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The future of connected and automated mobility in the UK – a call for evidence from the Department for Business, Energy & Industrial Strategy and the Centre for Connected and Autonomous Vehicles

Executive Summary:

Despite relative weaknesses in global collaboration and co-creation platforms, smart road and communication infrastructure, urban planning, and public awareness, the United Kingdom (UK) has a substantial strength in the area of Connected and Automated Mobility (CAM) by investing in research and innovation platforms for developing the underlying technologies, creating impact, and co-creation leading to innovative solutions. Many UK legal and policymaking initiatives in this domain are world leading. To sustain the UK's leading position, we make the following recommendations:

- The development of financial and policy-related incentive schemes for research and innovation in the foundations and applications of autonomous systems as well as schemes for proof of concepts, and commercialisation.
- Supporting policy and standardisation initiatives as well as engagement and community-building activities to increase public awareness and trust.
- Giving greater attention to integrating CAM/Connected Autonomous Shared Electric vehicles (CASE) policy with related government priorities for mobility, including supporting active transport and public transport, and improving air quality.
- Further investment in updating liability and risk models and coming up with innovative liability schemes covering the Autonomous Vehicles (AVs) ecosystem.
- Investing in training and retraining of the work force in the automotive, mobility, and transport sectors, particularly with skills concerning Artificial Intelligence (AI), software and computer systems, in order to ensure employability and an adequate response to the drastically changing industrial landscape

Response authors:

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About the TAS Hub:

The UKRI TAS Hub assembles a team from the Universities of Southampton, Nottingham and King's College London. The Hub sits at the centre of the £33M Trustworthy Autonomous Systems Programme, funded by the UKRI Strategic Priorities Fund.

The role of the TAS Hub is to coordinate and work with six research nodes to establish a collaborative platform for the UK to enable the development of socially beneficial autonomous systems that are both trustworthy in principle and trusted in practice by individuals, society and government. Read more about the TAS Hub here.

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List of abbreviations:

Artificial Intelligence	AI
Association of British Insurers	ABI
Autonomous Vehicles	AVs
Centre for Connected and Autonomous Vehicle	CCAV
Connected and Automated Mobility	CAM
Connected and Autonomous Vehicles	CAVs
Connected Autonomous Shared Electric vehicles	CASE
Department for Business, Energy and Industrial Strategy	BEIS
Department for Transport	DfT
Government Communications Headquarters	GCHQ
Human-Driven Vehicles	HDVs
Maritime Autonomous Surface Ships	MASS
Offshore Robotics for Certification Assets	ORCA
Trustworthy Autonomous Systems	TAS
UK Research and Innovation	UKRI
UK Robotics and Autonomous Systems	RAS
United Kingdom	UK
Unmanned Aerial Vehicles	UAVs

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This response addresses the following questions from the terms of reference:

I- Strength of CAM in the UK, here and now

Question 1: Are there any areas where the UK has strong capabilities in the CAM Sector and its supply chain? Please provide specific evidence to demonstrate these strengths. If you wish, you can also upload and attach any supporting documents using the upload option below.

Question 2: What factors could impact the UK's ability to maintain these strong capabilities? Please provide specific evidence to support your response. What factors could impact the UK's ability to maintain these strong capabilities? Please provide specific evidence to support your response.

Question 3: In your opinion, what are the relative strengths of the UK CAM sector and its supply chain compared to international counterparts? Where relevant please highlight if these capabilities are world leading and provide specific evidence to support your response.

Question 4: In your opinion, what are the relative weaknesses of the UK CAM sector compared to international counterparts, including important gaps in the UK CAM sector supply chain? Please provide specific evidence to support your response.

Question 5: What, if any, are the current barriers for your organisation in relation to the scale-up, commercialisation and deployment of CAM in the UK? Please provide up to 5 barriers ranked from most to least impactful.

Question 6: What role should government have, if any, in reducing and/or removing these barriers, and why?

II- Why is CAM important to the UK

Question 7: Will CAM support the decarbonisation of transport so as to meet Government's Net Zero ambitions? If yes, how will CAM support the decarbonisation of transport? Please provide specific evidence to support this.

Question 8: Will CAM support economic growth and the creation of jobs across the country as set out in Government's plans to level up the UK? If yes, how will CAM support economic growth and the creation of jobs across the UK? Please provide evidence to support this.

Question 10: Will the deployment of CAM have a substantial impact on the automotive industry and its supply chain? If yes, in what way will the deployment of CAM impact the automotive industry and its supply chain? Please provide specific evidence to support this.

Question 13: Will the deployment of CAM have a substantial impact on the insurance industry and its supply chain? If yes, in what way will the deployment of CAM impact the insurance industry and its supply chain? Please provide specific evidence to support this.

III- What Next?

Question 22: What areas should be priorities for the CAM sector in the UK in the period leading up to 2030 and why? Please provide up to 5 priority areas ranked from highest to lowest priority.

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I- Strength of CAM in the UK, here and now

1. Are there any areas where the UK has strong capabilities in the CAM Sector and its supply chain? Please provide specific evidence to demonstrate these strengths. If you wish, you can also upload and attach any supporting documents using the upload option below.

1. Recent figures reveal that UK's investment in AI is far more than any other European Country. It reached $1.48bn in 2020, third place in the world after the US and China. This number was only $5.38m and $4m for France and Germany respectively (BusinessCloud (2020)).
2. In its 2017 Industrial Strategy, the Department for Business, Energy and Industrial Strategy (BEIS) laid out five "foundations of productivity" which reflect its vision for a transformed economy. In the Strategy, BEIS also identified "Grand Challenges" which the UK must overcome to harness the opportunities that will arise from a changing global landscape. BEIS more recently published a policy paper detailing HM Government's plan to tackle the Challenges. Importantly, the first 3 of the 4 Grand Challenges are focused on AI and data, clean growth, and the future of mobility. These policy papers provides a clear roadmap for business across different sectors and at dissimilar levels to expand their competence and competitive advantages in AI and its application. This can benefit any sector like CAM which hinges on AI competence.
3. The UK has a national institute for data science and AI, the Alan Turing Institute. This signals the UK's strong commitment to the area and forms a platform for applied and fundamental research across sectors and disciplines.
4. On 28th April 2021 HM Department for Transport (Dft) announced that self-driving vehicles are allowed on British public roads and according to the Transport Minister this is a significant step towards the mass production and use of self-driving vehicles. This is a critical decision as more mileage driven by AVs means that they encounter more traffic scenarios and learn how to handle hazardous situations. This also provides regulatory bodies with the means to monitor the performance of current AVs on roads and introduce/enforce more detailed and statutory regulations to augment the safety of such a technology.
5. The Law Commission is currently undertaking a project on AVs (in response to a request by The Centre for Connected and Autonomous Vehicle—CCAV) to review the legal framework for AVs. This project is expected to conclude in 2021 and the final report will make a tremendous contribution to defining a comprehensive legal framework as well as anticipating the legal implications with regards to AVs functioning on public roads.
6. According to the Association of British Insurers (ABI), major UK insurers are focusing on *pilots of AVs* to provide solutions for ensuring safety and liability challenges after the market is disrupted by the AVs.
7. The Impact Assessment published by the DfT (*Pathway to Driverless Cars: Insurance for Automated Vehicles*) highlighted the AVs' insurance dilemmas in 2016 and called for Government intervention as well as policy review.
8. In 2018, the Automated and Electric Vehicles Act 2018 received Royal Assent and a new liability regime for self-driving cars was introduced. Given that the UK is one of the leaders

(first in Europe and fourth worldwide) (ABI (2019)) in the insurance industry, the recent intensive research by both academia and the insurance sector has identified potential barriers in insuring the AVs and share the liability in case of collision/loss (Taeihagh and Lim (2019); Collingwood (2017); Ryan (2020)). Although this is still an evolving area, the initiatives and direction are promising. Without a doubt, insurers are one of the main stakeholders of AVs and have the capacity to identify and quantify the risks. This can mitigate the liability implications to a satisfactory extent and pave the path for mass adoption of the technology.

9. The development of local AVs such as Oxbotica together with the legal flexibilities to test and ride self-driving vehicles in the UK massively contributes to generating data and training the AI-based algorithms that are capable of controlling vehicles autonomously.
10. There are already several initiatives to develop open data sets, including for the purpose of validation and verification. UK also has strong research and open innovation platforms for autonomous mobility involving other types of AVs (such as Unmanned Aerial Vehicles (UAVs), Maritime Autonomous Surface Ships (MASS), Autonomous Underwater Vehicles, *e.g.*, in the context of the Offshore Robotics for Certification Assets (ORCA) Hub)
11. There is a strong foundational research environment with significant multidisciplinary collaboration on holistic validation and verification of CAVs; examples of such are found throughout the entire TAS Programme, and in particular in the Hub and the Verifiability Node, as well as the UK Robotics and Autonomous Systems (RAS) Network, the Assured Autonomy Programme, and the Offshore Robotics for Certification Assets (ORCA) Hub.
12. Infrastructure for sustained collaboration and technology transfer from research environments to innovation ecosystems; examples of such infrastructure include the CAM Testbed resulting from the collaboration across Connected Places Catapult, Zenzic and a number of companies.
13. Cybersecurity: due to the connectedness (*i.e.*, V2I, V2V, V2X) the security and integrity of the communication infrastructure becomes crucial. Led by HM Government Communications Headquarters (GCHQ), the UK is a leading country in securing the cyberspace and maintaining/improving the security of the UK Internet to protect critical organisations, industries and Small and Medium-sized Enterprises (SMEs) against any cyber threat. The past records can demonstrate the scientific and technological capabilities that the UK possesses to respond to such threats (NCSC Annual Review (2020)). The past records can evidence that the UK has set very effective barriers to withstand any cyber-attacks.

2. What factors could impact the UK's ability to maintain these strong capabilities? Please provide specific evidence to support your response.

14. Sustained funding for multi-disciplinary funding for large scale projects that can address the foundational and industrial challenges of trust in autonomy.
15. Forming and assigning regulatory bodies to work closely with the stakeholders and develop standards for designing, manufacturing, owning, using and maintaining AVs. A main concern associated with the AVs in academic literature revolves around the lack

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universal/regional standards in designing and manufacturing AVs and the very fact that regulatory bodies are currently well behind the technology developers such as IT giants and car manufacturers. Moreover, widespread use of AVs will hinge upon well-established regulatory frameworks and calibrated trust in safe and secure operation of the technology (Lloyd's (2014)).

16. Rigorous risk assessment and mitigation analysis to pinpoint and evaluate the potential risks from a socio-technical perspective. According to a large body of academic literature determining factors in the willingness of consumers to adopt a disruptive technology are 'trust' and 'perception of safety'. A thorough and in-depth risk analysis and providing the public with the evidential support on how safe AVs can function in mixed traffic can promote trust in users and encourage them use it. With more adoption of the technology more (financial and technical) opportunities can emerge for the technology developers to evolve it and reach the desired maturity level.
17. Engagement of all stakeholders, including the general public, in building trust and evaluating the evidence of safety, environmental impact, and improved mobility in the case of CAM.
18. Fund the development of highly specialised 'Living Labs' that include test tracks, simulators, and other natural artefacts that will re-create normal driving. The University of Southampton is currently aiming to develop such a test track funded by the Enterprise M3 Local Enterprise Partnership.

3. In your opinion, what are the relative strengths of the UK CAM sector and its supply chain compared to international counterparts? Where relevant please highlight if these capabilities are world leading and provide specific evidence to support your response.

19. One of the relative advantages of UK is to provide large platforms of collaborations across the ecosystem of innovation; the TAS program with more than 100 partners and numerous interconnected projects (at the initial funding commitment of £33M) is the largest programme of its kind worldwide.
20. The UK's strengths lies mainly in its financial services and research base. UKRI, and soon the Advanced Research and Invention Agency (ARIA), has the capability to bring together world-leading research groups and industry as well as legal experts and financial services experts to provide a full suite of solutions to various CAM business models.

4. In your opinion, what are the relative weaknesses of the UK CAM sector compared to international counterparts, including important gaps in the UK CAM sector supply chain? Please provide specific evidence to support your response.

21. Relative lack of international collaboration platforms, with the decreased interest for UK-led European Union projects.
22. Communication infrastructure (*e.g.*, 5G): according to the Cellular Telecommunications and Internet Association the UK falls in the second cluster of infrastructure capacity and readiness for hosting 5G. Given the nature of CAVs which heavily rely on communication channels to receive and send information, having an up-to-date 5G infrastructure or more secure alternative(s) can serve as the bedrock for mass introduction of AVs to the public roads. However, it must be noted that 5G protocols still suffer from several vulnerabilities,

most notably the introduction of exposures to internet threats. In additions, several vulnerabilities have been found by researcher exploiting Tesla cars using drones and the WiFi of the entertainment system. As advocated here, AVs need to design a defense in-depth approach and they need to be resilient to potential threats.

23. Urban design (*e.g.*, road geometry, presence of obstacles and pedestrians, population density, traffic density, road capacity, etc.): the current urban design and traffic control infrastructure are designed for human-driven vehicles (HDVs) and based on the human cognitive abilities. Considering that autonomous driving is still in its infancy stage, modifications to the urban planning/design might be necessary to ensure the safety of AVs while operating on public roads. For example, the recent fatal collisions of AVs (Tesla in autopilot mode) in the United States indicate that a simple traffic scene for human drivers can involve blind spots for the AVs. One of the biggest challenges that AV manufacturers are currently dealing with is adapting their systems to the existing urban design. In the future, if CAM will become the norm, a massive adaptation plan will be required to improve our cities in order to push CAM capabilities.
24. Lack of universal/regional standards: one of the main concerns in the academic literature is the lack of agreed standards for manufacturing and testing such vehicles as the backbone of CAM. This can raise serious challenges to the supply chain of parts and integration of software and hardware components. According to research, one of the main challenges in the supply and inventory of spare parts for manufacturing robots is the heterogeneity of machines which makes it difficult to stock high variety but low volume parts for those machines. Furthermore, this can give upper hand to the developers and manufacturers to gain dominance over regulatory bodies and frame the regulations in their own favour.
25. Lack of public awareness, technical transparency, and trust in autonomous vehicle technologies: the drive towards CAM technology has mostly been by the technology providers and getting on board the general public and various stakeholders requires extensive public awareness programmes, increased technical transparency, and establishing trust in the technology. In the meantime, protocols and programmes for training and licensing users of partially AVs which still require human intervention to avoid a collision need to be formulated and verified. This is a vital step in achieving *calibrated trust* in automation and limiting overreliance on the capabilities of AVs

5. What, if any, are the current barriers for your organisation in relation to the scale-up, commercialisation and deployment of CAM in the UK? Please provide up to 5 barriers ranked from most to least impactful.

26. Lack of a talent pipeline. CAMs require experts in AI, Machine Learning, Computer Vision, in addition to traditional transportation engineering disciplines. There is also a need to upskill the legal and insurance sectors in CAM-related areas to ensure the adequate provisioning of certification processes, compliance measures, and legal recourse.
27. Clear incentives for industry-academia collaborations to take up low-TRL solutions and co-create them into higher TRLs; proof-of-concept and commercialisation grants to facilitate spin offs taking transformative research into value-creating innovations.

28. Lack of established co-creation platforms including standardised interfaces, and transparent validation and verification mechanisms: successful deployment of CAM requires smooth co-creation across the entire ecosystem from manufacturers of mobility technologies to their suppliers, to transport and logistic providers and their various types of customers. Such holistic co-creation platforms, particularly incentivising essential qualities such as responsibility, transparency, and trust, are not currently available.

6. What role should government have, if any, in reducing and/or removing these barriers, and why?

29. HM Government should play a role in developing standards to allow for interoperability: standards for vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication. Without Government intervention, each manufacturer is will try and create their own monopoly by developing their own standards which might not be compatible with others. This is already seen with electric vehicle charging. There is typically no incentive to be interoperable. But such attempts at monopolies reduce the effectiveness for CAM to maximise aims such as reduction of CO2 emissions.
30. A lot of private data is potentially exchanged with other vehicles and with the infrastructure/road network. This could impede trust and adoption of CAM and certain services. The AutoTrust project is designed to address these issues, and has produced an Internet of Vehicles landscape - this is a living document. HM Government has a role to ensure that the systems being developed are secure but also that end users provide consent for the use of information in line with *e.g.* GDPR guidelines.
31. Incentivising, both through governmental grant schemes and through policy, responsibility and trust in the ecosystem of CAM design, validation, and verification.

II- Why is CAM important to the UK

7. Will CAM support the decarbonisation of transport so as to meet Government's Net Zero ambitions? If yes, how will CAM support the decarbonisation of transport? Please provide specific evidence to support this.

32. Connected Autonomous Vehicles (CAVs) allow for vehicles to form platoons (collectives of coordinated vehicles). Recent work at the University of Southampton (Worrawichaipat, Phuriwat (2021)) has shown how CAVs can reduce delays at road intersections and hence the CO2 emissions and inefficiencies associated. The benefits grow exponentially with the size of the road networks and intersections.
33. CAM can be seen one part of CASE mobility with the potential to assist the move to decarbonisation. Connected and shared vehicles are expected in this view to reduce emissions and congestion
34. However, some people challenge this optimistic prognosis. For example, if autonomous cabs drive all day long without breaks, we might see an increase in energy consumption (Wadud *et al.* (2016)). Additionally, more mobility options and more efficient use of road space might simply lead to an increase in vehicle miles travelled, and hence to the same or similar levels of congestion. This may reduce rather than assist progress towards decarbonisation, and will have negative impacts on air quality through increases in particulate matter pollution. Improving air quality should be added to the list of relevant

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wider government priorities such as net zero, levelling up, and a strong economic recovery from coronavirus, to which the consultation document refers.

35. If CAM do not use innovative technologies designed for the potential for near-zero greenhouse gas emissions (*e.g.* electric, hydrogen cars), and ensure that the production of clean technologies do not generate more waste, it will also negatively impact air pollution. Even with the use of these technologies, greater numbers of vehicles will reduce air quality through the increase in particulate matter pollution (Frank Kelly (2017)).
36. Moreover, relying increasingly on the electrification of transportation will create challenges for the electricity grid. In particular, an increase in localised loads may exceed the capacity of the distribution infrastructure. To deal with this, it will become necessary to coordinate loads using smart charging algorithms. This will require considering the individual constraints and incentives of drivers, to ensure that charging is performed efficiently within the infrastructure constraints, and, where possible, such that it coincides with the production of renewable energy. At Southampton, we have developed such incentive-based mechanisms (Hayakawa *et al.* (2015); Robu *et al.* (2013)).
37. It is also unclear how the introduction of CAM in the cities is aligned with HM Government's vision set out in *Future of Mobility: urban strategy* and Decarbonising Transport: a Better Greener Britain where walking and cycling should be the preferred option for shorter journeys in the cities. In addition, strategies for CAM should also pay attention to sub-national and city strategies for urban mobility – for example, the Mayor of London's target in his Transport Strategy that by 2041, 80% of journeys should be by public transport, walking or cycling.
38. One promising opportunity for CAM to decarbonise transport will be to use electrified AVs for last-mile mobility. Here, AVs are closely integrated with other, greener forms of transport, for example to connect commuters to train stations or bus routes. This can be part of a wider mobility-on-demand ecosystem that also provides commuters with the option to walk or cycle for parts of a journey (including the use of rental bikes or electric scooters). In such systems, a key challenge is to design convenient payment mechanisms across multiple modes of transport. There is also an opportunity to provide innovative incentive mechanisms that reward commuters for choosing greener or more efficient options. At Southampton, we have designed such incentive mechanisms to help balance the availability of electric rental cars in car sharing schemes (Drwal *et al.* (2017)). Using similar incentive mechanisms, it is also possible to incentivise ridesharing and compensate passengers for the possible detours or inconvenience this might entail. This is something that we have explored at Southampton in recent joint work with Toyota (Iwase *et al.* (2021)).

8. Will CAM support economic growth and the creation of jobs across the country as set out in Government's plans to level up the UK? If yes, how will CAM support economic growth and the creation of jobs across the UK? Please provide evidence to support this.

39. CAM shifts the employability model for the whole sector towards the workforce skilled in modern technologies, particularly in AI and Software; in a society highly skilled in these aspects this will create immense opportunities for attracting business opportunities and

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supply sophisticated solutions to manufacturers and higher-tier developers both nationally and internationally.

40. CAM (or more generally CASE) is, hence, likely both to create jobs and to destroy jobs. The balance is very much influenced by the training and retraining of the workforce in the areas that are relevant to CAM. Without such re-training schemes, it may destroy more jobs than it creates. In general, however, if CAM/CASE supports economic growth overall, one would expect net job gain. However, the new jobs will likely require different skills to the old jobs, and may be located in different geographical areas. Previous experience with the economic and social impacts of technological change shows negative impacts on both individuals and communities, even within a context of overall economic growth. Government intervention, of various kinds, is needed to manage these risks for individuals and local areas. A strategy for managing the transition and mitigating negative impacts should be included as an essential component within the Government's overall approach to CAM.
41. We observed that the government paid great attention to testing and developing AVs. But less attention was paid to the impact on jobs and how disruptive this technology will be for businesses and society. This needs to change. The government should put people at the center of developing new technologies as it is planned in the Maritime sector (Maritime 2050: People). The government needs to set up a clear plan for reskilling workforces and prepare people for this new technological revolution not only to achieve its ambition of levelling up but also to avoid creating extra social inequalities.

10. Will the deployment of CAM have a substantial impact on the automotive industry and its supply chain? If yes, in what way will the deployment of CAM impact the automotive industry and its supply chain? Please provide specific evidence to support this.

42. Despite the enthusiasm palpable in some environments, there is a growing belief that, in the long term, electrification, connection, automation, and sharing can be sustainable and beneficial only if implemented together (Hannon *et al.* (2016); Fulton *et al.* (2017)). In particular, considering that private road vehicles are characterised by very low average values of occupancy rate (of the order of 1.5 persons per vehicle in the United Kingdom in the years from 2004 to 2008 (European Environment Agency, 2010)) and by very high average values of idle time (approximately 96 % of the total time in the United Kingdom in the years from 2002 to 2008 (Bates and Leibling (2012)), widespread adoption of CAVs is deemed by some to be beneficial to society and the environment only in a road-transport scenario dominated by shared electric mobility (Schonberger and Gutmann (2013); Offer (2015)) - (D'Amore and Qiu (2017)).
43. The automotive industry will be certainly affected, but the magnitude of impacts depends on several factors including regulatory standards, adoption rate, public acceptance, economy of scale, pace of infrastructure development and possible interventions by the Government. Any later regulatory or standard requirements can lead to alteration/modification of design, blueprints, materials, production lines and even testing procedures of a final product.
44. We have also witnessed that media coverage of (even minor) accidents involving AVs is immense (BBC (2020); BBC (2019); Guardian (2016); *etc.*). Car accidents involving

self-driving cars further suggest that the introduction of AVs in a mixed environment with human drivers and pedestrians will not eliminate all road accidents. The combination of these two can directly influence the intention of potential consumers to adopt or use AVs. Subsequently, lower adoption rates can slow down the maturation of embedded technologies into AVs and most importantly limit investments on research and development initiatives.

45. Currently, a significant range of hardware and software components of semi-AVs and those which are equipped with advanced driving-assistance systems are outsourced to multiple original equipment manufacturers and software developers. Several of these components are categorised as high value (*e.g.*, LiDAR), low volume and high variety, particularly in the early adoption stages. There are two main challenges that the automotive sector, especially designers and production planning experts need to overcome. First, ensuring the compatibility of those components and integrating them into a single platform in way that the safety and integrity of vehicles are not compromised. The second dilemma is about having a reliable and uninterrupted supply chain to feed production lines and simultaneously adapting to recent (and perhaps fast) technological innovations and software updates besides maintaining sufficient stocks to meet demands for maintenance of already sold AVs.
46. The competition climate in international markets seems to be very uncertain and this hinders formulating coherent long-term strategies. Apart from the impacts of COVID-19 and Brexit on economic recovery, regional legislations and policies can obstruct penetrating into some of overseas markets. For instance, not all the 50 states in the US share the same preferences when it comes to licensing and regulations (Alawadhi *et al.* (2020)). Some of those disparities are beyond safety standards and lie in ethical considerations and judicial systems (*e.g.*, Federal Law).

13. Will the deployment of CAM have a substantial impact on the insurance industry and its supply chain? If yes, in what way will the deployment of CAM impact the insurance industry and its supply chain? Please provide specific evidence to support this.

47. Probably yes. For example, there are important implications in terms of liability in case of accident when it's a machine that is driving. Private insurance of a privately owned vehicle may not be the best way to go
48. Risk models and probability of collision: it is beyond dispute that introduction of AVs and elimination of human errors (*i.e.*, around 94%—NHTSA (2018)) from motor vehicle crashes will affect the risk models and probability of collision as well as severity of accidents and subsequently the probability of loss. This mandates reformation of vehicle insurance policies and adapting the current risk models to capture emerging risk factors/variables due to automation.
49. Liability in case of collision (Davey (2020)): unlike the technological advances enabling AD, the UK liability regime remained static and unable to provide answer to *real and complex legal questions* that mass adoption of AVs can arise. Davey highlighted two main issues in his work with respect to how the existing liability regime can encompass probable conflict scenarios and 'edge cases'. The first issue relates to the compatibility between *General Negligence Liability and* pervasive AVs. The example used to clarify is

'when the motor vehicle is in use to be entitled to insurance'? The second issue revolves around 'causation'. Considering the weight of causation in the UK liability system, addressing causal questions may require more expertise and legislative measures.

50. Supply chain of vehicle insurance policies (products): the aforementioned challenges become even more difficult to overcome in the early stages of mass release of AVs where the technology is not mature enough yet and software updates/hardware upgrades may be a common practice. The supply chain might face serious disruption since the accident models are not sophisticated and collision databases are not rich in that stage. Storing and sharing pre-collision and accident information of AVs (*i.e.*, subject vehicle or vehicle under test) and other involved parties can raise serious privacy questions. On one hand concerns over data protection principles (*e.g.*, UK GDPR or Data Protection Act 2018), and on another hand, commercial interests of manufacturers may erect hurdles in sharing pertinent data. Hybrid traffic (presence of both HDVs and AVs) in urban settings can potentially add to the complications of accident risk analysis and liability sharing. This will be even more challenging with semi (not fully)-autonomous which require a driver on board to take over control in hazardous situations or when the autopilot mode is disengaged.
51. In the meantime, ambiguities over the definitions and nomenclature can be problematic for both insurers and legislators. For instance, what is the difference between a 'driverless' vehicle and a 'self-driving' car? What level of human intervention and under what circumstances should be considered as sufficient in preventing a collision in either of the cases? Are AVs autonomous or automated and what will be the legal and liability implications if there's any loss?
52. Potential impacts on the UK insurance sector (Bank of England Quarterly Bulletin (2017))**:** it is expected that the UK motor insurance will shrink 21% by 2040 if AVs gradually hit the roads and 80% of the new sales are for AVs in that year. This estimation is based on the assumption that AVs can reduce road accidents by two thirds and a shift towards sharing economy. The variables in this forecasting are *vehicle replacement rate, cost of severe bodily injuries, average mile per vehicle and population growth*. The main reason for this contraction in market size is increased safety of road travels due to domination of AVs.

III- What next?

22. What areas should be priorities for the CAM sector in the UK in the period leading up to 2030 and why? Please provide up to 5 priority areas ranked from highest to lowest priority.

53. Integrating, and possibly merging, CASE mobility and public transport. CASE mobility may modify the social landscape non-neutrally. In fact, social inequality may increase because of changes in the organisation of urban spaces or in the quality and quantity of access to mobility (Bissel *et al.* (2020)). To make the UK world-leading in this area, the HM Government should ensure that the CASE revolution benefits everyone, and not just a few privileged. Especially among Millennials, there seems to be a trend

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towards greater environmental awareness and reduced ownership of private vehicles (Klein and Smart (2017)). Although it is unclear whether such trend is due to sociological or economic factors, integrating, and possibly merging, CASE mobility and public transport is likely to become a necessity as well as a challenge and an opportunity (Zhang and Khani (2021)).

54. Reskilling existing workforce, training for new skills. Highly advanced technologies will require a new set of skills such as technical and digital competencies. People who are at risk of losing their job (*e.g.* taxi drivers) are less likely to benefit from new jobs created.
55. The government should align its strategy towards CAM in relation to other, related policy priorities. For example, the DfT's *Future of Mobility: urban strategy* and *Decarbonising Tranpsort: a Better Greener Britain* suggest that walking and cycling should be the preferred option for shorter journeys in the cities. In addition, strategies for CAM should also pay attention to sub-national and city strategies for urban mobility – for example, the Mayor of London's target in his Transport Strategy that by 2041, 80% of journeys should be by public transport, walking or cycling.