ZENZIC

The UK Connected and Automated Mobility Roadmap to

2035

Executive Summary | Building on from the 'Roadmap to 2030'

United Kingdom

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Contents

DISCLAIMER

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Abbreviations

Abbreviation	Definition
AI	Artificial Intelligence
CAM	Connected and Automated Mobility
CAV	Connected and Automated Vehicle
CCAV	Centre for Connected and Autonomous Vehicles
EV	Electric Vehicle
NUiC	No-User-in-Charge
ODD	Operational Design Domain
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Everything

1 | **Foreword**

In 2019 Zenzic published the UK Connected and Automated Mobility Roadmap, setting out a clear ambition and vision for Connected and Automated Mobility (CAM) in the UK for the first time, and laying out a clear path depicting how all the economic, environmental and societal benefits which CAM has to offer could be unlocked.

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That Roadmap was a foundational tool for the UK ecosystem to use in strategic decision-making, and was used by organisations across the world to define their own technology and business goals.

Since then the UK has continued to pursue with purpose its vision of becoming a world leader in CAM, and has been investing in the development of both the technology and the regulations needed to safely and securely deploy CAM services. The progress made in the UK so far has been effective, in part, due to due to alignment around the common vision of the Roadmap and the clearly defined 'critical enablers'.

Today the world looks very different, with the past four years seeing a monumental level of societal impact and change, both globally and domestically. It is only right that the UK CAM Roadmap is re-evaluated to understand its current status, and understand where the UK CAM sector should focus its efforts to maximise the opportunity ahead.

In an emerging sector where there is a global race to secure a new future for mobility, there is a need to identify how the UK CAM sector can remain competitive and continue to improve, and how the unique capabilities of the individual organisations can find a path to commercial sustainability and competitiveness.

The answer is not straightforward, and by no means can all the answers be found in this Roadmap, but some things have become clear as UK CAM stakeholders have tackled this challenge over the last few years, aiming to retain and improve the UK's competitiveness. Firstly, the UK must recognise where its strengths lie. Doubling down on areas of strength, and focus investment in places where the country is already competitive in established markets. The UK CAM sector must collaborate to provide the opportunity for value creation through the strength of supply chains to deliver world-class deployments, operations, and the regulatory and investment environment which will enable economic, environmental, and social benefits. This Roadmap is a tool for that collaboration.
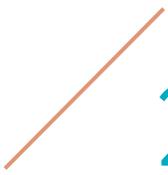
2 | **Introduction**

Connected and Automated Mobility (CAM) is a key priority for the UK, with an ambitious vision described by the UK government's Centre for Connected and Autonomous Vehicles (CCAV) as follows:

"By 2025, the UK will begin to see deployments of self-driving vehicles, improving ways in which people and goods are moved around the nation and creating an early commercial market for the technologies.
This market will be enabled by a comprehensive regulatory, legislative and safety framework, served by a strong British supply chain and skills base, and used confidently by businesses and the public alike."

(CCAV, 2022)

The UK CAM Roadmap is a tool to help realise the vision of CAM for 2025 and beyond, by showcasing the vital services and technologies being designed, developed and ultimately deployed in the UK, powered by high-value skills, a strong supply chain, and driven by public demand for the UK to benefit from proven CAM services and technologies.

This Roadmap explores the critical challenges and priorities which must be addressed to make the vision a reality, advancing the CAM stakeholders' actions towards creating value and, in-turn delivering the benefits.

2.1 Background

Over the past few years, the UK has been in a period of significant social and economic flux. Transport is a fundamental component of societal change because it delivers 'mobility', the effective and efficient movement of both people and goods. The improved movement of people and goods has the potential to increase productivity, accessibility and inclusivity, and thus make a positive impact on the UK economy as a whole.

Mobility itself is being transformed by the new technologies associated with connectivity and automation, including self-driving. Connectivity enables the flow and aggregation of data, leading to a better informed public and provision of new and improved services. At the same time, the advent of connected and automated vehicles (CAVs) brings the potential for improving road safety with a significant reduction in the opportunity for human error.

The global challenge faced is to deliver these benefits rapidly and competitively. The only way to make progress at pace is for the whole sector to increasingly align towards collective goals – working with a wide cross section of stakeholders who will be instrumental in reaching those goals. To enable the co-ordination and alignment of the vision for CAM, the Roadmap was created as a decision-making tool to unlock those challenges for policymakers, industries and investors in the CAM sector.

September 2019 saw the first release of the UK Connected and Automated Mobility Roadmap to 2030, updated in 2020 to reflect progress made and to showcase those organisations delivering on the vision detailed in the Roadmap, identified as the 'CAM Creators'.

2.2 Purpose

This update to the UK CAM Roadmap builds on the solid foundation of the previous version and provides an updated comprehensive guide to CAM in the UK. It can act as a decision tool to inform and guide the various stakeholders of the CAM ecosystem.

The focus of this update is threefold:

O1 /

A restructuring of the Roadmap

to bring clarity about the key drivers, problems and solutions of CAM, and a clear understanding of its benefits

O2 /

Improving its readability

for the sake of the diverse stakeholders involved in the CAM sector

O3 /

Extending its horizon

from 2030 to 2035

2.3 The UK CAM Integrated Roadmap: A Holistic View

The previous version of the Roadmap was focused primarily on the process (the activity to be undertaken), and the output (the deliverables) or outcome (the result of a process and/or output), which were described as the 'milestones'. This inevitably meant there was much more focus on the technology and systems without any clear link to either value creation or an economic, environmental, or social need. Each of these milestones had been categorised under a theme, and within each theme, a stream. These milestones were not adequately linked to value creation opportunities or wider benefits.

In this update of the roadmap the elements of the previous version were taken as the foundation. Through a series of workshops with a broad range of stakeholders the original elements were re-appraised to create a new CAM landscape. These stakeholders include:

1. Policymakers
2. Local authorities
3. CAM testbeds
4. Insurance and legal organisations
5. Investors
6. Transport services operators
7. Original Equipment Manufacturer (OEMs)
8. Vehicle service providers.

The process for the workshops can be described in three key stages:

- Identifying the 'why': global and regional trends and drivers; market opportunities for, and benefits, of CAM; to deliver economic, environmental and/or social benefits

- Determining the 'what': what products, services and solutions have the potential to address these trends and drivers. It is critical that this layer is capable of value creation and can enable the UK to be a leader in the CAM sector

- Defining the 'how': what capabilities and enablers are required to enable the realisation of the products services and solutions. These capabilities and enablers will support the products, services and solutions to create value and in turn deliver the economic, environmental and social benefits.

These stages align with how the Roadmap is represented in this edition. The process to work through these three stages with engagement from a range of stakeholders across the CAM ecosystem is vital to how the critical actions can be traced back to economic, environmental and/or social benefit.

A series of feedback sessions took place to test the content of the Roadmap and derive the key messages for stakeholders. This information was then synthesised into the integrated Roadmap to develop its key messages and priorities. The integrated Roadmap synthesises the information in three layers, each layer representing one of the key stages of the Roadmap update process as shown in Figure 2.1

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 & 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 & 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: Author Generated

3 | Why: Trends and Drivers

The workshops identified global trends and drivers, which enabled the stakeholders to identify opportunities for the UK CAM Sector. Table 3.1 shows these trends and drivers, and the various opportunities associated with each.

Table 3.1: Trends and drivers, with opportunities

	Trends and drivers	The opportunity for CAM sector	The opportunity for the UK government and industry	The opportunity for the public
Societal Needs & Demands	**Rising expectations and the need for easy access and convenient options**	The creation of CAM services and solutions that are demand driven, efficient, connected and easily accessible	Improved productivity, in turn helping the UK economy Improved access to transport services connecting rural areas to regional hubs New business prospects	Increased productivity Inclusive transport options
Sustainability	**A more sustainable, environmentally friendly transport solution**	Providing solutions which involve efficient planning and routeing to minimise environmental impact	CAM playing a part in the Net Zero objectives	A more sustainable and environmentally friendly world to live in
Societal Needs & Demands	**Public transport options & requirements for rural areas**	Providing CAM solutions which serve as public transport options, also creating services suitable for rural areas	Better connectivity for people in rural areas to regional hubs Increased productivity and investment in regions resulting from better transport solutions	Access to transport solutions when and where needed
Industry & Economic Benefits	**Government agenda for Levelling Up and growing the CAM supply chain in the UK, with development of new technologies**	Providing CAM services & solutions which build on the strengths in the UK CAM supply chain	Strengthening of the UK CAM supply chain, retaining and creating new highly skilled jobs for the UK Attracting investment into the UK which in turn improves productivity	New job opportunities Improving skills, qualifications, and training opportunities Improved geographic distribution of jobs

	Trends and drivers	The opportunity for CAM sector	The opportunity for the UK government and industry	The opportunity for the public
Industry & Economic Benefits	**Labour shortages creating a shortage in the availability of professional drivers for vehicles**	Providing solutions which are less reliant on drivers and create solutions for a better working environment for drivers/operators	A credible solution to labour shortages Increased productivity having a positive impact on the economy	Professional driving can become a more attractive, inclusive and accessible career Freight and logistics able to meet increasing consumer demand
	Developing and maintaining skills in the UK to remain competitive	Identifying skills and training requirements for both the design and development of CAM solutions as well as the operation of services	Investment in skills and training which ensure productivity in the longer term	Access to skills, training, and qualifications to support job security
	Strong international competition to stay on the forefront of driving innovation	Solutions and services which draw on the strengths of the UK CAM supply chain and utilise international expertise to the UK's advantage	Good positioning of the UK internationally such that it is recognised as a place to invest in CAM	UK strengths and investment bringing highly skilled jobs and job security
Societal Needs & Demands	**Increased safety and security travel options**	Providing services to help ensure the safety and security of solutions through testing and extensive validation Providing options for improved personal safety and security	Provision of world-class regulation which protects safety and provides the opportunity for the UK to be a leader Travel options for the public which are inclusive and safe	Confidence in the services and solutions provided as being safe and secure

Source: Author Generated

In addition to identifying the opportunities, the threats were also considered:

These threats are broadly applicable to all potential products, services and solutions being developed in the CAM sector. It is therefore critical that the threats can be mitigated by specific actions identified from the roadmap and ensure that selected capabilities and enablers are resilient to the presence of these threats. Some of the key imminent actions are described in Section 6.

- Rapidly evolving technologies with a rapid obsolescence cycle
- Slow-moving creation of regulation/standards inhibiting deployment of CAM at scale
- No clear overarching strategy aligning different transport solutions
- Lack of widespread bandwidth and low latency connectivity across the UK, preventing fully interconnected systems and CAM services

- Dependency on cross-sector ecosystem and development in the areas of connectivity
- Near misses or incidents potentially having an impact on public confidence and therefore the timing and adoption of deployments at scale
- No common language/understanding for the public and industry
- Unknowns in the longer-term threat landscape (e.g. cyber vulnerability)

4 | **What: Key CAM Areas for the UK**

As a product of the workshops, key areas (products, services and solutions) of opportunity for the CAM sector were identified; these were categorised into two groups:

01 /

CAM Applications

Services that can be deployed in the UK to realise the benefits of CAM:

- Off-highway (without public access) vehicles and services

- Freight & logistics vehicles and services

- Personal mobility vehicles and services

- Public transport vehicles and services

02 /

CAM Enablers

Services that enable the CAM applications:

- Verification, validation, and assurance services

- Infrastructure and data services

Off-highway (without public access) vehicles and services

The vision for off-highway CAVs is to create vehicles that can operate safely and efficiently in controlled environments which are off the public roads, including private sites, and remote and hazardous environments such as mines, construction sites and agricultural fields. The ultimate goal is to improve safety, increase productivity and reduce costs for industries that rely on off-highway vehicles, while also reducing the overall environmental impact, and improving the working environment for the operators.

Freight & Logistics (F&L) vehicles and services

The vision for CAVs for freight & logistics is to provide safe, efficient, and cost-effective transport of goods over both short and long distances. Short-haul connected and automated freight vehicles might include delivery robots or small vehicles that can transport goods within a city or neighbourhood or larger vehicles transporting goods. Long-haul connected and automated F&L vehicles might include vehicles such as heavy goods vehicles (HGVs) and light goods vehicles (LGVs) that can transport goods across the UK. By changing the demand for human drivers, these vehicles are expected to reduce transport costs and increase efficiency, at the same time reducing emissions and improving road safety. Ultimately the goal is to create a more sustainable and reliable freight transport system which benefits businesses and the public alike.

Personal mobility vehicles and services

The vision for connected and automated passenger vehicles is to have vehicles that can operate without human intervention, using sensors, cameras and advanced algorithms to safely and efficiently transport passengers to their desired destination. The goal is to improve safety, reduce traffic congestion, and increase accessibility for individuals who are unable to drive themselves. Ultimately the aim is for an enjoyable travelling experience.

Public transport vehicles and services

The vision for connected and automated public transport systems is to provide safe, efficient and affordable transport options for large numbers of people, using vehicles that operate without human drivers. These systems are expected to reduce traffic congestion, improve mobility and increase accessibility to transport, while also lowering emissions and reducing energy use. They may include vehicles with varied capacity of people such as buses, shuttles, and pods that are connected through a central control system, allowing for optimised routeing and scheduling. Ultimately the goal is to create a more sustainable and equitable transport system, one which benefits all members of society.

4.2 CAM Enablers

Verification, validation and assurance services

The vision is for the UK to be leading the way in developing and delivering assurance standards, services, and processes. This is critical for reassuring a range of stakeholders – from the public and government to industry and insurers – that self-driving vehicles are indeed safe and secure. This will position the UK as a leader in the provision of product development assurance, pre-certification, and whole-life assurance.

Infrastructure and data services

The vision for data services 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 provide an environment in which commercial services will develop and grow.
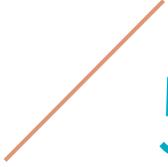
5 | How: Delivery of the key CAM areas

Collaboration is critical for realising the benefits of CAM, and the UK CAM sector therefore needs to identify its strengths and actively work in those areas, joining with other countries where they have strengths which complement the UK's specialisms.

The UK CAM Roadmap was developed to showcase those specialist capabilities.

In this update of the Roadmap, a link is made to the value creation opportunities that exist in the delivery of CAM products, services and solutions.

The capabilities and enablers are for one or more of: the products, the services, and the solutions.
The workstreams each have specific capabilities and enablers but also common capabilities and enablers, many of which can be initiated for one application, but later utilised for another application with appropriate changes. Table 5.1 identifies the areas that the stakeholders have identified as key to the delivery of CAM, dividing the capabilities and enablers into those to be fulfilled in the short, medium and long term.

Table 5.1: Key CAM areas capabilities and enablers

Product, services, solutions	Short term (2023–26)	Medium term (2027–30)	Long term (2031+)
Off-highway vehicles and services	**Early commercial service models ready for investment** • Partnerships between operators and technology or solution providers • CAM services within limited Operational Design Domains (ODDs) addressing driver shortage, efficiency, improvement and safety • Input to the development of legislation with early deployments, and supported with evidence • Vehicle platforms development, including identifying the supply chain requirements for the vehicle • Identification and establishment of training and skills required for this service • Identification of the CAM supply chain requirements for this service and creating cost-effective technology/product solutions	**Monitoring and refinement followed by expansion of the Operational Design Domains (ODDs)** • Supporting (adding value to) services and opportunities in other CAM applications • Manufacturing of vehicle platforms ready for No-User-In-Charge vehicles (NUiCs) at scale • Cost-effective technology/product solutions (e.g. for sensors, HD mapping, road infrastructure)	**Creation of integrated systems and services** • Integration with site systems and performance of complex tasks without human intervention • CAM-enabled integrated supply chains providing mobility solutions
Freight & logistics vehicles and services	**Commercial deployment pilots** • Partnerships between lorry operators and technology or solution providers • Deployment trials to support the development of service/business models for freight & logistics services • Artificial Intelligence (AI)-enabled load route/task planning • Development of vehicle platforms, including identification of the supply chain requirements for the vehicle and freight service • Identification of training and skills required for this service • Identification of the CAM supply chain requirements for this service	**Commercial service models ready for investment** • Deployment of long (>=10 km) and short freight (<10 km including last mile) services within identified ODDs • Manufacturing of vehicles, including major subsystems such as braking and steering (ready for NUiCs) at scale • Cost effective technology/product solutions (e.g. for sensors, HD mapping, road infrastructure) • End-to-end CAM skills pipeline established	**Monitoring and refinement followed by expansion of the ODDs** • Integrated business case of short- and longer-haul delivery

Product, services, solutions	Short term (2023–26)	Medium term (2027–30)	Long term (2031+)
Personal mobility vehicles and services	**Commercial deployment pilots** • Introduction of No-User-In-Charge vehicles (NUiCs) in specific use cases such as automated lane-keeping systems (ALKS), valet parking as optional feature in privately owned vehicles • Deployment trials to support the development of service/business models for personal mobility • Identification of training and skills required for this service • Identification of the CAM supply chain requirements for this service	**Commercial service models ready for investment** • Deployment of personal mobility vehicles for personal ownership and services such as sharing and car clubs within identified ODDs • Manufacturing of vehicles ready for NUiCs at scale • AI-enabled load route/task planning • Partnership between operators and vehicle providers • Cost-effective technology/product solutions (e.g. for sensors, HD mapping, road infrastructure) • End-to-end CAM skills pipeline established	**Monitoring and refinement followed by expansion of the ODDs** • Integrated business case enabling efficient transport of people
Public transport vehicles and services	**Commercial deployment pilots** • Partnerships between operators, local authorities and technology or solution providers • Deployment trials to support the development of service models for public transport • Development of mobile applications needed to access the service • Identification of training and skills required for this service • Identification of the CAM supply chain requirements for this service	**Commercial service models ready for investment** • Deployment of public transport services, and services within identified ODDs • Manufacturing of vehicles ready for NUiCs • AI-enabled load route/task planning • Cost effective technology/product solutions (e.g. for sensors, HD mapping, road infrastructure) • End-to-end CAM skills pipeline established	**Monitoring and refinement followed by expansion of the ODDs** • Integrated business case enabling efficient transport of people

Source: Author Generated

Product, services, solutions	Short term (2023–26)	Medium term (2027–30)	Long term (2031+)
Verification, validation and assurance services	**CAVs framework in place** • Pre-certification validation (within organisation) • Primary legislation in place • Consultation for secondary legislation – research to support assurance standards, and product development assurance • CAM ecosystem to collaborate to focus on the public perception of CAM and its benefits	**Framework for the life cycle of CAM services** • Secondary legislation in place for commercial service models • Whole-life assurance (includes aftermarket services of maintenance and replacements)	**Monitoring and refinement followed by expansion in CAM deployment areas** • Legislation and regulations to support the integrated business case, enabling efficient transport of people and goods
Infrastructure and data services	**Framework for the federated data architecture** • Defining the data requirements • Compiling, developing and building federated digital architecture • Real time digital twins of the operating environment, including HD mapping	**V2X (vehicle-to-everything) connectivity and data availability** • Regulatory information digitised with agreements in place to share the required data • Vehicle-to-vehicle (V2V) connectivity between different vehicles (owned by different providers) • Vehicle-to-infrastructure (V2I) connectivity between roadside infrastructure, vehicles and applications utilised to run services	**Seamless passenger connectivity** • Connectivity with Electric Vehicle (EV) charging infrastructure • Ubiquitous connectivity for the services enabled with connectivity • Geographic Information System (GIS)/digital/ data platforms driving services (public and commercial)

5.1 CAM Strengths and Weaknesses

The delivery of CAM services and enabling systems is wholly dependent on the UK having a competitive CAM supply chain; it is this competitive and fit-for-purpose supply chain which will deliver the value creation potential identified in the products, services, and solutions.

An analysis of the UK CAM supply chain was published in September 2022, and showed the areas in which the UK's strength lies – and where the UK can lead the way with its businesses taking a proportionate share of

the global market (Zenzic, 2022). Alongside, an evaluation of the strengths and weaknesses for the identified capabilities and enablers was conducted during the workshops, aimed at determining the UK's strengths to deliver the capabilities and enablers and in identifying potential weaknesses which would require action to close the gaps and ensure that products, services and solutions can be realised and deliver the economic, environmental and social benefits. Two major weaknesses stood out: one is the lack of detailed legislation and associated legal frameworks, and the other is the lack of the necessary connectivity required for the deployment of CAM services at scale.

The establishing of primary and secondary legislations is identified as both a strength and a weakness, demonstrating that while the UK does have the potential to create the primary and secondary legislation, action must be taken imminently if the UK's CAM leadership is to be maintained.

The actions within the key priorities seek to address some of the weaknesses identified, and build on the strengths, to give the best potential for value creation from the CAM services and enablers identified in Section 4.

CAM Strengths

- The UK has a broad understanding of the CAM landscape and ecosystem, one that cuts across current silos and enables a comprehensive strategy for CAM services to be built

- There has been progress towards establishing the UK primary and secondary legal framework and regulations, and promote appropriate legislation for CAM

- The UK has been a leader in the development of feasibility studies and innovation trials for CAM. The government has recently announced government and industry funded deployment projects

- Early initiatives have been taken in the direction of CAV 5G that can support the deployment of CAM services

CAM Weaknesses

- Not enough focus on planning and strategy development for CAM skills, including preparing wider industry and public for deployment of CAM at scale

- Greater alignment required across stakeholders to integrate CAM services into the transport network

- Slow movement of the work associated to harmonise international regulations

- Renewed effort across government and industry to achieve the target of having effective regulations by 2025

6 | Key messages and the priorities

From an analysis of each of the CAM services and enablers, examining the opportunity and feasibility of each, it is clear that there is significant opportunity in each of the areas, from small-scale to wider-scale deployments.

The feasibility, however, varies; engagement sessions with specific stakeholder groups identified the following actions as having the near-term potential to address any gaps.

A programme of regulatory developments:

The government should provide clarity and a timeline for the programme of work to introduce UK regulations to enable the CAM market to move to deployments at scale. This programme of work must have the full support and engagement from a cross section of the industry, from developers to operators.

Investment in public 5G and future infrastructure:

The Government should enhance public investment in public 5G and future telecommunications infrastructure to ensure that CAM services can access resilient, high-quality and low-latency communications. Whilst this recommendation is not a requirement for autonomy, it is

Skills and education:

The Government should work across departments to ensure that there is a clear understanding of the education and skills requirements of the sector. This applies to both the skills in designing and developing CAM systems as well those to operate CAM services.

Whole life-cycle costs for CAM services:

Government, industry and operators should collaborate to understand the whole life cycle costs of CAM services and CAVs. This will support the decision making of operators and local authorities.

Identification of the requirements of data:

There is a need to understand which forms of deployments at scale require which quality of data, and infrastructure for bandwidth, speed and latency. It is important to understand the requirements of which applications can use which parts of the existing infrastructure and which will require new infrastructure. It also important to have a clear understanding and agreement of who will own the data being exchanged on these systems and for what purposes.

Greater engagement with the insurance industry:

There is a need to ensure that insurance is an enabler and not a barrier to wide-scale deployments. Insurance will be a critical element in the successful transition to deployments at scale, and therefore a start should be made now on putting into place the requirements and systems.

Industry & operator awareness:

Government and industry should collaborate to help operators understand CAM services and their benefits better. A specific programme is required to ensure that the gap between CAM providers and operators is reduced, enabling more operators to make effective deployment decisions.

Public confidence in CAM:

Government and industry should collaborate to focus on the public perception of CAM and its benefits. Whilst some good work has already been done, this needs to continue as deployments take shape.

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Want to find out how the Roadmap can benefit your organisation and CAM projects?

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