrastructure and data services and the requirements that will help the UK build the data and infrastructure services. This is much wider than a technical group and must consider the development of commercial models and who pays for services which deliver collective benefits.

Identify the gap in skills

There is a gap in the skills required for data analysis and synthesis within and beyond CAM. By focussing on the data analysis and data science skills gap, the pressing industry need for a provision of processed data to support product and purpose can be addressed. Transferring cyber security and resilience skills from other sectors can also play a vital role in CAM services, and particularly with data.

UK CAM Roadmap to 2035 – Infrastructure and Data Services / Zenzic

7.0 / References

BSI (2023).
BSI Flex 1886 v1.0:2023-08 Remote operation of vehicles

Available from

www.bsigroup.com/en-GB/insights-and-media/insights/brochures/bsi-flex-1886-system-aspects-for-remote-operation-of-vehicles-guide/

[Accessed 11 February 2024]

Law Commission (2023).
Remote driving: Advice to Government

Available from

https://s3-eu-west-2.amazonaws.com/cloud-platform-e218f50a4812967ba1215eaecede923f/uploads/sites/30/2023/02/RD_Advice-paper_LC.pdf

[Accessed 11 February 2024]

UNECE 156 (2021).
4th March 2021 version

Available from

https://unece.org/transport/documents/2021/03/standards/un-regulation-no-156-software-update-and-software-update

[Accessed on 15 February 2024]

Zenzic (2024).
Identifying the UK CAM Supply Chain. An industry report authored by Zenzic with support from AESIN.

Available from

https://zenzic.io/insights/strategic-research/supply-chain/

[Accessed 15 February 2024]

Zenzic (2023).
The UK Connected and Automated Mobility Roadmap to 2035 | Executive Summary

Available from

https://zenzic.io/content/uploads/2023/03/Roadmap-to-2035-%E2%80%93Executive-Summary_v6.pdf

[Accessed 11 February 2024]

zenzic.io

United Kingdom