THE UNIVERSITY OF WARWICK

Legal and Regulatory Considerations

FOR CONNECTED AND AUTONOMOUS VEHICLES (CAV)

wmg.warwick.ac.uk

UK CITE
CONNECTED INTELLIGENT TRANSPORT ENVIRONMENT

Pinsent Masons

Table of Contents

Glossary

3GPP 3rd Generation Partnership Project
ADAS Advanced Driver Assistance Systems
AEV Automated and Electric Vehicles
AOR Area of relevance
CAV Connected and Autonomous Vehicles
CCAV Centre for Connected and Autonomous Vehicles
DARPA US Defence Advanced Research Projects Agency
DfT Department for Transport
DSRC Dedicated Short-Range Communication
DVSA Driver and Vehicle Standards Agency (DVSA)
EEBL Emergency Electronic Brake Light
ETSI European Telecommunication Standards Institute
EU European Union
IEEE Institute of Electrical and Electronics Engineers
IoT Internet of Things
ISO International Organisation for Standardisation
ITS Intelligent Transport Systems
ITU International Telecommunication Union
LTE Long-Term Evolution
OBU On-board unit
PKI Public key infrastructure
RSU Roadside Unit
SAE Society for Automotive Engineers
TCW Traffic Condition Warning
TMS Traffic Management System
UKCITE UK Connected Intelligent Transport Environment
UNECE United Nations Economic Commission for Europe
V2I Vehicle-to-infrastructure
V2V Vehicle-to-vehicle
V2X Vehicle-to-everything
VCA Vehicle Certification Agency

UK Connected Intelligent Transport Environment (UK CITE) aimed to create the most advanced environment for testing connected and autonomous vehicles. It involved equipping over 40 miles of urban roads, duel-carriageways and motorways with a combination of multiple wireless technologies, enabling seamless connectivity across the corridor. The project has established wireless technologies across roads that can improve journeys, reduce traffic congestion and provide entertainment and safety services through better connectivity. The UK CITE project was a collaboration between Visteon Engineering Services Ltd, Jaguar Land Rover Ltd, Coventry City Council, Siemens, Vodafone Group Services Ltd, Huawei Technologies (U) Co Ltd, HORIBA MIRA Ltd, Coventry University, University of Warwick (WMG), Transport for West Midlands and Highways England Company Ltd., co-funded by Innovate UK.

OVERVIEW

1. The Future of Transportation

Connected and Autonomous Vehicles (CAV) are poised to revolutionise transportation. Fully autonomous vehicles are expected to make traveling safer, cheaper, more comfortable, and more sustainable than current modes, as well as reduce the costs of travel substantially[1]. It is anticipated that CAV will provide unprecedented mobility for those without licenses to drive, including children, the elderly and the disabled.

Technology breakthroughs in CAV and rapid progress in wireless communication technologies intersect with digital development in Internet-of-Things (IoT), fueling significant transformation in the automotive industry. Advancements in these technologies create the possibilities of vehicles to partially or fully drive themselves, potentially and ultimately requiring no human driver participation at all. These vehicles will be able to collect data on their usage and activities as well as communicate among themselves and with road-transport authorities.

As a consequence, the industry faces not only the prospects of managing new value chains and business models, but also new regulations that re-define the roles of human drivers and vehicles.

2. What is a CAV?

Connected and Autonomous Vehicles (CAV) have also been loosely referred to as automated vehicles, autonomous vehicles, driverless cars and self-driving vehicles. Initially, CAV has been defined in terms of its "connected" and "autonomous" features separately.

Connected vehicles use communications technologies to send and receive information to and from other vehicles and road infrastructure, either via mobile phone networks or via the internet. The communication between vehicles is known as vehicle-to-vehicle or V2V, and communication between vehicles and infrastructure is known as vehicle-to-infrastructure or V2I. These are collectively known as V2X, or vehicle-to-everything.

Autonomous vehicles are those in which operation of the vehicle occurs without direct driver input to control functions such as the steering, acceleration, and braking. Autonomous vehicles are purposefully designed so that the driver is not expected to monitor the roadway constantly while the vehicle is operating in self-driving mode.

Today, some vehicles are both connected and autonomous, whilst others are either connected vehicles only or autonomous only. Those with both connected and autonomous features - hence, Connected and Autonomous Vehicle (CAV) - are often described in terms of their automated mode.

Vehicles with automated features are capable of "driving themselves", that is, they are not controlled and do not need to be monitored by a human driver at least for part of a journey[2]. Passenger vehicles available today are already equipped with some level of automated features such as collision warning systems, adaptive cruise control, lane-keeping systems, and self-parking technology.

Just like a human driver, a vehicle with automated features collects information, makes a decision based on that information, and subsequently executes an action. It is imperative that the automated features are classified in a common system to indicate the differing ratios of responsibility levels between the vehicle and the human driver.

[1] Meyer et al. (2017); "Autonomous vehicles: The next jump in accessibilities?"; Research in Transportation Economics.
[2] "Automated and Electric Vehicles Act 2018"; legislation.gov.uk.

Industry and policymakers often apply the SAE (Society for Automotive Engineers International) six-level classification system[3], which ranges from 0 to 5. The system offers a guide for a common understanding on the levels of automated driving.

For instance, the UK AEV (Automated and Electric Vehicles) Act 2018 distinguishes vehicles which "drive themselves" from those which do not. Additionally, the UK Department for Transport (DfT), in its 2015 report[4], had also described the respective roles of the human driver and the automated driving system.

Based on the SAE classification system, Levels 0 to 5 for automation are summarised as follows:

Level 0 – No automation. The human driver performs all aspects of all driving tasks, even when these are enhanced by warning or intervention systems.

Level 1 – Driver assistance. The driver assistance features can carry out either the steering or acceleration/deceleration.

Level 2 – Partial automation. The driver assistance features can carry out both steering and acceleration/deceleration. The driver is responsible for monitoring the driving environment and must remain engaged at all times.

Level 3 – Conditional automation. The driving automation features can perform all driving tasks but a human "fallback-ready user" is expected to respond appropriately to "a request to intervene". The fallback-ready user must be receptive to a handover request or to an evident system failure but is not expected to monitor the driving environment.

Level 4 – High automation. The driving automation features can perform all the driving tasks within their "operational design domain" (for example, motorways only). There is no expectation that the human user will respond to a request to intervene. If the limits of the system are exceeded, the system will put the vehicle into a "minimal risk condition", such as a safe stop.

Level 5 – Full automation. This is identical to Level 4 except that the driving automation features are not limited by an operational design domain. Instead, they are capable of performing all driving functions in all situations that a human driver could.

In summary, a classification system such as the SAE's indicates that the extent of automation functions in a CAV depends on the human driver's role in performing the dynamic driving task[5].

3. CAV Requires New Regulations

CAVs are expected to operate within the existing road transport infrastructure and regulations established for human-driven vehicles. In fact, the design and operation of vehicles are also subject to international regulations such as those administered by the United Nations Economic Commission for Europe (UNECE).

For instance, the Vienna Convention on Road Traffic 1968 stipulates that a human driver must always remain in full control of and responsible for the behaviour of the vehicle in traffic. Although the UK is in the process of ratifying this convention, the testing of autonomous vehicles on public roads required the introduction of new rules and guidelines. This led to the publishing of the "Code of Practice for Testing" in July 2015 by the UK Department for Transport (DfT) to promote safety during the testing phase of CAVs.

[3] "Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles" Standard J3016_201806; SAE International. 2018.
[4] "The Pathway to Driverless Cars: A detailed review of regulations for automated vehicle technologies", Department for Transport (DfT), 2015.
[5] *Dynamic driving task* refers to the tactical functions (object and event detection and response) and operational functions (longitudinal and lateral motion control) which comprise the task of driving a vehicle (SAE International, 2014).

A revised "Code of Practice for Testing"[6] (February 2019) has recently been released by the DfT and the Centre for Connected and Autonomous Vehicles (CCAV). The updated document includes new content based on tests and trials of CAVs that have been conducted in the UK. Some of the updates include improved understanding of technical developments, such as the need to access vehicle data, and development of a process to support advanced trials on public roads[7].

Although the updated 2019 Code of Practice replaces the 2015 version, it does not introduce new legal requirements or barriers. Instead, it offers greater clarity on the Government's expectations for responsible CAV trials. However it does re-iterate that any trials should be carried out in compliance with the existing road traffic laws, some of which may not be compatible with the automated driving features of the vehicles which are being tested.

These expectations are aligned with the Law Commission Report[8] of November 2018 which also focuses on safety. The Law Commission report provides some perspectives on the allocation of responsibility and liability that can enable the safe and effective deployment of automated vehicles[9]. The report acknowledges that some adaptations of existing rules must be given consideration. Thus, the Law Commission will be issuing a series of consultations with relevant stakeholders over the next three years.

At least four aspects of the existing rules require a review to support a commercial deployment of CAVs on public roads. These are: international frameworks, laws, regulations, and standards. Figure 1 depicts and describes these levels of rules.

Aspect of Rules	Description
International frameworks	• A structure used internationally to provide a common foundation • Followed by the countries who have signed up to the framework • *Example: Vienna Convention on Road Traffic 1968*
Laws	• System of rules which a particular country or community recognises as regulating the actions of its members • Agreed by Parliament • *Example: Road Traffic Act 1968*
Regulations	• Mandatory requirements developed by policymakers • Derived from laws, and in turn inform standards and codes of practice • *Example: Road Vehicles (Construction and Use) Regulations 1986*
Standards	• Engineering criteria developed by the technology community • Specify how a product should be designed or how it should perform • *Example: ISO 26262*

Figure 1: Four aspects of rules that are fundamental to support CAV deployment

[6] "Code of Practice: Automated Vehicle Trialling"; Department for Transport and Centre for Connected and Autonomous Vehicles; February 2019.
[7] Ibid.
[8] "Automated Vehicles"; Law Commission of England and Wales and the Scottish Law Commission, for the Centre for Connected and Autonomous Vehicles (CCAV); November 2018.
[9] Ibid.

One of the fundamental differences between a fully automated CAV and human-driven vehicles is the role of the driver. It is therefore imperative to review the role of technologies in the CAVs, particularly when they are designed to replace the function of the human driver.

For the purpose of this report, we discuss the technologies applied on-board the CAVs, the telecommunication networks that enable communication among the CAVs, and the infrastructure for monitoring and supporting CAVs while they are operating on public roads.

4. Aim and Scope of this Report

This report aims to provide a brief review of the current legal and regulatory landscape that can support the operation of CAVs on public roads.

In doing so, this report highlights selected examples of CAV technologies that have already been tested in the UK within the UK Connected Intelligent Transport Environment (UKCITE) project.

The UKCITE project aimed to create the most advanced environment for testing CAVs. Testing was conducted on 40 miles of urban roads, inter-urban A-roads and expressway, and motorway, by using combinations of communication technologies to enable V2X, namely LTE, ITS-G5, and WiFi, as well as test the feasibility of LTE-V. The project also aimed to establish how these technologies can improve journeys, reduce traffic congestion and provide entertainment and safety services through better connectivity.

By applying selected examples of CAV technologies from the UKCITE project, this report highlights the possible legal and regulatory implications of this industry movement.

CURRENT LEGAL AND REGULATORY LANDSCAPE

5. Relevant Laws for CAVs

While testing of CAVs is ongoing in various jurisdictions including the UK, US, and Germany, pressure is mounting for law-makers, insurance companies and manufacturers, among others, to address various legal issues.

Legal issues related to CAVs can be grouped into three branches of law[10]: administrative, civil liability and criminal (see Figure 2).

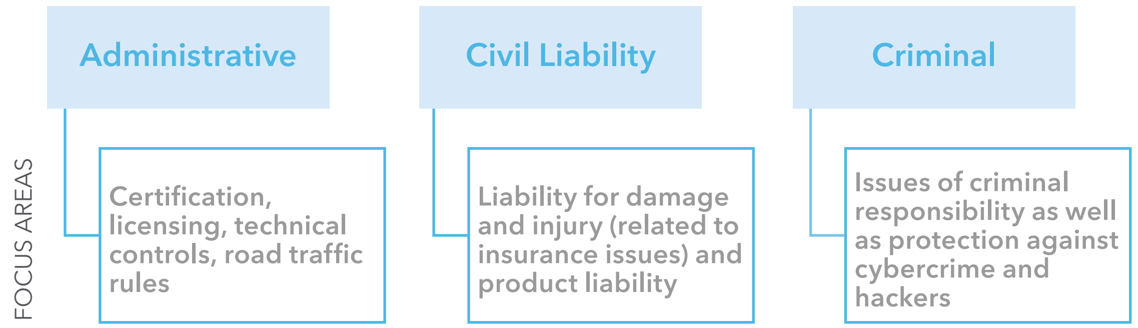

Figure 2: Three branches of law that affect CAVs

The scope of administrative law includes certification and licensing for both the human driver and vehicle, as well as road traffic rules. The issues surrounding criminal responsibility are particularly complex as some European states' criminal codes suggest that the human driver (or vehicle owner) may be charged with negligence even if the CAV was in a fully automated mode[11].

6. Regulations for Drivers and Vehicles

The UK Road Traffic Act 1988 requires that anybody who drives a motor vehicle on a road must hold a valid licence to drive that vehicle. There is also a requirement for drivers to be physically fit to drive.

The driver testing for licence acquisition purposes is administered by the Driver and Vehicle Standards Agency (DVSA), while regulating operation of vehicles by licensing drivers and issuing rules on the road are managed by the Driver and Vehicle Licensing Agency (DVLA)[12].

In a fully automated vehicle that does not require the presence of a human driver, the vehicle must be fully capable of controlling itself. However, a fully automated vehicle may also retain the option of handing back control to a person with an appropriate licence. In such a scenario, there is a need for human drivers to be conversant and competent with the features and functions of both automated and manual modes.

The driver-testing process will need to incorporate training on all the CAV features and functions. This also raises the need for vehicle type approval, which is the confirmation that production samples of a design will meet specified performance standards[13]. In the UK, the type approval process is administered by the Vehicle Certification Agency (VCA), a third relevant department within the DfT (see Figure 3 overleaf).

[10] Ilková, V.; Ilka, A. (2017) *"Legal Aspects of Autonomous Vehicles – an Overview"*. Proceedings of the 2017 21st International Conference on Process Control (PC), pp. 428-433.

[11] *Ibid.*

[12] *The Pathway to Driverless Cars: A detailed review of regulations for automated vehicle technologies", Department for Transport (DfT), 2015.*

[13] *Vehicle Certification Agency www.vehicle-certification-agency.gov.uk*

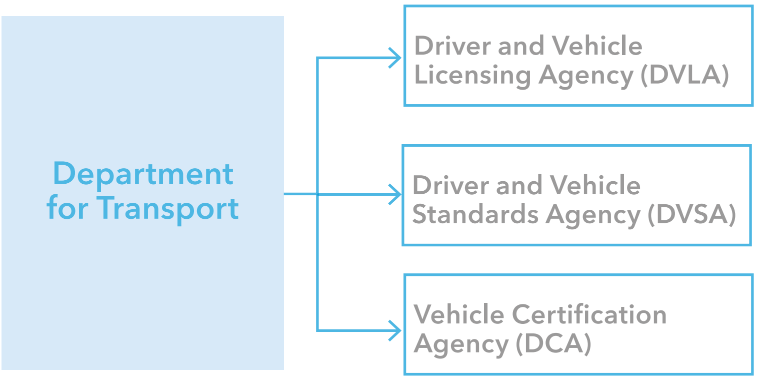

Figure 3: Agencies at the UK Department for Transport (DfT) that support CAV deployment

Currently, all vehicles are subject to a type approval process prior to being driven on the road. The process is based on existing international standards established by the United Nations Economic Commission for Europe (UNECE) and the European Union (EU).

Based on the type approval process administered by the VCA in the UK for instance, the vehicle manufacturer is required to submit components and systems for independent testing based on the established international standards. Current regulations issue performance standards based on the individual function of each component.

7. CAV Technologies and Standards

The introduction of CAV technologies can be traced to the demonstration of autonomous vehicle technical feasibility for driverless functions at the US Defense Advanced Research Projects Agency (DARPA) in 2004[14]. By 2014, numerous manufacturers including BMW, Ford, Nissan, and Volvo had begun testing various driverless technologies.

One of the critical focus areas of testing CAV technologies is safety. For instance, CAVs must be able to recognise other road users and objects, which requires the CAV sensor system to operate at least as well as, or better than, human drivers. In poor weather conditions such as fog and snow, the sensor system must be able to recognise reflective road surfaces and differentiate other vehicles of all sizes.

In other words, CAV technologies must follow specific standards not only based on technological specifications, but also acceptable “standards” based on the ability of a human driver who is equipped with a valid licence.

It is still unclear what kind of accidents CAVs are “capable” of. For example, the self-driving car project by Google Waymo on urban roads in Mountain View California found that the most common type of collision involving Google cars was being rear-ended by another (human-driven) vehicle[15]. During these collisions, the Google cars were supervised by Google engineers who were present in the vehicles during the tests.

The requirement for type approval for CAVs must consider that CAVs are not only set up with individual components, but these individual components may work within a system which may need to also competently interact with the outside world. For instance, a CAV may be equipped with an on-board unit (OBU) that acts as a brain to the entire control and operation of the vehicle, including navigation and communication (with other vehicles as well as with the road traffic infrastructure).

[14] Fagnant, D. J. & Kockelman (2015), K; *“Preparing a nation for autonomous vehicles: opportunities, barriers and policy recommendations”*; Transportation Research Part A: Policy and Practice.
[15] Teoh, E. R. & Kidd, D. G. (2017); *“Rage against the machine? Google’s self-driving cars versus human drivers”*; Journal of Safety Research.

Table 1 offers a summary of the three levels of standards for assessing CAV technologies.

Level of standards	Description and examples
Component	• Component-level standards are designed to mandate the existence or design of a particular part of a vehicle. • Regular vehicle example – camera for reversing that is installed at the back of the vehicle. • CAV example – a particular type of sensor for the vehicle to detect its surroundings while reversing.
Function	• Function-level standards are standards that relate to particular vehicle activities or processes. • Regular vehicle example – stop within a certain number of feet while traveling at a certain speed (braking function). • CAV example – stay within the painted lines of a motorway lane.
System	• A system-level standard is a standard that requires an overall level for safety of an entire driving system. • Regular vehicle example – not yet available. • CAV example – only applicable to certain types of collisions relative to distance travelled.

Table 1: Three levels of standards for the assessment of CAV technologies

Standards established at the component level have been useful to determine road safety regulations. Manufacturers are provided with precise guidance on how to comply with standards of a component, such as the vehicle camera for reversing; they are not burdened to ensure if the component can work seamlessly with other components.

However, for CAVs, the sensor installed at the back of the vehicle should not only detect the surroundings when reversing but should do so on all occasions. This requires assessing the sensor’s interoperability with other components.

Standards established at the function level are generally considered a better approach to determine vehicle safety compared to component level standards. Function-level standards allow manufacturers to conduct vehicle component tests based on a pre-set performance benchmark. The ISO 26262[16] series of standards, in particular, offer guidelines and requirements for the functional safety of electrical and electronic systems in road vehicles[17].

For instance, the brake-pad component in a regular vehicle is evaluated in accordance with the function of the vehicle braking system, based on the vehicle’s ability to stop within a specified distance when travelling at a particular speed. However, for CAVs, there may be a need to scrutinise how the CAV is programmed to accomplish basic tasks such as staying within the painted lines on the road. Because we are not accustomed to the “behaviour” of CAVs on the road, function-based standards may not be sufficient to ensure vehicle safety given the unpredictability of road surroundings.

[16] International Organisation for Standardisation; “ISO 26262, version 2, 2018 - Road vehicles; functional safety”.
[17] ISO 26262 defines functional safety for all automotive electronic and electrical safety-related systems, covering their entire life cycle including the development, production, operation, service and decommissioning (Naden C., 2018).

The system-level standards as described in Table 1 are considered more suited for CAV than other types of standards because they are designed to ensure the aggregate driving safety of a vehicle. In other words, CAV is considered as a system that can either operate on its own or be programmed for human driver intervention and control.

Viewing CAV as a system enables the design of system-level standards that cater to a safety-critical focus for both CAV drivers and other road users. The system-level approach will also encourage a direct focus on measurable safety metrics such as vehicle on-road performance, collisions, and injuries, instead of on performance metrics derived from road-tests.

However, the system-level standards approach for CAV may pose a challenge just like any technology-centric system that reduces human participation[18]. For instance, system-level standards may create non-uniform designs of CAV that lead to additional complexities in car servicing and replacement of parts.

To mitigate the potential challenge with system-level standards, one aspect of vehicle performance that should be reviewed is the labelling and rating systems for consumer protection[19]. This will ensure greater understanding by consumers of the different levels of capabilities of their CAVs.

Such a rating system should also be included in the driver training module, which should incorporate explanation on vehicle features. It is critical to ensure that vehicle owners are aware of the different features that indicate different levels of autonomy of the CAVs.

[18] For instance, the regulations for elevators in a building offer an interesting perspective as “any elevator that complies with safety rules and has automatic operation or continuous pressure operation” may still require a “competent person or competent persons regularly to operate” (Smith, 2014).

[19] Adkisson, 2018; *“System-Level Standards: Driverless Cars and the Future of Regulatory Design”*; University of Hawai’i Law Review.

LEGAL & REGULATORY PERSPECTIVES OF CAV IMPLEMENTATION

8. Application of Technologies in a CAV Environment

The technologies applicable in a CAV environment can be viewed as an interlaying of components and systems for alerts and messages, vehicle functions, and connectivity.

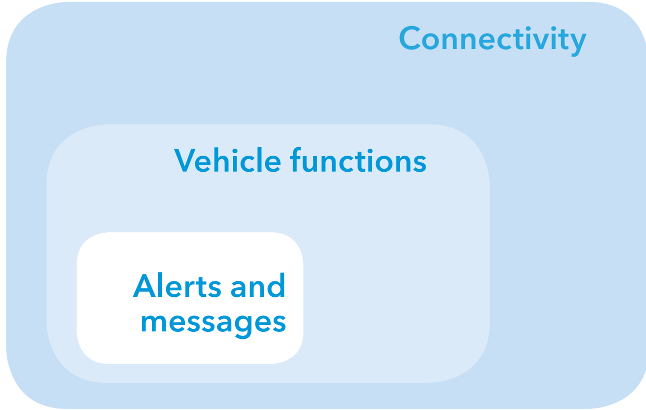

Figure 4: Technologies in CAV environment comprise those applied for alerts and messages, vehicle functions, and connectivity

For example, alerts are generated when a CAV detects emergency-braking by a vehicle in front it. The CAV then responds to the alert immediately by slowing down to avoid a collision. At the same time, the CAV communicates the emergency-braking incident to other vehicles in its proximity.

The interlaying application of various technologies in this case requires compliance to specific international standards. The following summary charts provide examples[20] of international standards that CAV alerts and messages, vehicle functions, and communication must comply with.

Figure 5: Examples of international standards that CAV alerts and messages must comply with

European Telecommunication Standards Institute (ETSI) standards for alerts and messages are based on the 2009 technical report "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Definitions"[21]. ITS include telematics[22] and all types of communications in vehicles, including vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I).

[20] Examples are based on the Feature Description Document v2.3 for the UKCITE project and the Law Commission consultation paper on Automated Vehicles (both 2018).
[21] "TR 102 638: Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Definitions", European Telecommunication Standards Institute (ETSI), 2009.
[22] The term "telematics" describes the combination of the transmission of information over a telecommunication network and the computerised processing of this information (Goel, 2007).

As an international organisation, ETSI produces a range of specifications, standards, reports and guides including for fixed, mobile, radio, converged, broadcast and internet technologies for Europe. ETSI works closely with other international standardisation organisations such as the International Organisation for Standardisation (ISO), Institute of Electrical and Electronics Engineers (IEEE), Society of Automotive Engineering (SAE), and International Telecommunication Union (ITU) in order to achieve internationally deployed and harmonised standards on ITS, which is essential to achieve worldwide interoperability for CAVs.

Figure 6: CAV functions must comply with standards set out by UNECE and EU

The UNECE and EU standards such as those for stand-alone driver assistance functions can help drivers to maintain a safe speed and distance, drive within the lane, avoid overtaking in critical situations and safely pass intersections. These functions are fundamental to determine the positive effects on safety and traffic management.

Type approval process based on the UN and EU standards involves testing components and systems against established standards. Once the individual components and systems have been approved, a vehicle is given a "whole vehicle approval certificate".

Currently, features and functions in a CAV require a separate process that tests against existing safety or environmental protection standards. A revised type approval process is needed to regulate the automated functions of CAVs.

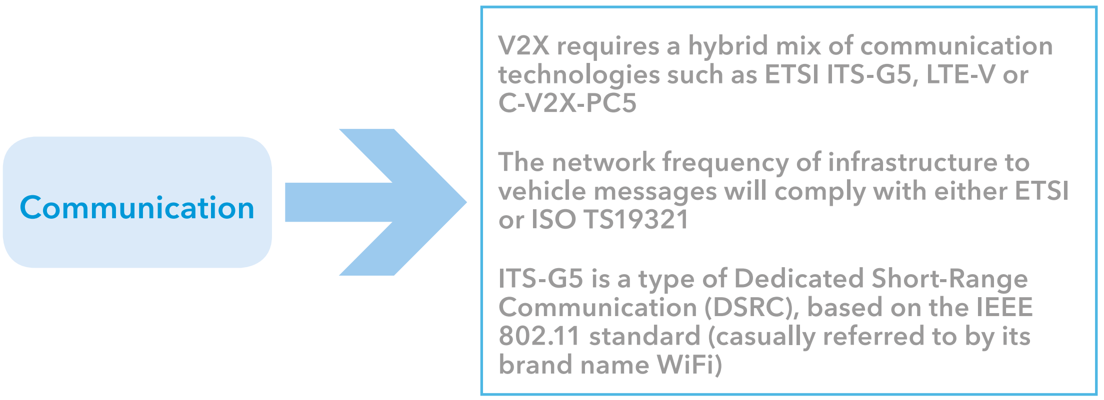

Figure 7: Examples of connectivity technologies in a CAV environment

CAV implementation involves enabling communication between vehicles (V2V) and between vehicles and the infrastructure (V2I), among others. The collection of possible communication pairings is commonly referred to as vehicle-to-everything (V2X). It is critical that V2X enables both safety-related and non-safety-related functions[23].

[23] An example of a non-safety-related function is the message "traffic light optimal speed advisory" which is designed to improve traffic flow by using periodic broadcasts to recommend the best speed (Filippi et al., 2017)which involves vehicles exchanging data with each other and the infrastructure, has proven to improve traffic safety and increase the efficiency of transportation systems. Direct Short Range Communication (DSRC.

Both cellular and local-range connectivity can be used in a CAV environment. These are depicted in Figure 8 below.

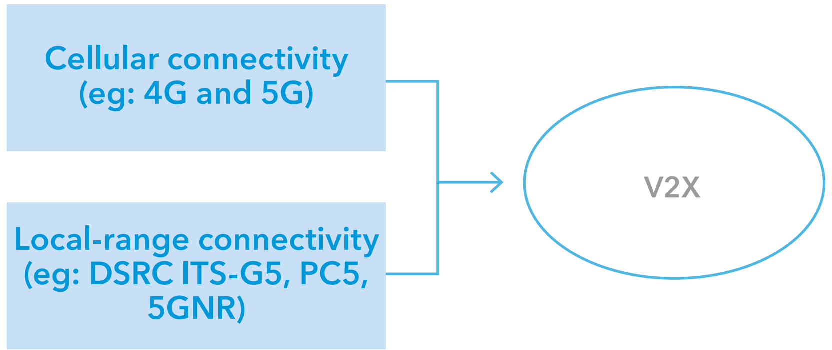

Figure 8: Cellular and local-range connectivity support V2X

5G is the latest standard for cellular communications that offers connectivity not only for road transport but for many Internet-of-Things (IoT) applications. The technical specifications for cellular are defined by the 3rd Generation Partnership Project (3GPP)[24]. Cellular connectivity is already widely available. Technically, vehicles today can access CAV applications via existing cellular mobile devices.

Local-range connectivity is tailored to road user applications and transmits data between vehicles and infrastructure using specific frequencies and protocols designed purely for transport. CAVs must be equipped with devices that can send and receive messages with these frequencies and transmission protocols.

ITS-G5 represents a mix of communication technologies for V2X. The most common local-range connectivity used for V2X today is Dedicated Short-Range Communication (DSRC). DSRC has undergone on-the-road testing over the last decade in various countries including the US, France and Germany.

Historically, the main difference between DSRC and cellular connectivity was that DSRC enabled direct communication among 802.11p equipped devices, while cellular connectivity relied on the mobile network. Recent advancements in communication technologies such as LTE-V are expected to blur this distinction to enable seamless connectivity between networks.

Arguably, DSRC is limited by several factors such as transmission range and transmission delays. For instance, in a limited transmission range, only vehicles that are within the "range" can receive alerts and messages.

[29] The 3rd Generation Partnership Project (3GPP) unites seven telecommunications standard development organisations to provide members with a stable environment to produce the Reports and Specifications that define 3GPP technologies (3GPP, 2018).

Figure 9 offers a simplified depiction of the connectivity via DSRC and cellular for V2X. The green-dashes line represents DSRC, while the black-dotted line represents cellular. Figure 9 also illustrates V2X connectivity with the broader back-end infrastructure and the presence of other road users.

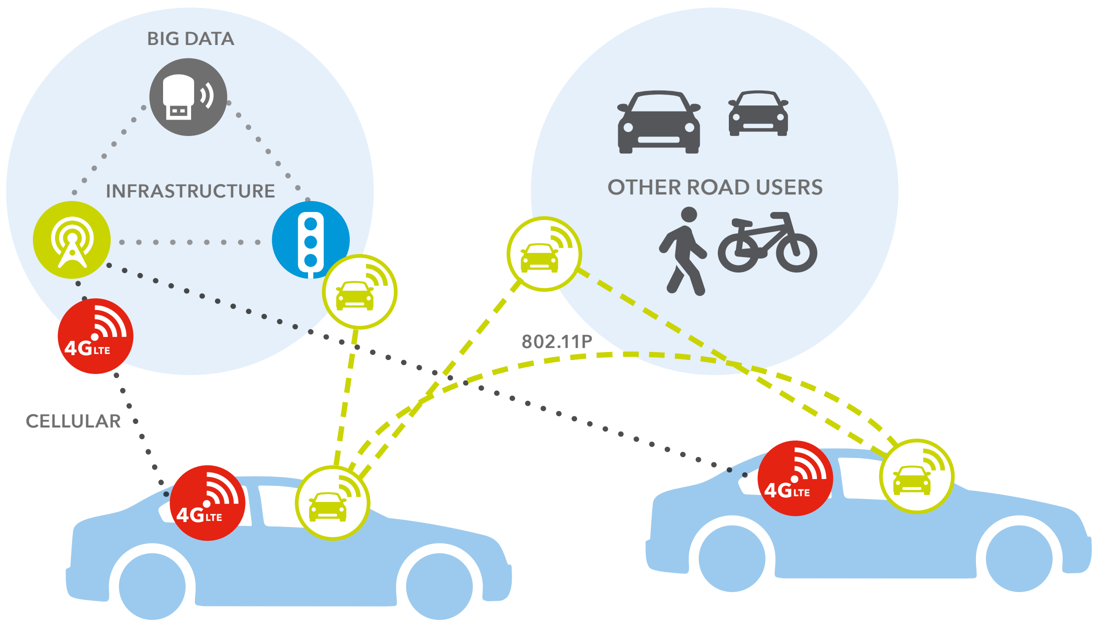

Figure 9: IEEE 802.11p and cellular connectivity for V2X25

Rapid progress in connectivity technologies usually demands updating of the communication networks. Implementing wireless technologies at this scale may require upgrading of bandwidth within the core communication network. This may lead to a demand to lay more fibre-optic cables, for instance along key trunk routes such as motorways. If low latency is not an issue, virtual roadside units can be placed along the route, which may mitigate some of these upgrade requirements.

The immediate challenge with connectivity technologies is also in ensuring interoperability with other systems and technologies, as different cellular systems are provided by different manufacturers. This can be challenging since CAVs are serviced by numerous hardware, software, and systems providers.

The interoperability of data and devices will have an enormous impact on the legal and regulatory requirements for CAVs. Topical issues on data ownership, anonymity of data, and the difference between driver and vehicle data will need to be considered.

9. Examples of CAV Technologies in Road Tests

For the purpose of assessing legal and regulatory implications in a CAV environment, we review some examples of technologies-in-action in CAVs. These examples provide a perspective on how selected features in CAVs are triggered, the types of messages exchanged among CAVs, and how components of the CAV infrastructure communicate with each other.

The examples also allow an assessment of CAV technologies from both V2V and V2I message transfer perspectives.

Communicating alerts and messages is core to the decision-tree parameters of the CAV system where the communications process is managed by the vehicle on-board unit (OBU). Because the technologies involved in the vehicle itself include triggering and responding functions, there is a need to understand the points at which the vehicle actuation system is activated to generate alert messages, before they are communicated.

[25] Filippi et al., 2017 "Why 802.11p beats LTE and 5G for V2X"; A white paper by NXP Semiconductors, Cohda Wireless, and Siemens.

For the purpose of this assessment, this report considers two examples, namely: Emergency Electronic Brake Light (EEBL) and Traffic Condition Warning (TCW). These examples are based on the tests conducted for the UKCITE project[26].

Example 1: Emergency Electronic Brake Light (EEBL)

EEBL is considered one of the main applications for CAV that has high safety benefit. The idea of the application stems from the need to extend drivers' visibility through the hard-braking notifications, particularly in situations of limited visibility such as during adverse weather and road conditions. By notifying drivers of braking vehicles ahead, it can allow for more timely evasive driving decisions, leading to fewer collisions.

As an illustration of EEBL, Figure 10 depicts vehicles A and B driven in the same direction in the same lane. Several assumptions apply to the illustration:

I. Both vehicles are traveling on the motorway.

II. Vehicle A is travelling at a speed that is greater than or equal to 30 mph (approximately 48 kmph or 13.4 m/s) prior to hard-braking.

III. Vehicle B is driven behind vehicle A in the same lane at a speed greater than or equal to the speed of vehicle A.

IV. The distance between vehicles A and B is assumed to be less than or equal to 600 metres.

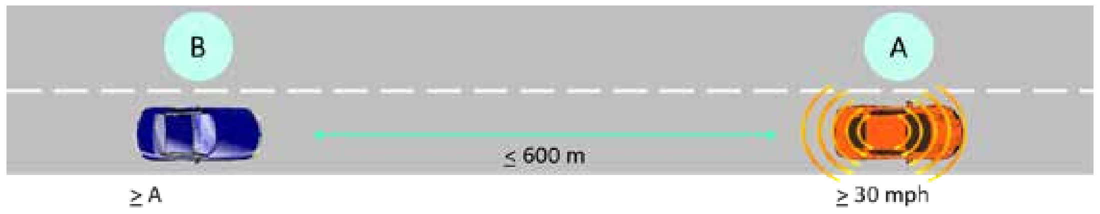

Figure 10: An illustration of EEBL parameters between vehicles A and B

EEBL is based on a trigger by vehicle A's hard-braking, which occurs when the deceleration rate is at least 4 m/s^2. The EEBL symbol is shown on vehicle A's OBU screen at the same time as the alert arrives at vehicle B. The same alert can reach other vehicles that are traveling in the same direction, or within the area-of-relevance (AOR), up to a range of 600 metres.

Figure 11 provides an illustration of vehicle A communicating its EEBL alert directly to vehicles within the AOR. The EEBL symbol is expected to be shown on all the vehicles' OBU screens within 2 seconds of vehicle A's hard-braking. The symbol disappears upon the receiving vehicle's deceleration in response to receiving the EEBL alert from vehicle A.

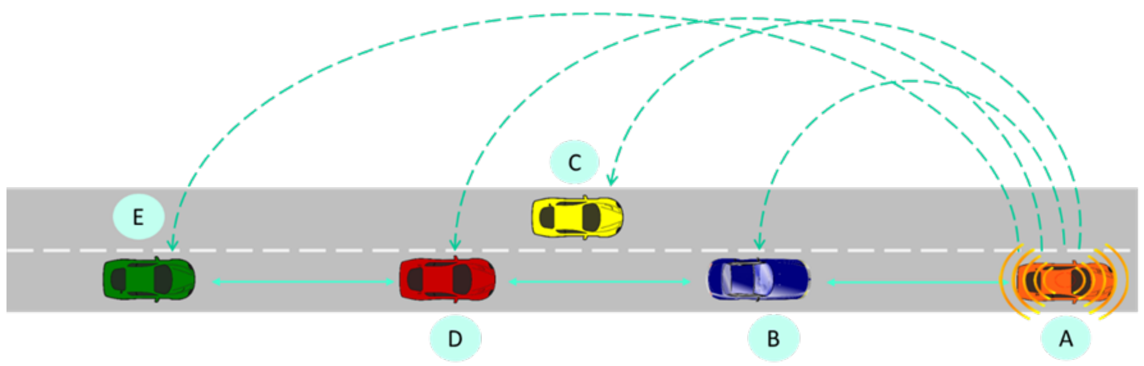

Figure 11: Communicating EEBL alerts from vehicle A to other vehicles within the Area of Relevance

[26] "UKCITE Feature Description Document V2.3"; January 2018.

The triggering condition of an EEBL alert is a built-in application that resides within the vehicle system. When assessing legal and regulatory implications in this instance, it is important to differentiate between the scope of the system and the reach of the EEBL alert. This is because, while the system that triggers the EEBL alert in vehicles can be relied upon to perform as specified in its technical functionality, it is the sending and receiving of the alerts, and any chosen subsequent action, or lack of, by the driver that pose a challenge (to legal and regulatory considerations).

For instance, if the vehicles in Figure 11 are traveling on a typically busy motorway during rush hour, the likelihood of vehicles receiving multiple EEBL alerts will increase due to the large number of vehicles in multiple lanes that may also be prone to perform hard-braking.

Over time, these multiple EEBL alerts may desensitise drivers from responding promptly, leading them to ignore the alerts. Further work, such as that of Szczurek et al.[27] is required to ensure that such systems operate effectively with minimal false warnings. It may also be deemed necessary to include responding to EEBL alerts as part of the learner-driver training module.

Also, since EEBL is a safety feature, it is important to ensure that the EEBL alert from the CAV system can reach all the vehicles in proximity, not only directly from the hard-braking vehicle(s), but also via roadside units (RSU). The successful communication of the EEBL alerts also relies on a reliable communication network along the motorway.

Example 2: Traffic Condition Warning (TCW)

Traffic Condition Warning (TCW) is a road-safety application in a scenario of slow-moving traffic. TCW alerts the driver in advance about traffic moving slowly in the direction of travel of the vehicle. The alert provides the driver some time to slow down, similarly to EEBL, or to take an alternative route to avoid the build-up of slow-moving traffic.

Looking in detail at one particular TCW scenario, vehicles performing hard-braking may lead to other vehicles receiving EEBL alerts, which in turn may cause a traffic slow-down as drivers react to the alerts and reduce their speed.

Figure 12 illustrates the communication of a TCW alert that originated from an EEBL event by vehicle A. Vehicle A transmits alerts directly to vehicles within its proximity, as indicated by the light-green V2V lines of A to B and A to C.

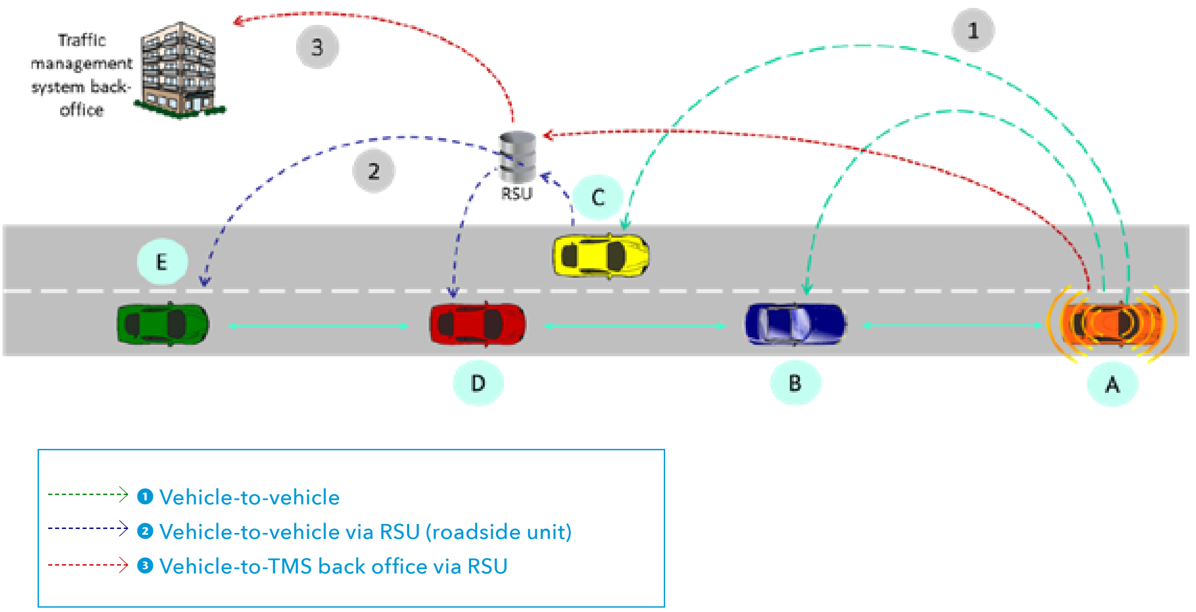

Figure 12: Communication of Traffic Condition Warning (TCW) alert based on an EEBL event

[27] Szczurek et al., 2012; "Estimating Relevance for the Emergency Electronic Brake Light Application"; IEEE Transactions on Intelligent Transportation Systems

In Figure 12, vehicle A will also transmit the EEBL alert to the nearest roadside unit (RSU), which then relays the alerts to vehicles D and E.

Both vehicles D and E may be able to detect the forming of slow-moving traffic on their OBU screens while receiving A's EEBL alert via the RSU. Vehicles D and E can then communicate TCW alerts to other vehicles behind them that are traveling in the same direction. These alerts can be transmitted via direct V2V communication or via V2I links to other RSUs.

Figure 12 also illustrates that vehicle C, upon receiving both EEBL and TCW alerts, can also communicate these via the nearest RSU. The RSU will then process all the messages received from both A and C, before sending to the TMS (Traffic Management System) back office.

It is apparent, considering Figure 12, that there is a high likelihood of vehicles and drivers being inundated with alerts, giving rise to potential issues with TCWs that relate to data. For instance, alerts and messages will require expiry dates so that systems are not burdened with storage. The CAV on-board system and the CAV infrastructure need to adopt standardised rules for data storage over a specified period of time.

Legal & Regulatory Implications Based on Examples of EEBL and TCW

Both the EEBL and TCW examples offer some perspectives on legal and regulatory implications for a CAV implementation. These can be summarised into four focus areas, namely: safety rules; standards of CAV components, parts, and systems; standards of connectivity for V2X; and data use and storage rules. These are noted in Figure 13.

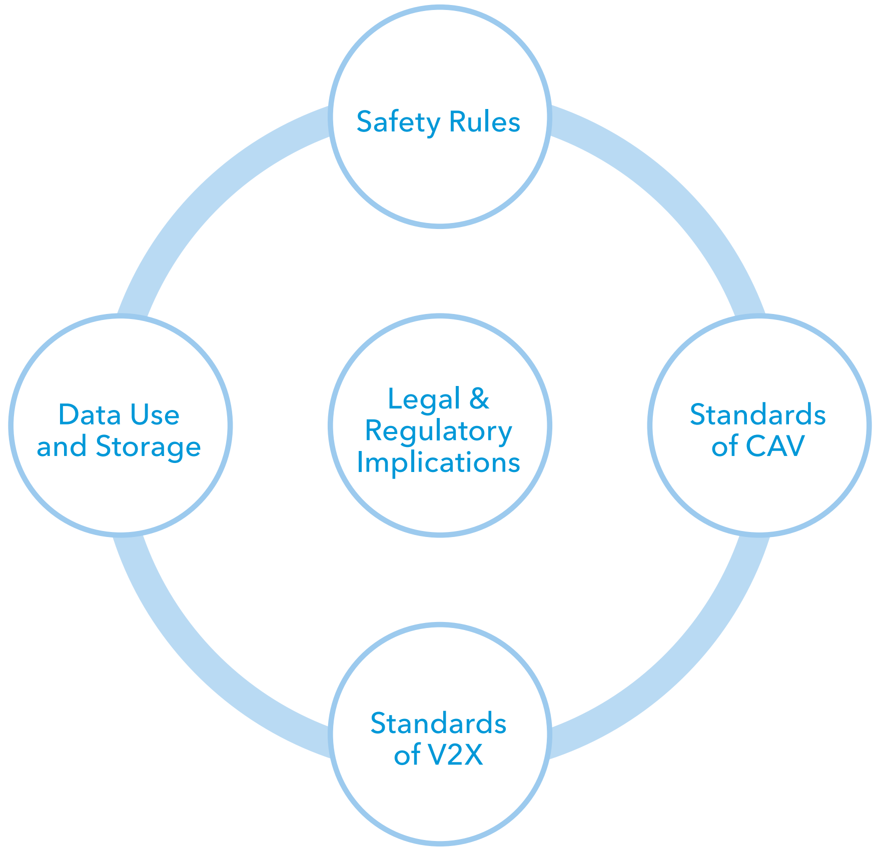

Figure 13: Legal and regulatory implications on four focus areas based on the examples of EEBL and TCW

Based on the EEBL and TCW examples, some of the elements of safety rules that will be affected are related to vehicle performance. This requires a review of the existing type-approval process since the type approval required for a CAV will need both focus on technologies and the combined role of the CAV with a human driver.

For example, testing the vehicle's automatic braking system as a function will need to include testing of the vehicle's sensing and object identification abilities, steering system, and tyre performance.

The human driver or owner will also need to be trained on the functions and capabilities of these technologies. The human driver training modules will need to be updated regularly to ensure awareness of the latest CAV technologies.

Another challenge to the current legal and regulatory rules may also relate to connectivity on the communications networks. Although there are common challenges such as geographical characteristics surrounding the road network, the possibility of alerts not delivered on-time and accurately, and the decision trees adopted by each car's Advanced Driver Assistance Systems (ADAS) to process all data received and act, or alert its driver to act, accordingly will vary the safety benefit of EEBL and TCW. Further challenges include the interoperability between cars, roadside equipment, road authorities and back office processing, and hence the development of common standards for the CAV communications systems.

Security of such systems and the storage of data will also present a number of policy decision requirements as the CAV industry progresses. Some choices, such as whether there is a need to develop a common 'cloud' and 'central security/PKI deployment centre', will require debate and endorsement at a national level.

To conclude, there are a number of implications and areas for consideration within the legal and regulatory framework as the CAV industry and associated technologies continue to develop. Communications standards, regulations around interoperability, data security and storage, and driver knowledge and awareness are all topics that will require further scrutiny, in particular as the "connected" and "autonomous" features of CAVs advance and combine in systems which are ever more linked and interconnected.

Shaping the future

Intelligent Vehicles Group

Intelligent vehicles (IV) are set to transform the UK economy and WMG are recognised as a centre of excellence for connected and autonomous vehicle research. Our multidisciplinary approach, including cooperative driving systems, connectivity, human factors and verification and validation, enables a full understanding of the practical applications that will help shape the future of transport mobility.

Principal Investigator: Professor Paul Jennings

Supply Chain Research Group

WMG's supply chain research group (SCRG) apply customer responsive supply chain theory into practical solutions that generate both economic and societal value. Collaborating with industrial partners, the SCRG seek to resolve complex business and organisational problems across agrochemicals, automotive, defence, consumer-packaged goods, retail and pharmaceuticals.

As a society aspiring to become more responsible consumers, we try to use less, use more sustainably and more ethically. In the automotive industry this is leading to the development of technologies that support low emissions mobility that is connected and autonomous. The supply chains for these new technologies do not currently exist. SCRG are developing methodologies to identify the market opportunities and design new sustainable supply chains for emerging technologies. Along with the transition to the next stage of industrial revolution, we have developed approaches to explore new business models that are supported by design in supply chains to deliver complex value propositions.

Principal Investigator: Professor Janet Godsell

Pinsent Masons

The automotive industry has entered the global arena of IT, communication and infotainment and is grappling with the opportunities and challenges presented by an increasingly connected world. Pinsent Masons is an international law firm with extensive experience in the automotive and technology sectors. Our international Automotive Team has advised clients on the legal solutions required for original equipment and parts manufacturers, IT and telecom suppliers, and infrastructure and insurance providers operating in an increasingly global market.

The team has extensive expertise advising clients on M&A, contractual arrangements, the procurement of software and hardware solutions, and regulatory issues against the background of telecoms and data protection laws - as well as giving operational support regarding risk management, supply chains, insurance, compliance and intellectual property.

We regularly host discussions around future developments in the sector and produce an annual whitepaper on the legal considerations with respect to connected and autonomous vehicles.

Contact: Ben Gardner

For further information please visit:
www.pinsentmasons.com and **www.out-law.com**

Thank you to our authors:
Sharbanom Abubakar, WMG,
Professor Jan Godsell, WMG

Getting in touch:

- wmg.warwick.ac.uk
- SCIP@warwick.ac.uk
- +44 (0)24 765 28038
- @WMGSupplyChain

WMG
University of Warwick
International Manufacturing Centre
Lord Bhattacharyya Way
Coventry
CV4 7AL

84157