Connected and autonomous vehicles

A UK standards strategy

Summary report

Prepared by BSI and the Transport Systems Catapult

March 2017

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CATAPULT Transport Systems

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About

BSI

BSI is a global thought leader in the development of standards of best practice for business and industry. Formed in 1901, BSI was the world's first National Standards Body (NSB) and a founding member of the International Organization for Standardization (ISO). Over a century later, BSI is focused on business improvement across the globe, working with experts in all sectors of the economy to develop codes, guidance and specifications that will accelerate innovation, increase productivity and support growth. Renowned as the originator of many of the world's best known business standards, BSI's activity spans multiple sectors including aerospace, automotive, built environment, food, healthcare and ICT.

Over 95% of BSI's work is on international and European standards. In its role as the UK National Standards Body, BSI represents UK economic and social interests across the international standards organizations ISO, IEC, CEN, CENELEC and ETSI, providing the infrastructure for over 11,000 experts to work on international, European, national and PAS standards development in their chosen fields.

Transport Systems Catapult

Transport Systems Catapult (TSC) is one of 11 elite technology and innovation centres established and overseen by the UK's innovation agency, Innovate UK.

It was created to drive and promote Intelligent Mobility – using new and emerging technologies to transport people and goods more smartly and efficiently.

TSC is helping UK businesses create products and services that meet the needs of the world's transport systems as they respond to ever-stretching demands. It helps sell UK capability on the global stage, while also promoting the UK as a world-leading test bed for the transportation industry.

With a clear emphasis on collaboration, TSC brings together diverse organizations across different modes of transport, breaking down barriers and providing a unique platform for meeting the world's most pressing transport challenges.

Authors

Nick Fleming – Project Lead, BSI

Dr Alan Peters – Principal Technologist, Transport Systems Catapult

Alberto Garcia-Mogollon – Emerging Technologies and Innovation Lead, BSI

Laura Cordell – Project Manager, BSI

David Serrano – Lead Information Specialist, BSI

Dr Jon Harrod Booth – Senior Consultant on ITS standards, Harrod Booth Consulting Ltd

For more information, please contact **CAV@bsigroup.com** or visit www.bsigroup.com/innovation/cav

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Disclaimer

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Executive summary

The British Standards Institution (BSI) and the Transport Systems Catapult (TSC), supported by the Centre for Connected and Autonomous Vehicles (CCAV), undertook research to:

- map the current international standards landscape relevant to connected and autonomous vehicles (CAV);
- better understand the key challenges and opportunities facing UK-based organizations working on CAV development and deployment; and
- identify areas where standardization may be needed to help accelerate CAV deployment in the UK.

Primary research was conducted using a combination of methods, including an online survey, a stakeholder workshop and a series of semi-structured interviews. A wide range of stakeholders from across the CAV supply chain contributed their views and expertise to this project. Primary research was supplemented by extensive domain research to identify national and international standards of relevance to the field of CAVs.

Key findings

The central findings of the research highlighted a number of barriers to the development and deployment of CAVs in the UK including: public acceptance of the technology, the reliability of the existing infrastructure, integrating CAVs with existing transport systems, assessing performance of CAVs, and a lack of common standards and consistent policy frameworks.

The research found that existing standards, such as the ISO 26262 standard on functional safety, were already widely used by the automotive industry and its supply chain. However, adaptations or new versions of such standards will be needed to fully address design, testing and operation of connected and highly automated vehicles. Existing standards for Intelligent Transport Systems were considered of particular relevance and important to the successful deployment of CAVs. Nevertheless, it was highlighted that the standards landscape is complex and further harmonisation is needed.

The research indicated that whilst globally accepted standards would be considered the end-goal for the CAV industry, there are opportunities for the UK to demonstrate leadership in standardization in strategic areas of UK strength.

Priority areas for CAV standardization

The project identified 15 priority areas for standards development. The top four areas, when rated against criteria for impact and feasibility, are:

- **Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communications** – standards for applications of V2V/V2I/I2V communications to support deployment, integration of communications technologies and priority message management.
- **Traffic and road-space management** – standards to enable coordination and integration of CAVs with traffic management systems and wider transport networks by authorities at regional, national and international levels.
- **Cyber security – whole CAV system** – standards across attacks surfaces to manage resilience of CAV systems.
- **Verifying CAV technologies – security of the supply chain** – standards to help demonstrate that CAV technology meets minimum desired security guidelines and that there are sufficient safeguards in the supply chain.

Building on existing areas of strength in the UK and enabling deployment of CAVs, standardization work should begin promptly in three further areas that are critical to public acceptance of CAVs:

- **Test-track and virtual design verification and validation** – standards to support the testing of CAVs, including road, test-track and virtual test scenarios.
- **Functional safety in CAV design** – standards for addressing functional safety in design of production-level automated systems.
- **Assessment and approval of CAV systems** – standards on safety of holistic connected CAV systems enabling the testing of CAV capabilities in a wider systems context.

Recommendations

This project identified six general recommendations to support CAV standardization efforts in the UK and internationally:

Recommendation 1: To support the delivery of a coherent and high-impact CAV standards programme, BSI, TSC and CCAV should establish a CAV standards steering group to guide and advise on strategic priorities for the UK, using existing industry groups and forums, where appropriate.

Recommendation 2: Harness the UK's expertise and experience in CAV R&D programmes, national trials, demonstration projects and feasibility studies by informing standards development in areas of strategic interest for the UK. This can help retain UK leadership in areas such as functional safety and testing, and help with first-mover advantage.

Recommendation 3: In order to achieve greater harmonization and adoption of standards globally, and to accelerate their development, BSI, in collaboration with industry and government, should identify priority areas where strengthening participation in European and international standards and/or collaboration with other countries would be in the UK's interest.

Recommendation 4: Public investment in standards and good practice should be made available with the aim of strengthening the UK's enabling framework for CAV development and deployment.

Recommendation 5: BSI should explore the adoption of agile standards development processes, where appropriate, with the aim of ensuring that good practice keeps pace with the rate of technological innovation in the field of CAVs.

Recommendation 6: BSI should explore the requirements for a standards navigator tool to help industry in navigating the existing and future standards landscape related to CAVs more effectively.

1 Introduction

Overview

Vehicles are incorporating more on-board technology, such as safety and navigation features, and dealing with greater levels of connectivity than ever before. As vehicle systems become increasingly centralized and software-dependent, boundaries between drivers, vehicles and systems are blurring.

With the move towards more connected and autonomous vehicles (CAVs), the need to engineer and manage more complex interfaces between systems has increased. Additionally, the development of highly automated vehicles will require new safety and testing procedures, and the development of connected vehicles brings with it new risks from cyber threats. New technical demands on the physical and digital infrastructure will also be seen in order to meet the challenges and opportunities associated with CAVs.

Standardization may be required to help overcome the barriers associated with CAV development, such as interoperability or public acceptance issues, while helping accelerate the deployment of the technologies, concepts and models for the industry. Further opportunities may exist to establish a lead position globally through international standards development where it complements the UK's relative technological capabilities.

In the UK, the Council for Science and Technology's (CST) recommendations in 2015 in a letter to the Prime Minister's Office recognised the potential for standards:

> *'Recommendation 2: The government should identify areas where it can usefully develop standards for key parts of the operating systems for autonomous and connected vehicles. It should work with business, the British Standards Institution and international partners to develop relevant standards and to promote their international adoption. Where appropriate, standards may include related UK-owned intellectual property'.*[1]

Between May and December 2016, the Transport Systems Catapult (TSC) and the British Standards Institution (BSI), supported by the Centre for Connected and Autonomous Vehicles (CCAV), undertook research to identify areas in which standardization may be needed to help accelerate CAV development and overcome challenges facing the industry.

Aims and objectives

The central aim of this project has been to determine the priorities for standardization to support the development of the UK CAV industry and accelerate deployment of CAVs in the UK and internationally.

More specifically, the aims of this research were to:

- identify key standards of relevance in the design, production, operation and testing of CAVs in the UK, Europe and internationally;
- examine known and perceived challenges facing development of the UK CAV industry and prioritize the areas where standards development could deliver tangible benefits, including increased interoperability, access to markets for new entrants, integration of systems, security and safety via testing procedures;
- consider the need for standardization to support the development of the wider infrastructure necessary to make possible the deployment of CAVs;
- understand where investment in standardization could support a core UK strength or competency.

1 Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/459521/cst-15-1-driverless-vehicles.pdf

Methodology

Extensive domain research – a mapping of the existing standards landscape – was carried out as part of the desk research by both BSI and the TSC. The purpose of this work was to identify national and international standards of relevance to CAVs using an agreed set of technology areas and keywords.

In addition, primary research was undertaken using a combination of the following methods:

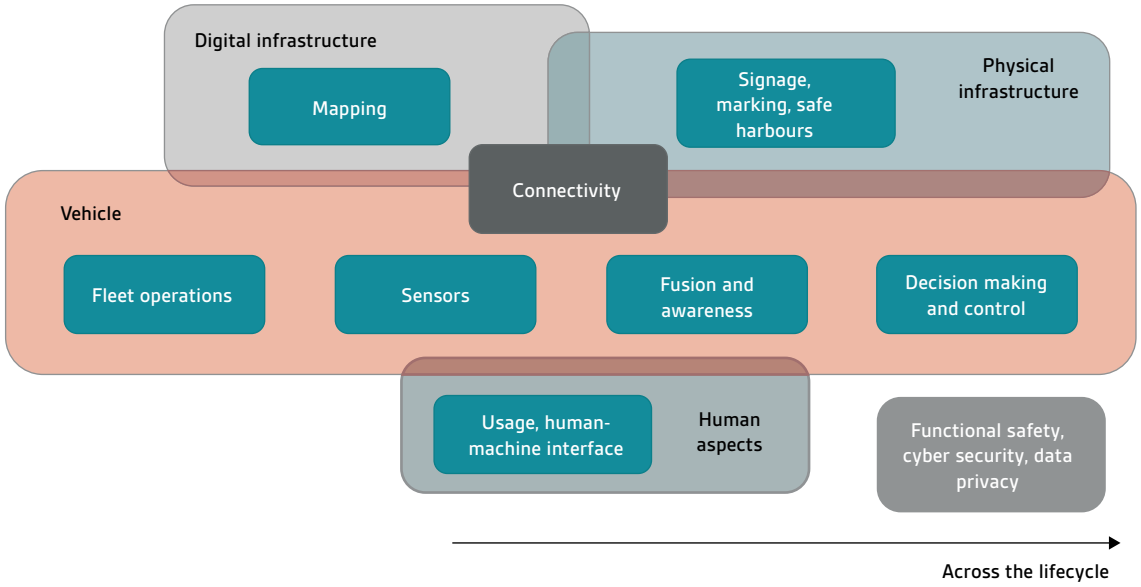
- online survey;
- stakeholder workshop; and
- targeted stakeholder interviews.

The data gathering phase was designed to enable participation from a wide range of stakeholders from across the entire CAV supply chain, including Original Equipment Manufacturers (OEMs), tier one and tier two suppliers, digital and physical infrastructure providers, CAV R&D project representatives, software and autonomy systems companies, industry bodies, test facilities, academics and government officials.

Project scope

This research considered standardization relating to both connected vehicles and autonomous vehicles. Connected vehicles and autonomous vehicles were treated as two distinct but overlapping topics for the purposes of this research, with many suggested implementations of automated vehicles requiring a degree of connectivity. Conversely, the research considered the opinion that highly automated vehicles may place little or no reliance on connectivity. Figure 1 depicts the extent of the project scope.

Figure 1 – Scope of work



2 Mapping the current CAV standards landscape

Highlights of BSI domain research

The domain research undertaken by BSI's Knowledge Centre identified existing standards in the field of CAVs in an agreed list of countries and SDOs.[2]

The list of countries and SDOs include:

- **Globally** – Australia/New Zealand (SA/NZSO), Canada (CSA), China (SAC), Japan (JS), Korea (KR), USA (ANSI, ASTM and SAE)
- **European countries** – Finland (FI), France (NF), Germany (DIN and VDA), Italy (UNI), Netherlands (NL), Sweden (SE), Spain (UNE) and UK (BSI)
- **International and European SDOs** – ISO, IEC, ITU, CEN, ETSI
- **Other SDOs**, including the Institute of Electrical and Electronics Engineers (IEEE)

The project team identified eight high-level technology categories of relevance to CAVs as well as a list of associated keywords. These technology categories and keywords were used to perform database searchers to assist in identifying all standards relevant to CAVs.

The two databases used to perform searches were:

- Perinorm: a bibliographic standards reference database, which indexes worldwide standards
- I.H.S. Standards Expert: a standards reference database

Additionally, the BSI Standards Development portal[3] was used to identify new standards proposals or standards in development.

Key findings of BSI domain research

Standards by country and SDOs

A total of **661** standards relevant to CAVs were found, published by selected countries and SDOs.

The majority of the standards identified are international in origin (ISO, ETSI and CEN). **381** standards have been published by ISO, including 18 standards that been adopted by CEN after the ISO publication. European standards (ETSI and CEN) are the second largest group of results, with **99** standards published by ETSI, **58** by CEN and **12** by the ITU.

Standards by topic

Most of the standards identified fall under the following four categories.

- 'Connectivity/connected vehicles – technology'. **244** standards were identified in this area, 171 of which have been published by ISO.
- 'Awareness'. **123** standards were identified in this area.

2 This research was limited to relevant standards relating to road and footways. The project was not intended to identify legislation or private standards.

3 See https://standardsdevelopment.bsigroup.com/

- 'Connectivity/connected vehicles – applications'. **91** standards were identified in this area. 74 standards within this category relate to Intelligent Transport Systems (ITS) or Cooperative ITS.
- 'Localization standards'. **84** standards were identified in this area.

Connected standards landscape

In the modern world, communications are often considered to be ubiquitous, with concepts such as smart cities predicated on mass interconnected communications. This is a relatively new concept in respect of road traffic and highway communications.

Standards supporting data-centred communications into and from vehicles to support different services and applications have been maturing since the 1990s, since the birth of Advanced Transport Telematics (ATT) and the subsequent migration into what is now referred to as ITS. Although there is a wide range of proprietary services and technologies provided by OEMs and after-market vendors, this report focuses on those that are the subject of acknowledged standardization.

From a legacy perspective, two of the best known mature areas of communication into and from vehicles in the field of ITS relate to electronic fee collection to support electronic tolling, and the provision of driver and traveller information services. These, and many other areas of ITS standardization, have been evolving since the establishment of CEN Technical Committee 278 in 1992 and its ISO sister committee ISO Technical Committee 204 in 1993. The diversity of standards development organizations actively participating in these domains has continued to grow.

Within the scope of this report, communications standards related to CAVs[4] cover a range of emerging application areas:

- V2V communications – often for safety-related applications, such as collision avoidance; electronic brake light warning; vehicle platooning, etc.
- V2I/I2V communications – for safety and traffic-efficiency applications, including vehicle–traffic signal interactions to support improved vehicle junction transit; replication of road-side signage in vehicle for driver warning, speed limit adherence, etc. These may be focused on either communications between vehicles and local devices or vehicles and remote traffic centres, and can also be referred to as Infrastructure to Vehicle (I2V) or V2X.
- Infrastructure-to-infrastructure (I2I) communications that support the aggregation of local sensors or vehicle-based messages that either extend communications from the vehicle to the road-side infrastructure or communications from road-side infrastructure to vehicles.

As penetration of CAVs increases, the communications landscape will evolve to support greater 'smart' integration. Some of these other forms of communication are already the subject of modification and adaptation of existing standards to support the connected vehicle. Primary CAV communications standards activities can be found in Table 1.

4 In the overall communications landscape supporting road transport, there are many other forms of communication that are subject to standardisation. Examples include electronic fee collection, e-call emergency call systems, vehicle–vehicle load tracking, traffic signal control communications, weather monitoring station communications, highways lane control systems, the provision of digital map data into vehicles, etc. However, these areas were out of scope for the purposes of this research.

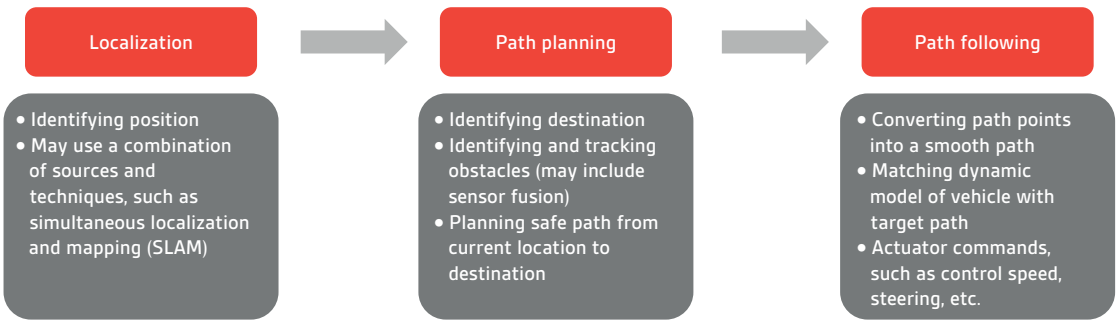
Table 1 – Main SDOs active in CAV communications standardization

Standards Development Organization	Primary CAV communications standards activities
ISO – International Organization for Standardization	
• Technical Committee 204 (TC/204) – Intelligent Transport Systems	• Developer of the 'CALM' (Continuous Access to Land Mobiles) suite of standards, including the jointly adopted C-ITS communications architecture • Extensive work on Co-operative ITS (V2X), higher-level applications and facilities in the C-ITS model (led by Working Group 16) • Working Group 14 has generated many vehicle/roadway warning and control system standards
• Technical Committee 22 (TC/22) – Automotive Vehicles	• Recently organized; promotion of the 'extended vehicle' concept
CEN – European Committee for Normalization	
• Technical Committee 278 – Intelligent Transport Systems	• Sister TC to ISO/TC204 • Considerable collaborative work, particularly through with Working Group 16 (working jointly with Working Group 18)
• Technical Committee 301 – Automotive Vehicles	• Sister TC to ISO/TC204
ETSI – European Telecommunications Standards Institute	
Technical Committee ITS	• Jointly adopted to C-ITS communications architecture • Developer of many of the V2V standards, particularly using 5.9 GHz (often referred to as ITS-G5)
ITU – International Telecommunications Union	• Task Force established in 2013, investigating standardization tasks force-connected vehicles
SAE – Society of Automotive Engineers	• Developer of many message set/data set standards for V2X communications (e.g. J2735, J2945)
IEEE – Institute of Electrical and Electronics Engineers	• Development of communications protocols • 802.11p • IEE P1609

View on state on standards for automated vehicles

'Automated vehicles' is a term for the end functionality achieved by a series of interconnected functions, specifically, localization, path planning and path following, as shown in Figure 2:

Figure 2 – Automated driving functions



In addition to these main functions, there are a series of properties of systems such as quality, safety and security, which could be standardized with respect to automated vehicles. The BSI domain research showed that there are very few existing standards specifically relating to automated vehicles. Existing international standards of relevance include:

- IATF 16949:2016, Quality Management Systems. Particular requirements for the application of ISO 9001:2015 for automotive production and relevant service part organizations
- ISO/IEC 27001:2013, Information technology – Security techniques – Information security management systems – Requirements
- ISO 26262:2011-2012, Road vehicles. Functional safety (Parts 1-10)

Despite the lack of published standards for automated vehicles, there are a number of initiatives focusing on related aspects as well as technical committees starting to work in this area. For example, from 2017, there will be a CEN/ISO committee working on standards for road adaptation for ADAS and autonomous vehicles. There are also published ISO standards and standards projects in development for a number of ADAS features that have relevance for full automation, namely:

a) ISO 11270:2014, Intelligent transport systems – Lane Keep Assistance Systems (LKAS) – performance requirements and test procedures
b) ISO 11067:2015, Intelligent transport systems – Curve speed warning systems (CSWS) – performance requirements and test procedures
c) ISO 22179:2009, Intelligent transport systems – Full-speed range adaptive cruise control systems (FSRA) – performance requirements and test procedures
d) ISO 15623:2013, Intelligent transport systems – Forward collision warning systems – performance requirements and test procedures
e) ISO/PWI 20901, Intelligent transport systems – Cooperative Forward Vehicle emergency Brake Warning Systems (C-FVBWS)
f) ISO/AWI 19638, Intelligent transport systems – Road Boundary Departure Prevention Systems (RBDPS)
g) ISO/CD 20035, Intelligent transport systems – Cooperative Adaptive Cruise Control Systems (CACC)
h) ISO/PWI 21200, Intelligent transport systems – Partially Automated In-lane Driving Systems (PADS)
i) PWI 21202, Intelligent transport systems – Partially Automated Lane Change Systems (PALS)
j) ISO/AWI PAS 21448, Road vehicles – Safety of the intended functionality

Other standards currently in development include ISO Approved Work Item 21434, Road Vehicles – Automotive security engineering, which will address engineering for security and information security issues in relation to connected and autonomous vehicles.

3 CAV standards strategy: research findings

Findings from survey

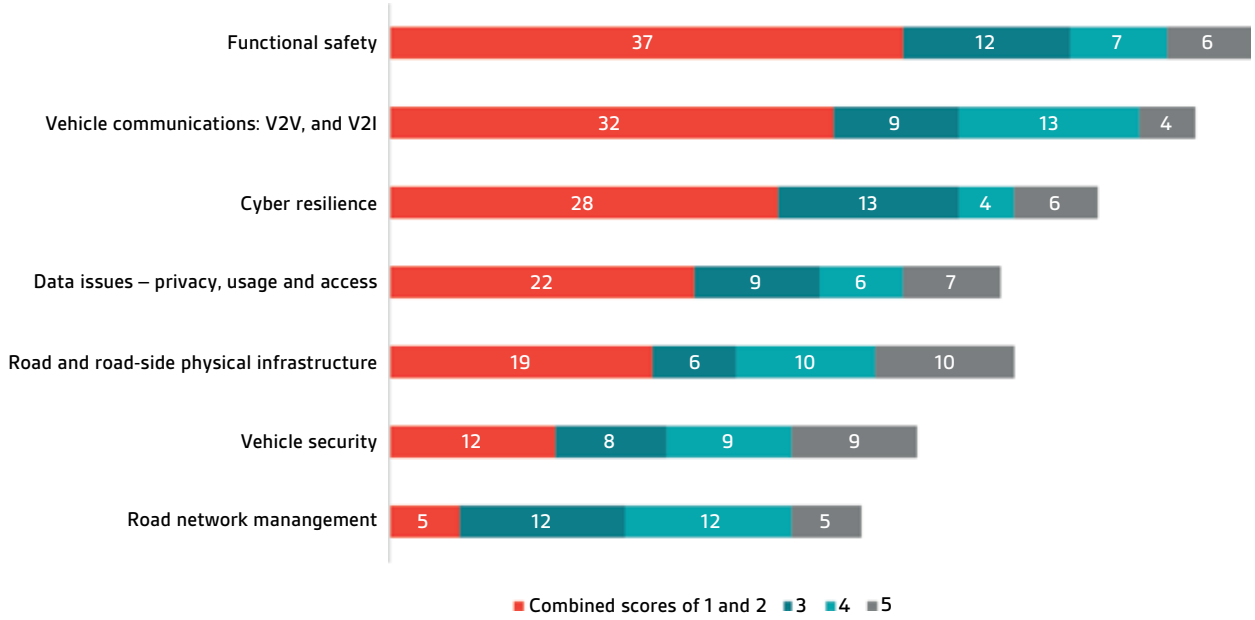
A survey was used to elicit and aggregate views from a large number of UK-based CAV stakeholders. The aim of survey was to understand:

- perceptions of UK capability and strength regarding CAV development;
- challenges facing the development of the CAV industry in the UK;
- key functional and technology areas where standardization could support CAV;
- the ways in which standards could help support the development of the UK CAV industry;
- key challenges facing the development of CAV standards; and
- interoperability issues facing this emerging industry.

Figure 3 shows the seven priority candidate areas that were ranked as a top five priority by 30 or more respondents. These areas are shown in descending order of usefulness, based on the frequency of a combined score of 1 and 2 (most useful and useful). The top seven priority candidate areas are:

- functional safety;
- vehicle communications (V2V and V2I/I2V);
- cyber resilience;
- data issues (privacy, usage and access);
- road and road-side physical infrastructure;
- vehicle security; and
- road network management.

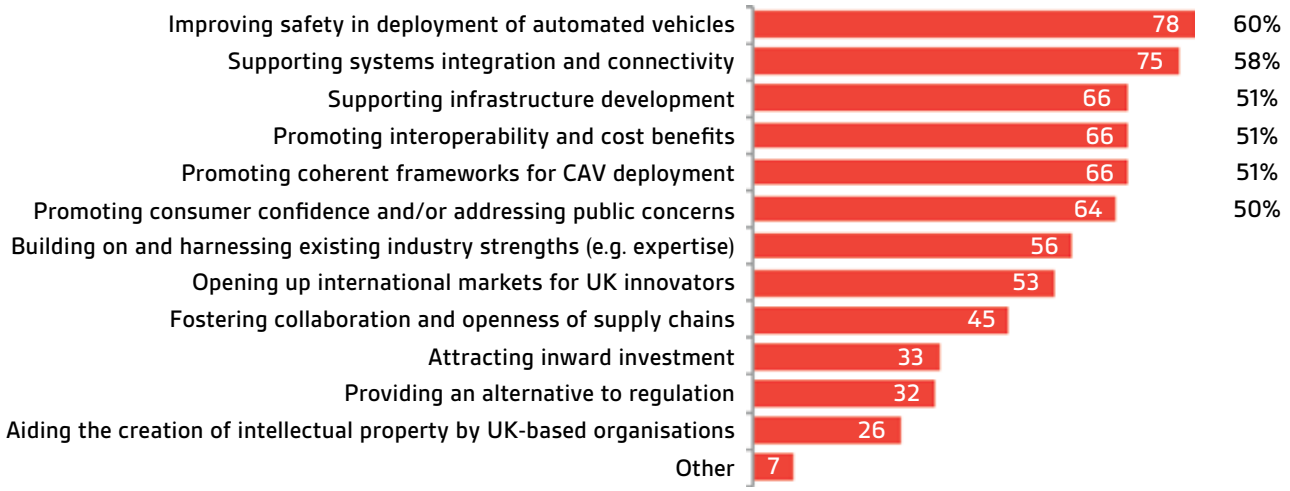
Figure 3 – Seven priority candidate areas for CAV standards development



The potential role of standards as enablers of CAV development

Once the priority areas for standards development were established, respondents were asked to consider the various ways in which standards, taken as a whole, could help support the development of the UK CAV industry. Figure 4 shows that the two primary ways in which standards are thought to be of help for the sector are by improving safety in the deployment of automated vehicles (78 out of 129 responses, or 60% of the total) and by supporting systems integration and connectivity (58%). Other ways in which standards could help, according to 50% or more respondents, were: by supporting infrastructure development (51%), by enabling interoperability (51%), by promoting coherent frameworks for CAV deployment (51%), and by helping boost consumer confidence (50%).

Figure 4 – Primary ways in which standards can help support the CAV industry



A workshop was also held to bring together relevant industry stakeholders to:

- help assess and prioritize the gaps for new standardization, including areas of UK leadership;
- share views on the key issues that standards can help address;
- share knowledge about relevant standards with industry, academia and standards users.

Findings from interviews with key stakeholders

Challenges to the development of the CAV industry

Public acceptance was outlined as a critical challenge for CAV deployment and adoption, mirroring the survey findings. Many public acceptance concerns were safety related and linked to the risks posed by CAVs, such as security threats or the negative impact from crashes or incidents. Some argued that public perception is yet to catch up with the 'reality' of the technology, implying that the potential benefits of CAVs (e.g. fewer accidents on roads) need to be spelled out more clearly.[5]

Five further barriers were identified from the interview transcripts:

1) Scalability issues. It is hard for UK start-ups and small, innovative companies to find the necessary investment to scale up. This is a well-known problem that is not exclusive to start-ups developing CAV solutions. A question was also raised as to whether there would be significant sized markets for niche vehicles (e.g. shuttles or pods) to be built and commercialized.

5 Others highlighted the need to analyse and discuss negative scenarios, including the possibility of road transport becoming too cheap as a result of autonomy.

2) Infrastructure. The need to upgrade the existing physical and digital infrastructure, with the key issue revolving around developing a business case supporting infrastructure investment decisions and subsequent cost allocations.

3) Insurance and liability. Who is responsible in the event of an incident/crash? What data sets will be available to insurers (and other parties) to establish liability? These aspects are likely to change the way in which the insurance industry operates.

4) Product liability issues. These encompass all the consumer aspects of CAVs, rather than the construction and operation of a vehicle. In a CAV context, OEMs will need to recognize the importance of a consumer-centric approach.

5) Fragmentation in the CAV landscape, both domestically and internationally. An increasing number of players in this space, including not-for-profit organizations, is causing some confusion in the marketplace in relation to roles and responsibilities.

The role of standards in overcoming market barriers

The role of standards as market enablers was one of the central areas for discussion in the context of these interviews. Participants identified areas where standards could help lower market barriers or resolve outstanding issues. Recurring suggestions were grouped into seven categories. Table 2 provides examples of standardization needs in each category.

Table 2 – Potential standardization needs in CAV-related areas

Potential standardization needs – Categories	
Communications and connectivity	• Vehicle-to-vehicle, vehicle-to-infrastructure and vehicle-to-any device standards • Common protocols and interfaces enabling data flows for CAV service providers • Standards to manage interoperability with legacy ICT systems • Integrity of data over different communications channels • Making connectivity work reliably in a diverse range of environments • Data communications between various autonomous systems • Communications in the context of smart cities (e.g. vehicle-to-grid) • Minimum quality of service (QoS) standards to take into account OEMs' liability concerns • Specify technical and communications requirements for truck platooning • Open APIs • Communications management for emergency and incident response
Safety and testing	• Templates including a comprehensive list of all potential risks incurred by CAVs • Description of safety cases for CAVs • Guidelines for trials of CAVs of similar nature/type (shuttles, pods, etc.) • A framework distinguishing safety-related functionality from other applications with lower priority • A performance, consumer-oriented safety rating system such as Euro NCAP[6] • A standard against which automatically-guided vehicles can be classified • A standard for verification and validation of systems • A standard for virtual design and validation processes • Learn responsible disclosure approaches from safety-critical industries, including aerospace and nuclear • Develop product certification schemes akin to the ones used in aviation and rail • CAV version of the US Transportation Recall Enhancement, Accountability and Documentation (or TREAD) Act, which requires OEMs to report issues with tyres in other jurisdictions back to the USA • Revision of ISO 26262 Road vehicles – Functional safety in a CAV context • Safety of road-side and wider city systems • Standards that help differentiate safety-related functionality from other applications and lower priorities

(*Continued*)

6 See http://www.euroncap.com/en

Table 2 – Continued

Potential standardization needs – Categories	
Security	• Cyber security guidelines to protect against threats to CAV vehicles and systems • Ensure ISO/IEC 27001 – Information security management is fit for purpose in the context of CAV • Develop guidelines for certificate management • Road-side and wider infrastructure systems
Software	• Validate software and algorithms • Validate black boxes used for insurance purposes • Specify on-board redundancies in case of attacks to or interferences with CAVs
Data management	• Specify vehicle-to-passenger guidelines setting out the various ways in which CAV passenger/driver data will be used
Human-machine interface (HMI)	• Describe and clarify automation handover and handback scenarios • Design philosophy for autonomy • Minimum capabilities for automated cars
CAV operations	• Build on the uniquely large proportion of fleet vehicles in the UK to promote deployment and adoption • Update related standards, including duty of care at work, and health and safety at work • Standards for retrofitting fleets

Conclusions

This research identified a number of common themes. These broadly relate to:

- the current standards landscape;
- the role that standards can play in supporting UK CAV development; and
- opportunities to support UK capabilities and leadership with standards.

Existing standards landscape

Based on the survey data and industry workshop, there was a common view that the existing international standards landscape, and in particular, communications standards (incorporating standards for ITS), was overly complex and that users require support in navigating it. A prevailing opinion was that further clarity was needed on the existing relevant standards for CAV and around standards projects in development.

This view was not limited to CEN and ISO standards, but also included national standards and international standards developed by other SDOs. Some suggested the UK was often poor at embracing the existing standards and should take a more active role in their development.

Role of standards in supporting CAV development

Given the global nature of the automotive markets and CAV supply chain, research participants commonly held the view that European and international standards should be considered an end-goal for CAV standardisation. While globally accepted standards remained a target for industry, the UK should take opportunities to lead the development of CAV standards where this supports a particular strength, niche capability, or can provide strategic advantage for the UK.

Supporting UK capabilities

The research data identified major UK strengths in CAV-related areas as well as features unique to the country, but also pointed to the significant barriers to UK CAV development. Barriers included:

- scalability;
- limitations with the existing physical and digital infrastructure;
- lack of CAV test beds;
- insurance and liability issues; and
- fragmentation of CAV industry groups and stakeholders.

Research participants outlined that standards would be particularly valuable where they:

1) promote or build upon a specific UK capability or uniqueness, e.g. establish the UK as a world leader in vehicle testing and the opportunity to test vehicles exclusively using UK roads, cities and airports;
2) support global leadership in a niche field or specialism such as new CAV services, HMI or simulation; or
3) help overcome barriers to CAV development, including market barriers.

4 Key areas and requirements for standards

Ten evaluation criteria were used to determine impact and feasibility, with each criterion weighted with reference to:

- results of the survey question on the ways in which standards could help support the development of the UK CAV industry;
- key challenges facing the development of standards for CAVs to help with assessing feasibility for each technical area; and
- an assessment drawing on all the data gathering activities.

Following the evaluation exercise, a rating system was applied to the outcomes to indicate priorities for standards development.[7] The following rating scale was used:

- **VH** – Very high priority for standards development
- **H** – High priority for standards development
- **M** – Medium priority for standards development

A consolidated table of the priority areas for standards is given in Table 3.

Table 3 – Key areas for CAV standardization

	Topic	Indicative scope	Rating
A	Test specification for CAV	Practical document for providing detailed guidance on testing of autonomous vehicles on UK roads to extend DfT Code of Practice. NCAP testing does not extend to CAVs.	**H**
B	Test-track and virtual design verification and validation	Standards of best practice for CAV verification and validation techniques, including on-road, test-track, virtual test scenarios and formal verification methods including assessing safety performance against all possible use cases.	**H**
C	Assessment and approval of CAV systems	Methods are needed for assessing the safety of CAV systems, including connectivity, digital and physical infrastructure, i.e. approval of CAV capabilities in a wider 'systems context'.	**H**
D	Functional safety in CAV design	Incorporating functional safety processes into 'production-level' autonomous vehicles (SAE Level 3-4, e.g. connected cars), and additionally, in vehicles with higher automation (L5), including passenger pods or shuttles. May extend to type approval testing. Would need to include maintenance, recall and other production-specific aspects.	**H**
E	Safety and incident data sharing	Minimum standards and agreements to encourage sharing by industry of safety-critical and incident data.	**H**
F	Passive safety	Standard for design and test of passive safety of highly automated vehicles (SAE 4/5) with potentially different seating arrangements, driving styles, lighter vehicles, etc.	**M**

(*Continued*)

7 Opportunities that were deemed of low priority were omitted from this selection of topics, but can be found in the research data.

Table 3 – Continued

	Topic	Indicative scope	Rating
G	V2V and V2I/I2V communications	(1) Frameworks for assessing and deploying multiple applications and enabling the integration of various communications technologies. (2) Standards for deployment-level communications and message management to help balance use of channels including data-flow prioritization. (3) Standards for key road use efficiency applications e.g. truck platooning, geo-fencing for environment air quality protection.	**V–H**
H	Traffic and road-space management	Common standards for coordination and centralization of traffic and road-space management, e.g. how CAVs communicate with existing road-side infrastructure and expected behaviour when CAV receives conflicting data from multiple sources.	**V–H**
I	Vehicle intelligence (data) sharing	Standards to enable better capture and sending of road data, e.g. description of road conditions, quality, hazards, environmental factors by vehicles.	**H**
J	Vehicle positioning and localization	Establishing minimum standards around data accuracy, access and quality to improve navigation.	**H**
K	Data management	Addressing data privacy, usage/storage and security.	**M**
L	Cyber security – whole CAV system	Setting minimum standards for improving resilience against cyber-attacks on vehicles and infrastructure.	**V-H**
M	Software security and authentication	Ensuring security of software and diagnostic services used in CAVs, for example, trusted firmware updates, including over-the-air updates.	**H**
N	Verifying CAV technologies – security of the supply chain	Standards to help demonstrate that CAV technology meets minimum desired security guidelines and that there are sufficient safe guards in the supply chain.	**V-H**
O	Design manual for roads and bridges – updates to account for CAVs	Updating and/or supplementing current Design Manual for Roads and Bridges to address planning for autonomous vehicle road infrastructure.	**M**
P	Human–machine interface between CAVs and other road users	Exploring how standards might support interactions between CAVs and other road users.	**M**
Q	Human–machine interface for using L4/5 automated vehicles	At highest levels of autonomy, standardization to enable communication between the occupant and the vehicle.	**M**
R	CAV classification systems	Common classification systems for Automated Guided Vehicles, Personal Rapid Transit systems and other variants of autonomous vehicles.	**M**

389 Chiswick High Road
London, W4 4AL
United Kingdom

E: CAV@bsigroup.com
www.bsigroup.com/innovation/cav

The Pinnacle
170 Midsummer Boulevard
Milton Keynes MK9 1BP

E: alan.peters@ts.catapult.org.uk
www.ts.catapult.org.uk