ZENZIC

UK Connected and Automated Mobility Roadmap to 2035 –

Verification, Validation and Assurance

April 2025

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United Kingdom

Contents /

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Acronyms

Abbreviation	Definition
AI	Artificial Intelligence
ASDE	Authorised Self-Driving Entity
AV	Automated Vehicle
CAM	Connected and Automated Mobility
CAV	Connected and Automated Vehicle
DCAS	Driver Control Assistance System
NUiC	No User In-Charge
ODD	Operational Design Domain
OTA	Over the Air
SoS	System of Systems
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
V2X	Vehicle to Everything
VVA	Verification, Validation and Assurance

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 data of the first CAM Roadmap to 2030, 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 detail of the key area – 'Verification, Validation and Assurance Services'.

This topic Roadmap presents the recommendations of a project updating Zenzic's Verification, Validation and Assurance (VVA) topic roadmap, as well as showing some of the underlying evidence base that helped inform the recommendations. The VVA topic roadmap forms part of the 'What layer' of Zenzic's three layered UK CAM Roadmap to 2035. The three layers are:

Why? Trends and drivers

What? Products, services and solutions

How? Capabilities and enablers

The report findings are based on a synthesis of information from the three strands of work that informed this project:

- Review of the existing VVA topic Roadmap
- Extensive evidence reviews of VVA and adjacent areas, both in the UK and internationally
- Stakeholder engagement workshops with subject matter experts and representatives from across the commercialising CAM ecosystem.

1.1 Recommendations

The following key recommendations should be considered for verification, validation and assurance of the CAM services.

Lifecycle Safety Assurance

Extend the horizon of VVA from focusing on the development of vehicles and systems to focus on covering the whole life span of safety assurance for Connected and Automated Mobility (CAM).

Continuous Verification, Validation, and Safety Assurance (VVA) processes are required throughout the life cycle of CAM products or services.

Processes for CAM infrastructure

VVA should not be considered as only encompassing the vehicle and its system. CAM-related infrastructure as well as the interconnecting capabilities (is considered to be part of the CAM service delivery) will also require VVA processes to ensure safe operation.

Credible simulation toolchains

Simulation toolchains contribute to the VVA processes. For example, a robust simulation tool is a prerequisite for meaningful simulation results. Better understanding of the correlation between physical and virtual testing also needs to be established.

Priority need for sectors that are engaged in early-stage deployment

Options for possible routes to be considered for enabling advanced trialling and early commercial pilots to be deployed in advance of full implementation of the AV Act. This includes working with industry to explore what they need and how to deliver this within existing legislation as their more urgent demand for a VVA and approval process should be managed dynamically in the short term until established VVA processes are developed.

These early adopters could also inform via lessons learned how to continuously improve the end-2-end process.

Roles and responsibilities among stakeholders

Roles and responsibilities among stakeholders have changed. For instance, regulators and insurers will likely need to be able to have access to the data and development processes in contrast to the current situation.

Two entities have been created in the AV Act to address the Responsibility shift (ASDE/NUiC Operator)

Two new entities have been created in the AV Act to address the responsibility shift. The VVA processes related to Automated Self-driving Entity (ASDE) and No User in Charge (NUiC) operator are recommended to be considered in the VVA processes and landscape.

Timeline for the CAM VVA roadmap

To underpin the timeline for the CAM VVA roadmap, it is important to consider the scale of the needs for each stage in product/service life cycle.

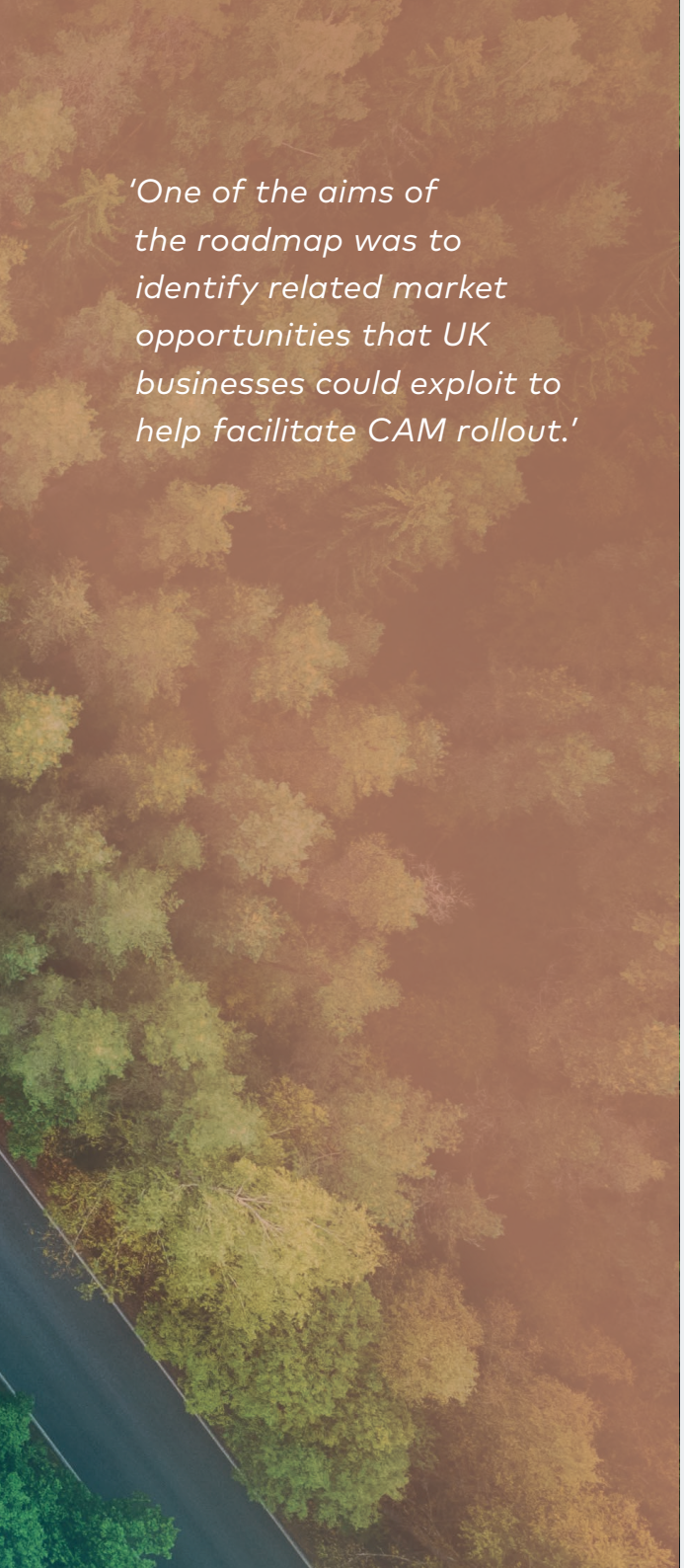
2.0 / Overview

2.1 Background

In 2020, Zenzic launched the UK's first CAM roadmap, a comprehensive multistranded document designed to present all the different activities that needed to happen in the CAM space and related areas to lay the path to deployment of automated vehicles in the UK. One of the aims of the roadmap was to identify related market opportunities that UK businesses could exploit to help facilitate CAM rollout. This initial roadmap was given a significant revision in 2022, and is now undergoing a third substantial update. To improve usability and focus, the latest revision has split the roadmap into distinct topic areas.

TRL have been commissioned by Zenzic to undertake a review and update of the verification, validation and assurance topic of the roadmap. A methodology was developed that would ensure:

- Relevant elements of the current roadmap were kept in place
- Key gaps or omissions were identified and filled
- Updates based on information not available at the time of the previous roadmap were incorporated.



'One of the aims of the roadmap was to identify related market opportunities that UK businesses could exploit to help facilitate CAM rollout.'

2.2 Purpose

The role of the roadmap is to identify areas of potential development that may be needed to deliver on VVA ambitions by different organisations (including government).

The roadmap is primarily used by three groups:

1. Firstly, it is of use to those who already work in the CAM sector and who are already positioned in the supply chain. It is designed to help them navigate the sector and understand how what they are doing connects and relates to everything else in the CAM ecosystem, and therefore who they should be talking to, and where there are opportunities to collaborate.

2. Secondly, because CAM is a dynamic, growing and multi-faceted industry, new entrants often with proven technologies or solutions from other sectors, want to understand how they or their products may fit into CAM, and how they might interface with other aspects of the sector, and therefore who they should potentially be talking to and collaborating with.

3. The roadmap in combination with supply chain analysis enables government to take a view to where interventions may be necessary to develop UK capability or provide incentives for innovation in specific areas.

3.0 / Why

The Role of Verification, Validation and Assurance in CAM

3.1 What do we mean by Verification, Validation and Assurance within CAM?

In the automotive sector, verification and validation are well established elements of the vehicle development process that help ensure manufacturers meet the type-approval and certification requirements that allow them to place their vehicle on sale, thereby providing the assurance, particularly in relation to safety, needed. Traditionally, the verification and validation process has involved a substantial amount of physical testing, predominately on purpose-built test tracks. As technology has evolved, the features being offered are more complex. This complexity is further exacerbated by the exponential growth in computing power. The result is that an increasing proportion of verification and validation that has incorporated simulation-based testing.

The complexities and nature of connected and automated vehicles (CAVs) mean that robust verification and validation of their capabilities and safety are critical to regulatory and public acceptance. Furthermore, the ability to update and change features on a CAV across its lifespan, and the diffuse range of responsibilities once deployed, means that VVA is an essential whole life activity if safety and trust in automated vehicles are to be maintained.

Fundamentally Automated Vehicles (AVs) and closely adjacent technologies necessitate a paradigm shift in the definition and scope of VVA. This poses substantial challenges but will also enable significant opportunities within the CAM ecosystem as CAM VVA activities undergo the incremental shift from trials and testing to commercialised products and services.

VVA as an area is likely to be relevant to a very broad spectrum of the extended CAM community, from those in practical and hands on roles, via those with deep technical knowledge, to those writing legislation, regulation and standards. Distilling the key elements of VVA across such a spectrum in a way that everyone can understand is paramount for maximising market opportunities for UK businesses.

'Fundamentally, the cross cutting nature of CAM... means that VVA necessarily cannot fall under the remit of one sector, organisation or agency. Instead it demands a collaborative approach.'

3.2 Review of Verification, Validation and Assurance in the current roadmap

The Zenzic Roadmap was last updated less than two years ago. A number of factors have determined how CAM has progressed against the roadmap since then. These factors are likely to remain in play to varying degrees for the lifespan of the roadmap, and may have considerable impact on timings and milestones, for example legislative progress and technological advances. Fundamentally, the cross-cutting nature of CAM – dictated by the wholesale shift in how people and goods are transported that CAM envisages - means that it necessarily cannot fall under the remit of one sector, organisation or agency. Instead it demands a collaborative approach, but with actors that have considerably different dynamics, operating models, responsibilities, legal obligations, and appetites for risk. As a result, progress against the existing roadmap is expectedly mixed. Furthermore, some fundamentals, a number of which fall under VVA, are likely to remain. This will include elements like approval processes both for the vehicle and the service, and how whole life assurance is realised.

A detailed analysis of the existing roadmap falls outside of the scope of this report; however some high level observations can be made. Predominantly these observations are the number of the short-term items on the roadmap that continue to be on-going. Key amongst these is arguably the requirement to get primary legislation in place. This has progressed considerably recently thanks to the Automated Vehicles Bill and now the AV Act (Automated Vehicles Act, 2024), however until the exact wording of the bill is finalised and legislation is in place, there is still an element of uncertainty.

The other main element of the current roadmap that should be highlighted is the whole-life assurance element. It is evident from engagement with the sector that it is important we consider whole life assurance and the activities that underpin it when we think about delivery of CAM services.

3.3 Evidence review of current Verification, Validation and Assurance practices and capabilities

In the UK

Following the Law Commission report on Automated Driving (covered in the existing roadmap) an AV Act has been introduced and the primary legislation is created.

In addition to primary legislation, activities are underway at DfT and its agencies, and at an international level, to formulate both type approval and in-use monitoring requirements. DfT, working with the Vehicle Certification Agency (VCA), has established the GB approvals scheme, which is expected to utilise the forthcoming UNECE Automated Driving Systems (ADS) approval regulation to provide an approvals pathway for CAVs. DfT officials are playing a leading role in the development of this UNECE regulation. It is noteworthy that engagement with existing trial and deployment projects within the UK has helped regulators to help understand and identify emerging requirements and lessons learned which have the potential to impact on developing regulations.

Europe and International

CAM is positioned as prime near-future technology that will lead to a range of societal and economic benefits, but at the same time presents fundamental challenges. The disjunct between technological progress and legislative caution is present in how VVA is addressed overseas.

A targeted review of selected European nationalised legislation related to automated vehicles shows that the focus has been on the legislation for trials and testing. Where this is present, VVA is addressed to varying degrees, and may give an indication of how VVA may be treated in eventual laws that facilitate the approval and deployment of AVs. Some of these have already been progressed as shown in Table 5.1.

However, the main work to develop approval requirements for AVs is being undertaken at the UNECE's World Forum for Harmonisation of Vehicle Regulations. Here a new informal working group on ADS, led by the UK, US, Canada, Japan, China and European Commission, has started drafting technical requirements. This work builds on the output from the previous informal working groups on Functional Requirements for Automated and Autonomous Vehicles (FRAV) and Validation Methods for Automated Driving (VMAD). The latter's mandate was defined as 'to develop assessment methods', including scenarios, to validate the safety of automated systems, based on a multi-pillar approach. This encompasses the following assessment and test areas:

- A scenario catalogue
- Simulation/virtual testing
- Track testing
- Real-world testing
- Audit/assessment procedures
- In-service monitoring and reporting

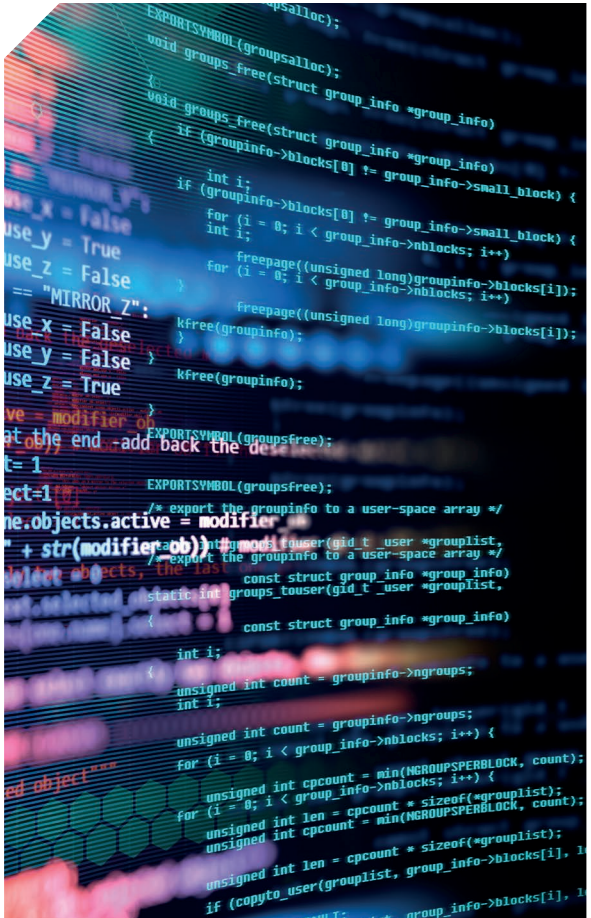
In 2023, VMAD issued guidelines relating to the assessment of ADS. These guidelines provide further information on each pillar and are designed to help steer regulatory development.

While the US specifically has currently no specific federal regulation or legislation relating to VVA (Zenzic, 2023), it has implemented an incident reporting scheme for automated vehicles operating or trialling on public roads. This feeds into the whole life element of VVA, as the data collected through this has the potential to be used to analyse causes and recommend improvements.

'It is also noteworthy that the GB regulators have engaged extensively with existing trial and deployment projects within the UK to help understand and identify emerging requirements and lessons learned which have potential to impact on developing regulations.'

4.0 / What

Identifying CAM Verification, Validation and Assurance Services



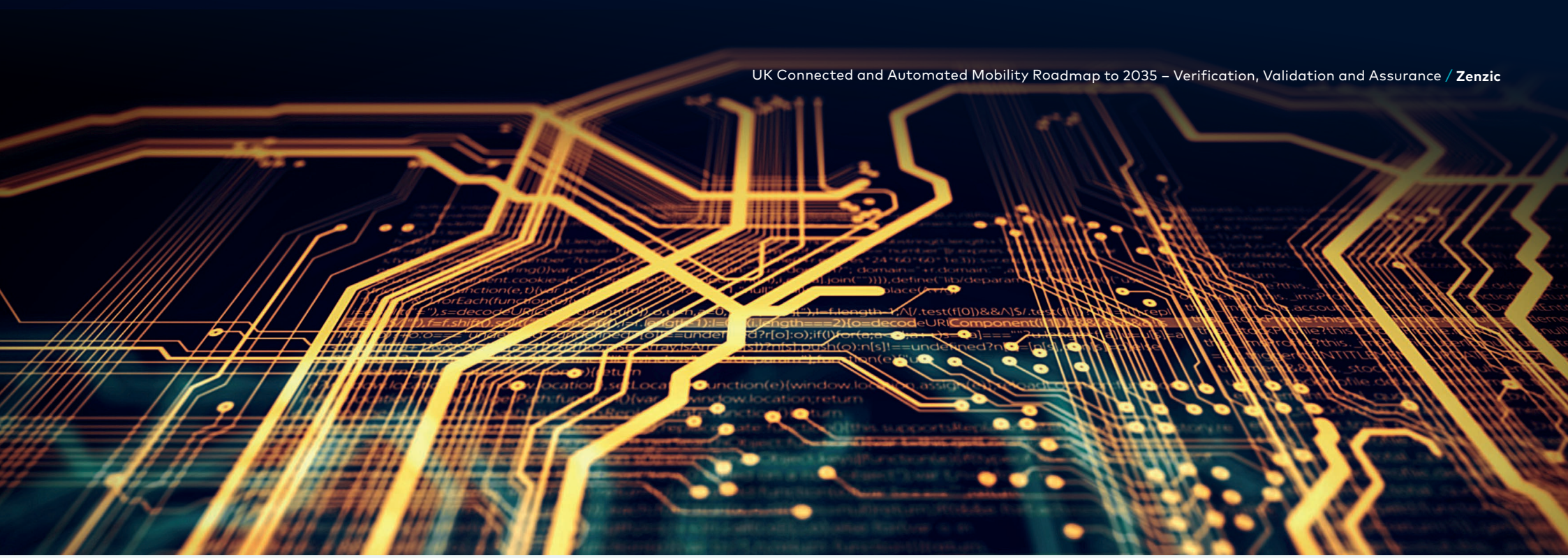
Although VVA is now happening for CAM products and services, there are still clearly defined phases across the lifecycle where these key services will be required. These are the products and services that the UK should look to develop across the evolution of CAM to help realise its benefits.

Product development testing

The requirement for pre-approval VVA remains. Despite the substantial novel systems and technologies involved, the fundamental element of a CAV will necessarily always be the V – the vehicle. Regardless of whether all elements of a CAV have been developed together, for example by an OEM, or whether vehicle and ADS cross system integration needs to take place, various forms of VVA are required. These may include bench, simulation and test track testing, and several existing test houses are reformulating their VVA offerings to cater for CAM. Furthermore, initiatives like CAM Testbed UK have allowed next generation testbeds to rapidly set-up and scale up to align with the specific needs of CAM.

Development of assurance standards/methods

Pre-certification VVA activities are only useful if they have something to aim towards. Usually these are the type approval requirements a vehicle needs to meet. Type approval requirements are still being defined for CAVs and it is yet to be known what impact the introduction of novel VVA activities will have on the production of CAVs



Legislative harmonisation

Ensuring UK developed products and services are compatible with regulatory environments in key potential markets is important to aid import and export. Consideration should be given to undertaking an interoperability and compatibility assessment on regional/local legislation, and then maintaining an international regulation tracker. Securing UK representation from government, industry organisations and companies in positions on international regulations and standards committees and working groups, as well as other influential organisations is one way of maintaining visibility and helping shape the future evolution of VVA.

Over the Air and ODD updates

How is the safety of these assured, and how can they be delivered in a timely manner? How can the ODD be increased safely when a vehicle is already in service? A comprehensive ODD database, perhaps including a national map, should be developed, as well as systems for approving, distributing, monitoring OTA updates (covered under UNR-156).

Data accessibility for incident investigation

Timely access to relevant and accurate data is needed for legal and practical requirements. This will require authorised access to in-use monitoring reports (being considered under the UN regulations), and infrastructure data for independent incident investigation.

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

To validate findings so far, and to provide further insight, a range of stakeholder engagement was undertaken. Stakeholder groups likely to have a relationship to VVA were identified (Table 4.1)

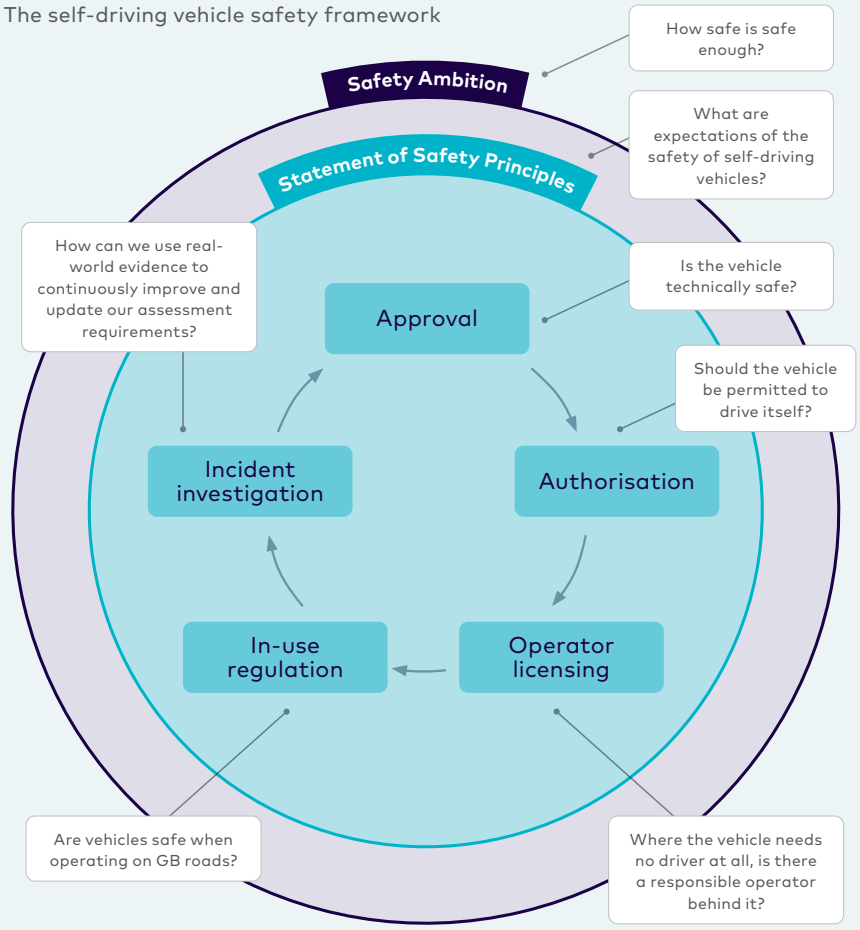
Table 4.1: CAM stakeholder groups and their relationship to VVA

Stakeholder group	Relationship to VVA
Approval/roadworthiness authorities (VCA/DVSA/DfT)	Responsible for setting the regulatory, approval and roadworthiness requirements VVA activities will aim to meet.
Test case providers	Develop scenario databases for developers to test against.
Testbeds (inc. simulation)	Where ADS developers will test to ensure they meet VVA requirements.
ADS developers	Responsible for ensuring their ADS meets or exceeds specified VVA targets.
Vehicle platform developer	Physical vehicle developer. May also be an ADS developer. Responsible for platform meeting traditional VVA testing and certification.
Operators	Once in service, responsibility for maintaining ongoing roadworthiness is likely to shift in part to AV operators.
Service Authorities	Will need reassurance that whole-life safety assurance is maintained while operating in their areas.
Insurers	Will require sufficient evidence of VVA compliance to make insurance decisions.
Cybersecurity	Responsible for ongoing VVA activities specific to cybersecurity.
Maintenance providers	Keep CAM products and services working safely once in use.
Infrastructure operators	Road and V2X, essential in the on-going safe operation of CAM.

It is worth noting here that formal roles have been defined in the Automated Vehicles Act (e.g. Authorised Self-Driving Entity (ASDE), No User-in-Charge Operator (NUICO), and some of the stakeholders may also perform one of these newly defined roles provided in the proposed safety framework (Figure 4.1) which is expanded upon the AV Act's 'Statement of Safety Principles' (previously known as the National Safety Principles) (CCAV, 2024).

Table 4.2: Proposed Safety Framework

The self-driving vehicle safety framework



Source: Consultation outcome of self-driving vehicles:
new safety ambition – summary of responses and government response (CCAV, 2024)

5.0 / How

Enabling the delivery of Verification, Validation and Assurance Services

TRL held an internal workshop of subject matter experts covering a wide range of areas, including vehicle safety, roadworthiness, real world testing, and compliance.

This workshop built on the initial roadmap review and gap analysis, and allowed a further development of the material that would be shared ahead of the broader stakeholder workshop. The external stakeholder workshop encompassed a wide range of attendees from the sectors identified in Section 4.1. An interactive session allowed participants to proactively comment on suggestions made by TRL based on our evidence review, as well as contribute their own thoughts on what VVA in the CAM sphere should include. In addition to this, they were also asked to identify what they believed were priorities for the three time phases of the Zenzic Roadmap.

The feedback and contributions received in the workshop were used to validate and build on existing findings, and help identify any outstanding gaps or blind spots, and were given due consideration when developing the recommendations and timeline found in this report.

5.1 Key elements which underpin the roadmap timeline

The VVA roadmap timeline for CAM is critical to ensure these vehicles remain safe, reliable, and meet regulatory requirements before a large-scale deployment on public roads. Key enablers that the VVA roadmap timeline should address include:

1 **Regulatory and legislative milestones**

Regulatory and legislative milestones establish the set points by which specific VVA objectives need to be achieved to ensure compliance. The key timeline included in Table 5.1 considered the safety requirements, regulation amendments, and regulatory harmonisation at the UN, EU, and UK levels.

Table 5.1: Regulatory milestones

Short-term (2024-2026)	Mid-term (2027-2030)	Long-term (2031+)
• **EU GSR: Type Approval (2022) / Vehicle registrations (2024)** Mandatory safety technologies (ADAS) • **EU GSR: Type Approval (2026)/ Vehicle registrations (2029)** Mandatory Event Data Recorder (EDR), driver availability monitoring, Platooning (AV trucks) • **EU ADS Regulation 2022/1426 (2024)** In-service reporting / Type approval for ADS	• **EU GSR: Type Approval (2026)/Vehicle registrations (2029)** Mandatory Event Data Recorder (EDR), direct vision requirements • **EuroNCAP (2026)** Safe driving, crash avoidance, crash protection, and post-crash safety • **UK AV Act implementation (2025-27)** Misleading marketing, Statement of Safety Principles, type approval, authorisation, user-in-charge (UiC), no-user-in-charge (NUiC) operator licensing, authorised self-driving entity (ASDE) registration, incident investigation, in-use regulation, automated passenger service permitting, and data exchange protocol.	• **EU GSR: Type Approval (2028)/ Vehicle registrations (2034)** Pedestrian protection

2 Technology and Infrastructure Readiness

The maturity level of technologies in vehicles and infrastructure also indicates the scale and type of needs in VVA processes. For the CAM life cycle, this can range from the research and development (R&D) phase to technology proven in operational environments.

Table 5.2: Anticipated technology advancements

Short-term (2024-2026)	Mid-term (2027-2030)	Long-term (2031+)
• **Increased transition to Driver Control Assistance Systems (DCAS):** ADAS will see broader integration and refinement, enhancing safety and driver convenience and transitioning to DCAS and user in-charge ADS system • **Early Deployment of Level 4 Automation:** Limited deployments in controlled environments, such as specific urban zones or shuttle services. • **Expansion of V2X Communication:** V2X communication technologies will advance, facilitating better traffic management and safety. • **Public Trials and Demonstrations:** Increased public trials of AVs to gather data and improve public perception of autonomous technologies.	• **Widespread Adoption of Level 4 AVs:** Expansion to more areas, including inter-city services and logistics. • **Enhanced Infrastructure:** Development of smart infrastructure equipped to support CAM technologies, including smart road signs and traffic management systems that communicate with AVs. • **Integration into Public Transport Systems:** AVs and connected vehicles will become integral parts of increasingly inter-connected public transport systems, offering last-mile solutions and flexible routing. • **Advancements in Cybersecurity:** Robust cybersecurity measures will be critical, with standards and practices well-established to protect against increasing cyber threats.	• **Level 5 Automation:** Fully autonomous in all conditions without human intervention. • **Fully Integrated CAM Ecosystem:** Integration of CAM technologies across transport networks, with AVs, connected infrastructure, and V2X. • **Transformed Urban Landscapes:** Changes in urban planning and infrastructure to accommodate and leverage the benefits of CAM technologies, possibly reducing the need for parking spaces and changing road layouts. • **Innovative Mobility Services:** New business models and mobility services are emerging that leverage full autonomy and connectivity, offering personalised and efficient mobility solutions.

3 Testing and certification phases

Defined testing phases that align with a product or service's different lifecycle phases are also important. Within each phase, particularly the operational phase, further sub-phases of testing are likely to be required. Specific requirements are likely to be determined by the specific product or service.

Table 5.3: Testing and certification required in each product/service life cycle phase

Product development	Approval/Licencing	Operation	Decommission
• Simulation for function verification • Proving Ground functional verification	• Real-world operational validation • Evidence through simulation for type approval • Authorisation and licensing for the self driving entity	• In-use monitoring • In-use regulatory safety report • Operational validation for the OTA updates	• Data security assurance • Certification for Repurposed Components

4 Stakeholder engagement

A holistic approach is needed to ensure that all relevant stakeholders are taken on the journey that whole life VVA demands. For a CAM developer this means early engagement with key bodies, for example approval authorities, insurers and operators. Early engagement will help ensure clarity of roles and responsibilities and that all VVA requirements happen when they should and are carried out by the correct party to suitable standards.

5 Safety and Performance Benchmarks

Clearly defined targets and goals for evidencing safety through verification and validation to ensure consistency and ultimately clarity for end users of the CAM products and services.

6 Cybersecurity Assessments

Cybersecurity should be front and centre when considering VVA across all stages. Maintaining up to date cybersecurity capabilities will be essential to the ongoing safety assurance around CAM offerings. Security of systems and connectivity are clear areas where VVA needs to offer new and compelling whole life cycle solutions in order for CAM to provide the levels of safety assurance expected by regulators and the public. Cybersecurity testing and cyber threat response protocols need to be addressed, and cybersecurity and data protection will need to feature in type approval and in-use requirements like MOT requirements.

7 Iterative Feedback Loops

The features of CAM products and services that mean they must submit to whole life VVA also provide some of the tools that can help ensure that VVA remains up to date and relevant.

8 Compliance Certification

A certification and/or self-certification process for CAM that provides both initial and on-going safety assurance will need to be developed. It is likely that this will evolve out of existing certification requirements, however consideration should be given to what roles and responsibilities sit with which actors once a CAM product or service is in the operation phase of its lifecycle.

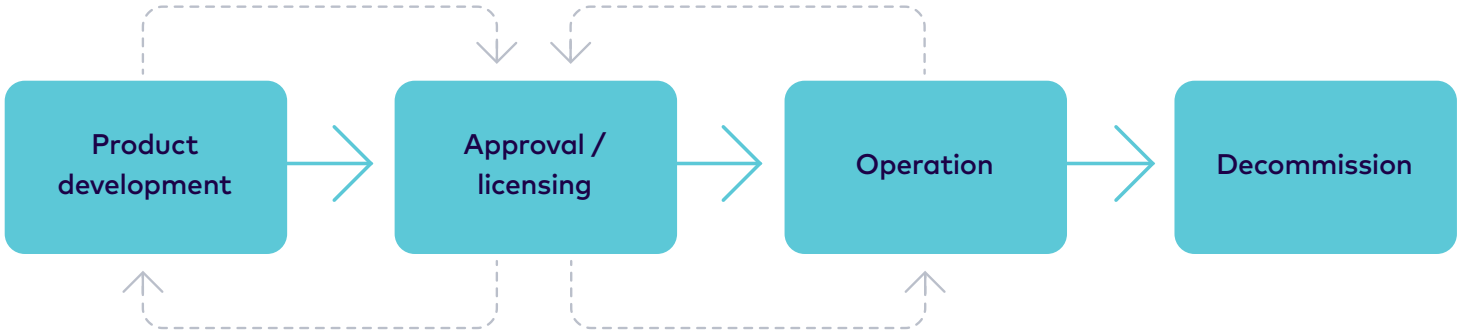
'Maintaining up to date cybersecurity capabilities will be essential to the ongoing safety assurance around CAM offerings'

6.0 / Key Messages and Priorities

The key message that should be taken away from this report is that whole life assurance is the basis of VVA for the CAM sector, and transitioning between these phases is also important.

Figure 6.1 presents some logical distinct stages in the life of a CAM product or service that could be used to separate out VVA requirements. It is not a linear process but rather a continuous development and the individual stages feeding back into the process. Priority should be given to developing and implementing the full regulatory framework, and thereby clearly defined roles and responsibilities, in place, which includes the safety framework covered in Section 5.1. This will provide the certainty needed for the elements of whole life VVA to then be put in place. Other priorities are more fluid and highly dependent on the specific requirements of stakeholders and their individual paths to deployment of their product or service. However, some universal topics that should be prioritised include management of in-service updates through OTA, and resilience in cybersecurity.

Figure 6.1: Possible stages of VVA for whole life assurance of a CAM product or service



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