Autonomous vehicles: automotive, maritime and aerial

A policy landscape review

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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 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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Abbreviations

ABI	Association of British Insurers
AEV Act	Automated and Electric Vehicles Act
ALKS	Automated Lane Keeping Systems
AUVs	Autonomous underwater vehicles
AVs	Autonomous vehicles
BVLoS	Beyond visual line of sight
CAA	Civil Aviation Authority
CAVs	Connected and autonomous vehicles
CCAVs	Centre for connected and automated vehicles
COLREGs	Regulations for the Prevention of Collisions at Sea 1972
DfT	Department for Transport
EASA	European Union Aviation Safety Agency
IMO	International Maritime Organisation
LiDAR	Light detection and ranging
MAA	Military Aviation Authority
MARLab	Maritime Autonomy Regulation Lab
MASS	Maritime Autonomous Surface Ship
MAXCMAS	Machine Executable Collision Regulations for Marine Autonomous Systems
MCA	Maritime and Coastguard Agency
MoD	Ministry of Defence
NATS	National Air Traffic Service
NCSC	National Cybersecurity Centre
RPAS	Remotely Piloted Aircraft Systems
SAE	The International Society of Automotive Engineers
SMMT	Society of Motor Manufacturers and Traders
TAS	Trustworthy autonomous system
TAS Hub	Trustworthy autonomous systems Hub
TDA	Temporary Danger Area
UAM	Urban Air Mobility
UAV	Unmanned aerial vehicle
UNECE	The United Nations Economic Commission for Europe
USVs	Unmanned Surface Vehicles
V2V	Vehicle to vehicle

Executive summary

This report is a horizon scanning review of issues surrounding the application of autonomous systems on public roads, and in the maritime, and aerial sectors. For the purpose of this review, autonomus systems are defined as "system(s) involving software applications, machines, and people, that is able to take actions with little or no human supervision" (TAS-Hub, 2020).

We present the results from scanning the grey literature (government publications, non-profit organisation reports, or other industry-relevant reports). Some sections were supplemented with findings from academic papers. This policy review was produced for the TAS Hub, which has been created to help the UK to deliver world-leading best practices for the design, regulation and operation of autonomous systems that are trustworthy and socially beneficial.

In this review, we consider three sectors: automotive – autonomous vehicles (AVs) on public roads; maritime – unmanned surface vehicles (USVs); and aerial – unmanned aerial vehicles (UAVs), focussing our analysis on three key areas: regulation and legislation, safety, and public acceptance. The aim of this report is to compare policy issues and activities in each sector and provide some areas for further exploration. This is not an exhaustive, systematic review of all policy issues and available academic literature or industry-relevant reports.

Key findings

1. There are different degrees of autonomy and a lack of clarity over what fully autonomous technology is

According to the Society of Automotive Engineers (SAE), fully automated vehicles should be able to operate without a driver. There is less clarity on whether a system can be classified as "fully automated" when there is non-direct human intervention. Although the Law Commission (2020) launched consultations to understand the threshold of when a vehicle should be classified as "self-driving car," the government recently announced that vehicles with Automated Lane Keeping System (ALKS) could be legally defined as self-driving cars, as long as they meet certain criteria (Department for Transport et al., 2021). This decision adds confusion about what classes as a fully automated car. It also raises questions about the responsibilities of the driver when driving a vehicle with ALKS technology.

There have already been accidents in the US where the driver failed to pay attention to the road and surroundings while using driving assisting features. As such, when they are promoting self-driving cars, the government needs to be explicit about their actual capabilities and what the driver's responsibilities are.

For UAVs, the picture is clearer. Based on the levels of autonomy distinguished by Drone Life (2019), a human presence is out of the loop in high and full automation levels.

For USVs, our review of academic papers and academic literature showed an expectation that human presence in highly automated ships might still be required, for example, in the role of on-shore operators.

2. The word “autonomy” is often used interchangeably with “automation”
This was especially seen in descriptions of different levels of autonomy. Further clarification about the definitions of these terms, and the area of overlap between them would be very helpful.

3. In the UK, there have been more policy activities around development, testing, and regulation for AVs than for UAVs or USVs
This may be linked to the government’s priority to introduce new forms of accessible mobility to support the UK’s ageing population. There is an assumption that the majority of AVs will be shared and connected, rather than individual driverless vehicles. Shared and connected autonomous vehicles (SAVs) could merge taxis, carsharing, and ridesharing systems into a singular transportation mode and so offer huge potential to reduce road traffic. As such, the government is promoting AVs as a solution to issues like congestion, pollution, and limited parking spaces in cities, and AV technology plays a key role in the government’s goal to lower carbon emissions.

Another reason there have been more policy activities around AVs than UAVs and USVs is that there has been a stronger push from technology companies for the introduction of self-driving cars than for UAV or USV technologies.

4. Despite economic incentives for introducing autonomous systems on public roads and in maritime and aerial sectors, the unintended consequences and impact on jobs, businesses and society have not been fully considered – this needs to change.

5. There has been public perceptions research into what people think about these technologies, but less is known about how the introduction of these technologies will impact society.
The government has a people-centred strategy when it comes to USVs, with plans to reskill the existing workforce on new unmanned service vehicle technology. By contrast, no such plans yet exist for AVs and UAVs and so far, only general public attitudes research has been conducted in these areas.

7. The regulation of Unmanned Aerial Vehicles primarily focuses on the safe operation of drones.
Little consideration has been given to integrating UAVs into airspace and developing a liability framework for self-flying aerial vehicles, in contrast to regulation for autonomous vehicles.

The UK Drone Delivery Group (an industry body) has issued a White Paper to suggest the necessary steps for the UK to launch UAV technology commercially.

8. The development of autonomous systems in the maritime industry is happening at a slower pace compared to the other sectors.

The government established the Maritime Autonomy Legulation Lab (MARLab) in 2019 to investigate regulatory approaches towards developing USVs. The report produced by MARLab in 2020 suggests that existing regulations are hindering innovation.

The same safety questions – including around the elimination of human and human/machine error, ensuring safe operation, and cybersecurity threats – will arise from the introduction of autonomous systems across the automotive, aerial and maritime sectors.

Introduction

The UK government has taken a proactive approach towards encouraging the development of autonomous vehicles. According to a KPMG (2020) report, the UK has positioned itself as a global leader in the regulatory framework, testing and cybersecurity of AVs. The government recognises the benefits of AVs in their plans to tackle emissions and decarbonise transport, and takes a flexible, forward-looking approach in order to promote innovation.

> *"Regulation itself will change, as it always has. But our goals will not change. We want transport to be cleaner, safer, healthier, greener, cheaper, more convenient, and more inclusive. As regulators, we will judge every innovation on whether it serves those ends, or undermines them."*
>
> **– Rachel Maclean, the former Parliamentary Under-Secretary of State for Transport (Mehmet, 2020)**

Automation can be applied to many different sectors, for example, aerial, maritime, automotive, aerospace, military and warehousing. Nonetheless, political attention and policy activities seem to focus mainly on automation on public roads.

Comparison across automated vehicles, unmanned aerial vehicles and unmanned surface vehicles shows a clear government focus on AVs, with significantly less attention paid to UAVs and USVs. For example, the government has established liability in the case of an accident caused by a listed self-driving car;[1] launched consultations toward the regulatory framework for the safe deployment of automated vehicles with the Law Commission; and provided testing facilities to support this (Law Commission, 2020).

By contrast, legislation around UAVs is mainly confined to protecting against events relating to the malicious use of drones – eg the delivery of illegal packages to prisons using drones, and responding to disruptions caused when drones were flown over Gatwick airport (Home Office, 2019).

When it comes to USVs, there is ambiguity in the current regulations as it is unclear whether a person is required on board (eg see Rolls-Royce, n.d.). In the UK, the USV industry is relatively underdeveloped compared to UAVs and AVs, and this uncertainty is widely regarded as a contributing factor. However, some countries are making more progress with USVs. For example, Scandinavia is pioneering developing autonomous shipping (Pospiech, 2018), which could forecast an industry push to introduce autonomous vessels in these countries.

Despite the political appetite for autonomous vehicles, development has stalled in recent months. Uber sold its autonomous division to Aurora, Ford has postponed its trials for autonomous taxis (Topham, 2021), and Elon Musk's prediction of having one million fully autonomous vehicles by the end of 2020 proved wrong (Nuttall, 2021). A key issue here has been the Covid-19 pandemic. Zenzic, which was created by government and industry to accelerate the roll-out of self-driving cars in the UK and is responsible for testing and developing AV technology, updated its roadmap to reflect challenges in the coming months and years, based on interviews with

1 Automated and Electric Vehicles (AEV) Act 2018

UK Public General Acts 2018 c. 18 PART 1 Section 2 key stakeholders. In 2020 Zenzic interviewed 117 organisations to understand the impact of Covid-19 on the industry. The majority of responders expressed the view that there may be more focus on freight rather than personal mobility in future, and the industry might need to respond to this shift (Zenzic, 2020). Based on the report issued by Zenzic (2020), although no one can fully predict what the future holds, many people in the automotive industry forecast fewer investments and a push for quicker payback from the investors.

However, the pandemic might increase interest in other modes of transport for different purposes. Projects have already been launched to support the NHS response to coronavirus (eg space-enabled technology to deliver testing kits) (UK Space Agency, 2020). In addition, the pandemic may encourage freight and logistics to become early adopters of autonomous systems.

Our approach

In the next section, we provide an overview of what we mean by autonomous systems in AVs, UAVs and USVs based on the classification of different levels of autonomy, and the current extent of their deployment. We then present a summary of the UK government's actions in each sector, before explaining them in more detail and supplementing analysis with findings from academic research and industry-relevant reports. We have identified three major reccurring themes via a scoping of the relevant policy publications in the UK. These themes are **regulation and legislation**, **safety** – technological issues, cybersecurity and data privacy and ownership – and **public acceptance** – public opinion, impact on jobs and society, and unintended consequences of the technologies. We decided to broaden the narrow concepts of safety and public acceptance in order to explore several different issues. However, these categories are not unconnected. For example, safety and privacy issues will have an impact on the public's views, while privacy is very often a regulatory concern too. It must also be pointed out that this policy landscape review is not an exhaustive, systematic review of all policy issues, available academic literature, and industry-relevant reports.

Definitions and levels of autonomy

Autonomous vehicles (AVs)

AVs – also referred to as self-driving cars or driverless, robotic vehicles – offer enormous opportunities in the transport industry. Shared, connected and net zero emission AVs are expected to reduce collisions, deaths and injuries, emissions, and congestion, as well as providing a more inclusive transport system (DfT, 2019). At the same time, AVs raise many challenges, such as new types of accidents caused by system failures, privacy issues, and job losses for drivers (ibid.).

In the Future of Mobility, the UK government suggests great opportunities for new modes of mobility to facilitate a transition to net zero emissions and address issues of congestion (ibid.). Hannon et al. (2019) claim that AVs that are shared, electrical and connected could potentially lead to seamless mobility, characterised by five indicators: availability, affordability, efficiency, convenience, and sustainability.

However, there are many possibilities for how the future of mobility might evolve. For example, as Wadud et al. (2016) noted, if autonomous taxis drive all day without breaks, energy consumption will increase. Additionally, while AVs might be more accessible for older or disabled people (Fagnant and Kockelman, 2015), "this, in turn, can also lead to an increase in traffic density due to higher usage rates" (Hohenberger et al., 2016: 375).

The SAE (2019) level of driving automation sets out increasing levels of autonomy in vehicles ranging from Level Zero, where there is no automation and all driving tasks are performed by a human driver, to Level Five, where it is fully automated and a human driver is not needed for any driving tasks. Table 1 summarises these different levels of automation.

TABLE 1: LEVELS OF AUTONOMY IN VEHICLES

Level Zero	**No automation:** All driving tasks are performed by a human driver.
Level One	**Driver assistance:** There is support for tasks like steering, braking and acceleration, but the human driver performs all remaining aspects of driving.
Level Two	**Partial automation:** One or more driver assistance systems are engaged, but the human driver performs all remaining aspects of driving.
Level Three	**Conditional automation:** The vehicle can be driven without human intervention, but the human driver needs to take over the driving task when required.
Level Four	**High automation:** The vehicle can be driven without human intervention under limited conditions, even when a human driver does not respond to take over the driving task
Level Five	**Full automation:** The vehicle can be driven without human intervention under all conditions, even when a human driver does not respond to take over the driving task.

Source: SAE (2019) & International Transport Forum, 2015

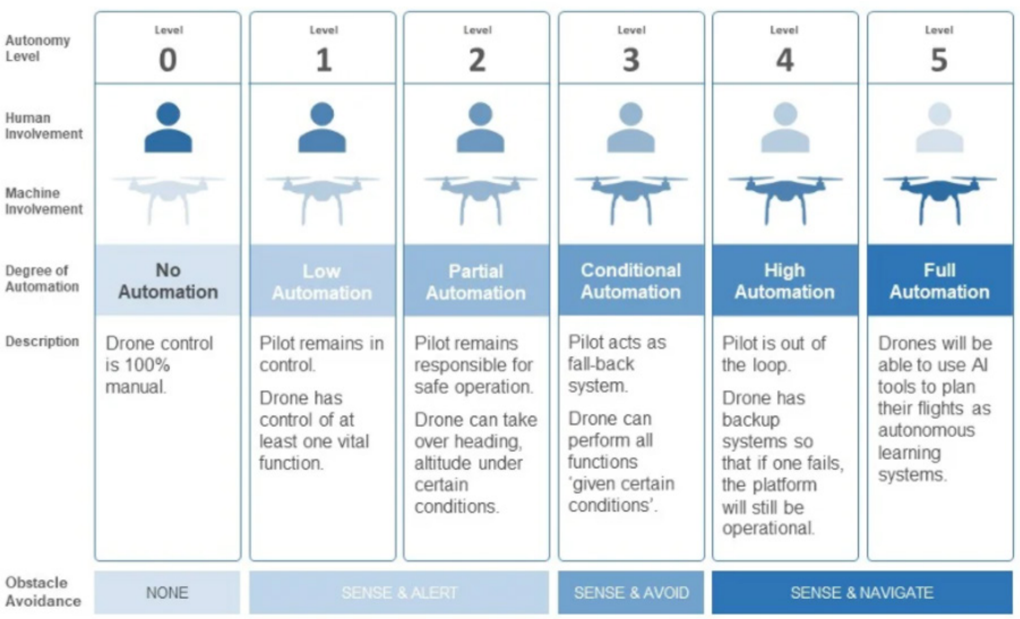
Although the CEO of Tesla Motors, Elon Musk, claimed that we would see fully automated cars by the end of 2020, this has not happened yet (Nuttall, 2021). Currently, there are cars with partial automation (Level Two) on the roads (eg Tesla Autopilot), and cars with automation Level Three could appear on British roads by the end of 2021 (DfT et al. 2021). Companies such as Waymo are also working on fully autonomous driving systems. Although Waymo has started introducing its first fully autonomous ride-hailing service in some cities in the US, it is difficult to predict when this technology will be widely available to the public (The Waymo team, 2021).

Unmanned Aerial Vehicles (UAVs)

UAVs, referred to as “drones,” can range in their sizes from small to large aircraft. They can be operated by using a remote pilot or be autonomous (Haylen, 2019; CAA, 2015). Traditionally, drones were used in the military for surveillance. Currently, they are mainly used by the public for photography, videography, or commercial purposes (DfT and DoM, 2016).

Similar to the levels of driving automation, Drone Life (2019) identifies levels of drone automation ranging from Level Zero (no automation) to Level Five (full automation). Figure 1 provides a summary of different levels.

FIGURE 1: THE FIVE LEVELS OF DRONE AUTONOMY



Source: Drone Life (2019)

In the UK, we generally see drones with low or partial automation, where a pilot remains in control. The exception is military drone swarms, where the potential level of automation is higher but the drone is still controlled from a central ground station (Royal Navy, 2021). Apart from their recreational uses, drones are mainly used in the UK by commercial operators that have obtained special permission from the Civil Aviation Authority (CAA) (NESTA, 2018). For example, Amazon Prime Air obtained special permission to develop and test drone deliveries, but it is hard to predict when this technology will be rolled-out. A recent article, written by Andrew Kersley (2021) in Wired magazine, reported mass redundancies of people working on Amazon Prime Air, suggesting that the future of Amazon drone deliveries in the UK is uncertain.

Outside the UK, there have been tests of highly advanced flying vehicles. For instance, Germany-based company Volocopter is currently testing an electrical air-taxi and it secured the necessary design and production approvals to build this technology before the company had even launched (Reuters, 2021). In the UK, there are plans to build the first flying taxi hub in Coventry (Sifted, 2021).

The UK Drone Delivery Group issued a White Paper highlighting necessary steps for the UK to enable drone development beyond visual line of sight (BVLoS), a step that would kickstart the UK's drone industry. They suggested that regulatory barriers make testing and evolving the technology expensive and very slow, and warned that standards are being prepared in isolation from a large proportion of the current industry knowledge base.

Unmanned Surface Vehicles (USVs)

Autonomous vessels can take the form of Autonomous Underwater Vehicles (AUVs) or Unmanned Surface Vehicles (USVs). This report refers mainly to USVs, also called Maritime Autonomous Surface Ships (MASS).

The use of autonomous vessels, both surface and underwater, is expected to minimise the risk for people who operate in the maritime environment and reduce the number of accidents. Apart from improving safety, autonomous systems should also bring savings to operating costs (see, eg Porathe et al., 2014).

There is no set international definition of unmanned vessels, and there are various levels of autonomy referenced. For example, Lloyd's Register refers to the classification of six levels of autonomous ships – AL 1 to AL 6 – while the European Commission classifies different levels of automation into three categories: Remote Ship, Automated Ship, and Autonomous Ship (UK P&I, 2019: 4). For the purpose of this report, we will refer to six levels of autonomy provided by the MASS UK Code of Practice (2018). Below, Table 3 describes different levels of autonomy, from Level Zero to Level Five.

TABLE 2: LEVELS OF AUTONOMY IN VESSELS

Source: Maritime Autonomous Surface Ships UK Code of Practice Version 2 (2018)

Level Zero	**Manned:** Vessel/craft is controlled by operators aboard.
Level One	**Operated:** All cognitive functionality is controlled by the human operator. The operator has direct contact with the unmanned vessel over, eg, continuous radio (R/C) and/or cable (eg, tethered UUVs and ROVs). The operator makes all decisions, directs and controls all vehicle and mission functions
Level Two	**Directed:** Some degree of reasoning and ability to respond is implemented into the unmanned vessel. It may sense the environment, report its state, and suggest possible actions to the operator, eg prompting them for information or decisions. However, the authority to make decisions is with the operator. The unmanned vessel will act only if commanded/ permitted to do so.
Level Three	**Delegated:** The unmanned vessel is now authorised to execute some functions. It may sense environment, report its state and define actions and report its intention. The operator has a set time in which to veto intentions declared by the unmanned vessel, if they do not, the unmanned vessel will complete the action. The initiative emanates from the unmanned vessel and decision-making is shared between the operator and the unmanned vessel.
Level Four	**Monitored:** The unmanned vessel will sense the environment and report its state. The unmanned vessel defines actions, decides, acts and then reports its action. The operator may monitor the events.
Level Five	**Autonomous:** The unmanned vessel will sense the environment, define possible actions, decide and act. The unmanned vessel is afforded a maximum degree of independence and self-determination within the context of the system capabilities. Autonomous functions are invoked by the onboard systems at occasions decided by the same, without notifying any external units or operators.

Autonomous vessels or remotely controlled vessels are already in use at sea, mainly for carrying measuring devices (Felski & Zwolak, 2020: 41). Many companies are working on fully autonomous systems; for example, Rolls-Royce envisages an autonomous unmanned ocean-going ship by 2035, and IBM plans to send an autonomous research vessel across the Atlantic next year (Rolls-Royce, n.d.; Levin, 2020).

Comparison of AVs, UAVs and USVs based on government activities

This section provides a brief summary of some of the findings in each sector for each category before explaining them in more detail and supplementing analysis with sources from academic and industry research. Table 3 below compares all government's activities in each industry.

Regulation

The UK government has taken a proactive approach to the regulation of autonomous vehicles, establishing liability and a definition of self-driving cars (Section 2[1] and Section 8[1] AEV Act 2018). They also conducted consultations into regulation for automated vehicles on roads (Law Commission, 2020).

By contrast, the government have taken a more responsive approach to reduce the malicious use of drones. For example, they developed a "Counter unmanned aircraft strategy", which imposed restrictions for flying drones. This also introduced requirements for owners of drones weighing 250g or more to register their drone and take an online competency test before operating it (Home Office, 2019; House of Commons and Science and Technology Committee, 2019: 8). However, there is still a need to develop further legislation around the operation of UAVs with manned aircraft in non-segregated (shared) airspace, as this strategy deals only with the malicious and illegal use of drones.

Compared to AVs and UAVs, there has been relatively little progress developing legislation for USVs. This could be driven by the fact that maritime regulation is complex and the current regulatory framework assumes that someone is onboard, but is ambiguous as to whether onboard attendance is actually required.

Safety

There are a number of unanswered questions when it comes to safety. Starting with the AV sector, the UK government recognises the need to conduct trials to learn how major technological features used in autonomous vehicles behave in different conditions. Although AVs are expected to be safer than human drivers, it is hard to confirm this assumption before AVs are more widley used. Additionally, partially automated cars have caused accidents when a driver did not pay attention to the road and overly relied on the technology (BBC, 2020). There are also unknowns in terms of how and what data should be collected, and how it should be stored or shared with other third parties (Law Commission, 2020). Cybersecurity is another major concern, and the Centre for Connected and Autonomous Vehicles (CCAV) is leading on this policy.

There are three main safety concerns in the UAV industry: air risk – risk to other air users; ground risk – drones can cause accidents, damages to property, and fatal injuries when there is a system failure or lack of safety design features; and the illegal use of drones.

Safety issues in the adoption of USVs do not seem to be the government's primary concern. The Department for Transport (DfT) (2019e) published the Technology and Innovation in UK Maritime route map which centres around three themes:

infrastructure, technology and people, but largely overlooks safety. Similarly, the government's Maritime 2050 paper, only mentions safety in passing, in relation to introducing testing facilities for autonomous technologies. This is a concerning omission given that similar safety issues will arise in the maritime sectors that have been identified for AVs and UAVs, namely cybersecurity threats, and questions around the safety of design.

Public acceptance

A UK government report, published in 2019, concluded that that AVs must be safe, accessible to all, and good for jobs and society, and that people should be still in control of their transport choices. While it suggested that new bodies for oversight should be created (DfT et al., 2019), the government did not provide clear guidance on how it would achieve these objectives. There appear to be no plans for reskilling the existing workforce, and it is not evident how the introduction of AVs would be good for people who drive for their profession. What is more, most responders in the UK suggest that they would not feel comfortable riding in a self-driving car, and the number of people trusting self-driving vehicles does not seem to have significantly grown over the years (Adams, 2015; Thales, 2019).

The government has responded to some concerns expressed by the public around autonomous aerial vehicles, such as anonymity and traceability, safe use of drones by operators, and the quality of materials used to build the vehicles (DfT and MoD, 2016: 5). For example, it is now required to register a small, unmanned aircraft – a drone between 250g and 20kg – and for owners to take an online competency test. In addition, the CAA and National Air Traffic Service (NATS) created The Drone Code to help people understand laws about drones, and introduced an application called Drone Assist to help operators follow the safety rules and fly in suitable locations (MoD and MAA, 2017). Despite these measures, however, there is limited information available regarding how fully autonomous drones would work, what issues they might cause, and what this technology might mean for the public.

When it comes to unmanned surface vehicles, the government recognises the important role of reskilling the existing workforce and attracting new talent. The roadmap set out in *Maritime 2050: People* sets up a long-term strategy with a people-centred approach (DfT, 2019c). However, there has been a lack of public dialogues to understand the views of seafarers and the attitudes and concerns of the general public.

TABLE 3: COMPARISON OF ALL SECTORS BASED ON THE PROGRESS OF THE GOVERNMENT'S ACTIVITIES AND EXAMPLE CONCERNS

Key Steady progress (green) · Some progress (amber) · Limited progress (red)

	Regulation	Safety	Public acceptance
Autonomous vehicles	(Steady progress) • Defined what a 'self- driving' car is. • Liability was established. • Consultations were conducted to examine the options to regulate automated vehicles on roads.	(Some progress) • Better technological solutions that operate in all weather conditions are needed. • Improved technological design is required for when there is a need for a driver to observe the road. • Strategies for data management and cybersecurity must be developed. • Clarity over a driver's responsibilities when using a vehicle with assisted driving features is needed.	(Limited progress) • The public lacks confidence when it comes to riding a self-driving car. • Public dialogue showed that AVs must be good for jobs and society, and inclusive. It unclear how the government is going to achieve this aim.
Unmanned Aerial Vehicles	(Some progress) • Drones are currently regulated under the Civil Aviation Act 1982 (s76.2) • Regulations mainly apply to UAVs that weigh more than 250g, stating where they can be flown and by whom. Further adoption of drones will require legislation where drones can operate with manned aircraft in the airspace.	(Some progress) • Drones pose an air risk and ground risk. • They also can be used for malicious damage.	(Some progress) • The government has implemented regulations that address some of the concerns expressed by the public (eg the requirement to register, online tests, and restrictions zones).
Unmanned Surface Vehicles	(Limited progress) • Regulations for autonomous ships have not developed at the same pace as in other transport industries. • Questions of liability for autonomous ships have not yet been answered.	(Limited progress) • The autonomous ships will need to be at least as safe as existing ships. • There are plans to provide testing facilities.	(Limited progress) • There is a risk of job loss. • There are plans to reskill the existing workforce.
Example concerns	**Autonomous vehicles:** How to make sure that self-driving vehicles are safe to be driven along with human-driven vehicles? **Unmanned aerial vehicles:** Should there be a new liability framework for fully autonomous drones? Further adoption of drones will require legislation where drones can operate with human-crewed aircraft in the airspace. **Unmanned surface vehicles:** A new approach to regulations needs to be established.	• In all the sectors, autonomous vehicles, drones, and ships need to be as safe as (or safer) than human-operated technologies. • How do we measure/ensure safety? • Other challenges involve: identifying and preventing threats relating to the use of autonomous systems now and in the future; the development of autonomous systems to avoid collisions; and improvement of currently existing solutions.	**Autonomous vehicles:** Hearing more diverse views, listening to the views of potentially affected businesses and people, developing plans for reskilling. **Unmanned aerial vehicles:** Limited understanding of people's views on the application of drones (eg flying taxis). Listening to the views of potentially affected businesses and people. **Unmanned surface vehicles:** Listening to the public's views. **Policy issues:** How do we shape policy so that AVs/UAVs and USVs are good for society? What are the risks to society?

Autonomous vehicles

Background

This section describes policy issues and areas for further research and consideration around autonomous vehicles on public roads. Some of the regulatory issues presented are based on the case study used by the Law Commission on introducing Automated Lane Keeping Systems (ALKSs) on British roads. While the Law Commission is planning to publish its final recommendation by the end of this year, the government has already announced that cars with ALKS could be legally defined as self-driving cars (DfT et al., 2021). This poses challenging questions over what a self-driving vehicle is, what the responsibilities of the driver are, and who is liable for an accident when a driver's attention is still required to operate the vehicle. We discuss the issue in more detail below.

Self-driving cars are expected to be safer than human-operated cars, but it is difficult to validate this statement, and developers would need to develop new methods for measuring safety while policymakers should take a flexible rather than fixed approach towards regulation with the assumption that technology evolves (Kalra and Paddock, 2016). AVs have already caused some accidents where the human drivers over-relied on the vehicle's technical abilities, so the government would need to be clear how it promotes self-driving cars as the technology becomes more widely available. AVs also raise further questions in terms of data ownership and privacy. Who should own data? What data should be collected? And how should it be stored? Cybersecurity risks are another safety concern, and pose the risk of new types of accidents.

AVs don't just need to be safe to use, they also need to be perceived as safe by the public. Different studies show that most UK citizens would not feel comfortable in a self-driving car (eg Thales, 2019). There is also limited knowledge about the socio-demographic differences affecting the UK's acceptance/perception of self-driving vehicles. Although connected and shared vehicles (CAVs) are expected to create new jobs, they will also destroy some jobs. Therefore, the unintended consequences of introducing AVs and their impact on society need to be considered.

Regulation

Three significant developments towards regulations have been made. First, liability was established where an insurer becomes liable for accidents caused by a listed vehicle "when driving itself" (Section 2(1) of AEV Act 2018). Secondly, the definition of a self-driving car was provided. Section 8(1) AEV Act 2018 defines "driving itself" as "operating in a mode in which it is not being controlled, and does not need to be monitored, by an individual". Three consultations were also launched to investigate options to regulate AVs on roads (Law Commission, 2020)

Consultation paper 3 – a regulatory framework for automated vehicles on roads presented the introduction of ALKS as a case study to draw attention to some pressing issues that need to be answered now, and may impact the structure of AV regulations in the future (Law Commission, 2020).

ALKS is a feature that enables drivers to delegate the driving to the vehicle. As this technology will allow the driver not to be responsible for driving the vehicle for the first time, it challenges the current UK legal framework. ALKS would only be used at low speeds (up to 37 miles an hour) on motorways (Law Commission, 2020).

There are several questions asked by the Law Commission (2020), but we want to particularly draw attention to the problem of defining of a self-driving vehicle. In the Automated Electric Vehicles (AEV) Act 2018, an insurer becomes liable for accidents caused by a listed vehicle "when driving itself"(Section 2(1) of the AEV Act 2018). The definition of a self-driving car is very important as if the ALKS is classified as a self-driving vehicle (with the automated driving system being engaged), the human user would not be liable for criminal offences in the case of an accident involving these vehicles (Law Commission, 2020: 18). Therefore, one of the crucial questions that the government needs to answer is "when does a vehicle meet the definition and threshold for self-driving?" In August 2020, the CCAV launched a call for evidence on exploring whether ALKS meets a definition of a self-driving car as set out in the AEV Act 2018.

The government has proposed two tests as ways of defining when a vehicle meets the definition of a self-driving car: the monitoring test and the control test.

The monitoring test suggests:

An individual does not need to monitor the vehicle if the vehicle can safely achieve the following without human monitoring:

1. Comply with relevant road traffic rules;
2. Avoid collisions which a competent and careful driver could avoid;
3. Treat other road users with reasonable consideration;
4. Avoid putting itself in a position where it would be the cause of a collision;
5. Recognise when it is operating outside of its operational design domain.

The control test suggests:

A vehicle is not being controlled by an individual if the individual controls none of the following:

1. Longitudinal dynamics (speed, acceleration, braking, gear selection);
2. Lateral dynamics (steering).

Source: Adopted from CCA, 2020: 23

Based on these tests, the UK government concluded that cars with the ALKS feature meet the definition of a self-driving car as set out in the AEV Act 2018 (subject to further evidence) (Law Commission, 2020: 30). The Law Commission (2020) drew attention to two opposing views that responded to the CCAV call for evidence on whether ALKS meet the definition of a self-driving car. One side of the argument, supported by the Association of British Insurers (ABI), sees ALKS as the extension of already existing driving assistance features and ALKS should not be listed under the AEV Act 2018 as self-driving. In turn, the Society of Motor Manufacturers and Traders (SMMT) claims that the definition of a self-driving car in AEVA 2018 is aligned with the requirements of UN Regulation No. 157 and vehicles with approved ALKS should not be subjected to any more tests or checks:

> *"Vehicle manufacturers will design, develop and manufacture vehicles with ALKS for global markets. As such, it is of paramount importance for contracting parties to follow and apply international regulations in order to avoid a patchwork of fragmented individual national regulations."*

Source: SMMT cited in Law Commission, 2020: 30

Although the Law Commission has stated it will publish its final recommendations by the end of 2021, it is worth noting that the government has already announced that vehicles with ALKS that are GB type-approved and do not raise questions over their self-driving capabilities "could be legally defined as self-driving" (DfT et al., 2021). This is somewhat surprising, as a vehicle with ALKS would normally be classified as SAE Level Two or Three rather than Level Five. What is more, a similar technology to ALKS already exists. For example, Tesla "Autopilot" keeps a car centred in a lane and maintains a safe distance between other cars. The only difference between Tesla "Autopilot" and ALKS is that a driver would not be required to keep their hands on the wheel under the ALKS proposal, whereas they are required to do so with Tesla "Autopilot" (BBC, 2021; The Register, 2021).

The US federal agency has recently opened an official investigation into Tesla's "self-driving" Autopilot system. The agency's concerns particulalry relate to Tesla's apparent inability to cope with vehicles stopping on the road , eg emergency vehicles (BBC, 2021a). This suggests that we need to better understand both the technology and the interaction between the technology and how people use it.

In the UK, a rapid introduction of vehicles with ALKS features, and definining these as "self-driving" may be good for attracting business and fostering innovation, but it could have catastrophic consequences on gaining public acceptance if it leads to accidents.

Safety

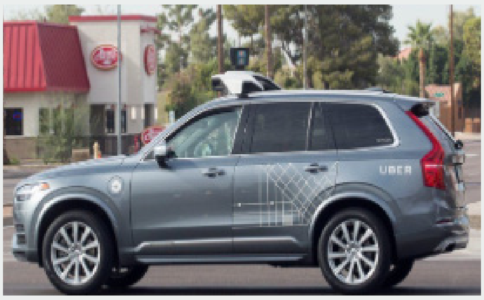
Self-driving cars rely on four major technological features: cameras – spotting speed signs, lines on the roads, traffic lights; light detection and ranging (LiDAR) technology – mapping the distance to surrounding objects; machine learning – training computers to identify objects; and radar – radio frequency ranging sensors.

Most of the self-driving tests have been carried out in the US in good weather conditions, however, it is less known how LiDAR technology behaves in difficult weather conditions, eg heavy snow, rain or fog (BBC, 2019). The UK government recognises this issue and is undertaking test trials in the UK under more variable weather conditions.

AVs are mainly seen on highways, where there are fewer distractions than in rural and urban areas. In fact, AVs seem to be coping less well in an environment with unpredictable behaviours and vulnerable users (eg pedestrians, cyclists), as has been seen in recent accidents involving self-driving cars (see Box 1). To support the adoption of automated vehicles and build public acceptance, early versions of AVs or partially automated vehicles need to be proven to be safe.

Box 1: Uber accident

In 2018, Elaine Herzberg was hit by an Uber self-driving vehicle with a back-up driver as she wheeled a bicycle across the road in Tempe, Arizona. The investigators found that the back-up driver did not pay attention to the road and monitor their surroundings. Footage before the fatal accident showed that the back-up driver was distracted by watching a show on a mobile phone.



Source: BBC 2020

The future of transport in towns and cities report (DfT, 2020a) finds that walking and cycling are the preferred mode of transport in cities and urban locations. AVs would therefore need to develop highly predictable technology that allows a safe operation in this environment.

As defined by the SAE (2019), AVs can range from Level Zero (no automation) up Level Five (full automation). These levels are distinguished by different features and the driver's engagement. Currently, Level Two – where there is partial automation but the driver needs to remain alert and take control of the vehicle when required – is the highest level found on the roads.

The accidents that have occurred involving partially automated self-driving cars suggest that people may not be paying attention to their surroundings and what is happening on the road when in these vehicles, despite this being an essential requirement for Level Two automation. It might therefore be necessary to develop technology to monitor drivers in semi-autonomous cars and educate users about their responsibilities in relation to the different levels of automation. Additionally, it may be prudent to use caution when marketing cars as "self-driving" when these vehicles still require a driver's attention and readiness to take over the driving task. For example, as previously discussed, the UK government has announced that self-driving cars will be seen on British roads by the end of 2021. However, they were referring to vehicles with ALKS (DfT et al., 2021), not fully automated vehicles. This potentially misleading marketing strategy could lead to people overly trusting vehicles with assisting driving features and may contribute to road accidents, like those that have already been seen in the US.

Although AVs are expected to be safer than human-operated cars, it is going to be difficult to validate this statement before the commercial deployment of AVs. Kalra and Paddock (2016: 10) run formulas to see "the number of miles that AVs would have to be driven as a method of statistically demonstrating their safety". They found out that "autonomous vehicles would have to be driven hundreds of millions of miles and sometimes hundreds of billions of miles to demonstrate their reliability in terms of fatalities and injuries" (Kalra and Paddock, 2016: 10). The authors concluded that developers and third parties need to develop new methods to establish the safety of AVs, while policymakers should take a flexible approach towards regulations.

Data privacy and ownership is another aspect of safety concern and public acceptance. Data sharing between different companies might be crucial to ensue the safe operation of AVs, which would need to operate in various conditions and learn how to respond to them and data sharing would assist this learning process. For example, Vakil et al. (2019) suggest that engaging in vehicle-to-vehicle (V2V) communication and data sharing between vehicles will expedite the time needed for AVs to learn and adapt to various situations. However, sharing data and collecting vast amounts of data poses many challenging questions concerning privacy. For example, Glancy (2012) noted that sharing information between vehicles for safety reasons might also expose other information, such as identifying an AV user's location. Furthermore, as AVs are able to collect more data than just driving conditions, questions arise as to who should own that data, how should it be used and stored, and what types of information should be collected? (Anderson et al., 2014; Boeglin, 2015; Glancy; 2012; Vakil et al., 2019)

Cybersecurity issues also pose the threat of causing different types of accidents. The government issued the key principles of cyber security for connected and automated vehicles (HM Government, 2017). These non-binding principles place the responsibility on companies developing connected and automated vehicles to prevent cyber threats and manage potential cyber-attacks. Additionally, a National Cybersecurity Centre (NCSC) was established in 2016 to detect and avoid cyber threats.

Table 6 on the next page summarises different challenges and questions that arise from them.

TABLE 4: SAFETY IN AUTONOMOUS VEHICLES: SUMMARY OF ISSUES AND QUESTIONS

Issue	Area for further exploration
Technological improvements • Autonomous vehicles that perform well in any weather condition. • Development of highly predictable technology that allows a safe operation in any environment (eg cities). • Partially automated cars might need better safety features to make sure that the driver pays attention and does not pose a risk to themselves and others.	• What technological improvements/or solutions can be introduced to make sure that AVs are operating safely in any environment or weather condition? • What safety features should be developed to ensure that the driver is ready to take over the driving task when required?
Measurements of safety	• How to ensure and measure safety?
Data ownership and privacy	• Who should own data? How should data be stored, shared and used? • What information needs to be collected? And what sort of data can be collected taking into consideration privacy concerns? • How can users' personal information be protected without slowing down innovation?
Cybersecurity	• How to deliver a robust cyber-resilient transport system? • What processes and assurance methods are needed?

Public acceptance

Public acceptance is a necessary condition for the successful introduction of AVs. The UK government, in partnership with Sciencewise, conducted public dialogues on attitudes towards connected and autonomous vehicles (DfT et al.,2019). 158 participants took part in two or more sessions from five different locations. The report concluded that, apart from the technology being safe, it must also be accessible to all, be good for jobs and society, and allow for people to remain in control of their transport choices. There should also be clear guidance on accountability, and new bodies for oversight should be created (DfT et al., 2019: 58). However, the government did not specify how it is going to respond to these challenges. As this was a qualitative study, these findings cannot be generalised and assumed to be representative of a broader population in the UK (DfT et al., 2019a).

Workshops also included conversations with specialists – industry experts, academics and other relevant bodies. The engagement of the public with specialists could influence their responses and interactions, as well as other stimuli used in the data collection process. However, the authors tried to overcome the limitations of their study by introducing an oversight group and specialist group to review the materials and activities (ibid.).

In relation to other relevant literature, public acceptance can be divided into three sections: perception of AVs in general, views on AVs' technology and operation, and socio-demographic characteristics affecting the acceptance of AVs. Starting with the first category, several studies investigated the public perception of AVs. Adams (2015), by surveying 1,099 UK adults and applying weighting to make the results representative to the UK population, found that 61 per cent of participants would probably or definitely not consider buying a self-driving car. Furthermore, 51 per cent of respondents reported that they would not be comfortable using a driverless car. Research from Thales (2019) reveals that more than half of UK citizens (57 per cent) would not feel safe riding in a self-driving car.

These findings are less optimistic than the initial government ambition to have driverless cars on the road by 2021. In addition, the number of people expressing positive attitudes towards self-driving cars does not seem to have significantly grown over the years. Research would need to be undertaken to understand if public perception and acceptance of AVs technology are changing over time. What is more, there is a need to ensure that AVs are safe and perceived as safe by the public (Wilby cited in Thales, 2019). For example, artifical intelligence (AI) simulation could be used to show how driverless cars operate and are safe on the road in order to increase public confidence in the technology (Jennings cited in Thales, 2019).

Public views on the operations of AVs do not seem to be conclusive. For example, Kyriakidis et al. (2015) found that software hacking, legality and liability are the main concerns expressed by the public. However, a survey conducted by Schoettle and Sivak (2014) in the US, the UK and Australia showed that UK responders were "moderately concerned" about system security (hacking) and vehicle security when compared to responders from the US and Australia who were "very concerned".

There is consensus across different studies that men, young adults, well-educated people and those living in urban areas seem to be more optimistic towards AVs (eg Kyriakidis et al. 2015, Payre et al. 2014, Schoettle and Sivak, 2014). The research conducted by Schoettle and Sivak (2014) in the UK, the US and Australia found out that the female group expressed more concerns regarding self-driving cars than the male group, and were less optimistic about the benefits arising from the use of AVs.

Hohenberger et al. (2016) and Hohenberger et al. (2017) investigated the differences between socio-demographic groups in their attitudes towards AVs. The findings from German responders showed that general emotions may partially impact views towards AVs. Women are more anxious towards AVs than men, which impacts their acceptance of the technology (Hohenberger et al., 2016). Based on a sample of residents from China, Liu et al. (2019) found that elderly people have a less positive attitude towards AVs when compared to younger people. Lee et al. (2017) found out that age negatively affects the public perception of AVs by looking at responses from 1,765 adults in the US. Older adults considered self-driving vehicles less valuable compared to younger people.

As seen from the above short review, more research is needed to understand the socio-demographic differences affecting the acceptance/perception of self-driving vehicles in the UK.

Impact on jobs

Relatively little research has been conducted on the impact on people working in industries where driving is the primary skill. Market projections suggest that connected and autonomous vehicles (CAVs) technologies will produce 6,000 direct UK jobs in the production of CAV technologies and 3,900 indirect jobs in the supply chain by 2035 (Catapult, 2017: 4). CAV technologies are "defined as the on-vehicle technologies that provide CAVs with their autonomous/connected capabilities" (ibid: 3). However, CAVs can both create new jobs and also destroy other jobs by displacing workers – eg transportation jobs, auto-body works and parking attendants – unlikely to take advantage of new jobs being created (Ipolitics, 2018).

It is unclear how the government is planning to reskill the existing workforce. Although there is an increasing shortage of truck drivers in the UK, the number of licenced drivers (private hire vehicles and taxi drivers) continues to grow (Logistics UK, 2019). There were 364,900 licensed drivers in 2020 in the UK – an increase of 0.6 per cent from 2019 (DfT, 2020a). This is an example of a group that is more likely to lose their jobs and not benefit from the new jobs created by the introduction of AVs.

Apart from a direct impact on people depending on driving as a profession, automation will require highly skilled people, favouring those who can quickly adapt to the changing environment. A common belief is that automation or autonomous systems are going to replace humans. However, as Baxter et al. (2012) noticed, "the more we depend on technology and push it to its limits, the more we need highly-skilled, well-trained, well-practised people to make systems resilient, acting as the last line of defence against the failures that will inevitably occur." The re-skilling and adaptation to new jobs of those whose current jobs will be under threat will not happen in the absence of significant policy interventions by the government.

Autonomous vehicles: public acceptance and possible research areas

- Develop tools and measures to encourage public trust in autonomous vehicles.
- Develop a better understanding of how socio-demographic differences in the UK affect attitudes to AVs.
- Provide AI simulations or find other ways to increase the public's confidence in self-driving cars.
- Investigate the unintended consequences of introducing AVs on jobs and society.

Unmanned aerial vehicles

Background

This section refers to the policy activities and issues surrounding the introduction of UAVs in terms of regulation, safety, and public acceptance. The government introduced restrictions for small, unmanned aircraft, and from 31 December 2020, new regulations came into force in the UK to standardise regulation across the European Union (House of Commons and Science and Technology Committee, 2019; BBC, 2020b). Following the UK's exit from the EU, the government plans to publish "all UK aviation law (including retained EU law) on legislation.gov.uk in due course" (CAA, 2020a). However, there are still outstanding issues, including whether a new liability framework should be established for UAVs or the whether manufacturers should be required to include software that restricts drones from entering a restricted area.

Safety issues are grouped into three domains: risk to air users, ground risk, and malicious use of drones, including cyberattacks. The public has shown limited knowledge of drones' application and there is also little understanding of unintended consequences of introducing commercial drones and their impact on society. One of the main areas of concern expressed by the public, which was noted by different studies, was privacy.

Regulation

The government takes a control-oriented approach by implementing policies and regulations towards UAVs to manage risks and ensure safety. The CAA is responsible for regulating civil aircraft, including drones, and the key regulations and developments include:

- From November 2019, it became mandatory for operators of small, unmanned aircraft – a drone between 250g and 20kg – to register themselves and take an online competency test. It is also prohibited to fly any drone above 400ft (120m) and to fly a drone within 1km of an airport (when a Flight Zone Restriction has not been established) (House of Commons and Science and Technology Committee, 2019: 8; NATS, 2021).

- Airport and airfield restrictions "around every protected aerodrome in the UK, which is a 2 (or 2.5) nautical mile radius cylinder and a series of 5Km rectangular zones from the end of each runway threshold" have also been introduced (DroneSafe, 2021).

- The CAA and NATS introduced the Drone Code to help people to understand regulations, and created an application called Drone Assist to understand safety rules (MoD and MAA, 2017).

- After an incident at Gatwick Airport over the 2018 Christmas period, police have been given more power in grounding drones and enforcing rules (Home Office, 2019).

- In the current regulation, there is no distinction between commercial and non-commercial operations (BBC, 2020b). The new rules set out three categories of drone operations based on the risk of the flight:
    - **Open:** low risk, does not require an authorisation from the CAA.
    - **Specific:** requires an authorisation from the CAA.
    - **Certified:** high risk, operations of drones are subject to the same regulatory regime as manned aircraft. The specific regulation in the certified category is still being developed in the UK, and have not been published yet (CAA, 2015).

There are several further points for consideration:

- **Geo-fencing:** the UK government does not impose a requirement for manufacturers to include software that restricts drones from entering a restricted area (Haylen, 2019:18).

- **Detect and avoid technology:** the UK Government is collaborating with businesses to develop a technology that detects and avoids obstacles (and more importantly, other airspace users) to integrate drones into the airspace (ibid.:23)

- **Privacy:** drones can be equipped with a small camera and can take pictures, record videos, and in some cases, track the locations of individuals. One major concern is that they can be used to collect personal information without people's consent (Library of Congress, n.d.). Collecting such information could breach The Data Protection Act 1998 (DPA) and the CCTV Code of Practice (CAA, 2021b). It is believed that current legislation is able to deal with privacy concerns.

- **Liability:** operators of aircraft weighing more than 20kg are required to obtain insurance, but there is no such requirement for aircraft less than 20kg (CAA, 2021c). Drones are currently regulated under the Civil Aviation Act 1982 s76.2, where a broad definition of an aircraft also includes a drone. This regulation suggests that the aircraft owner would be liable for accidents caused by fully autonomous drones. With AVs, an insurer would be responsible for accidents caused when a listed vehicle drives itself. This poses the question of whether a new liability framework should be established for autonomous drones as we have seen with AVs?

Unmanned aerial vehicles: regulation and possible questions

- What technologies are required to ensure safe integration of drones into airspace?
- Should there be other regulatory frameworks or guidelines for monitoring capabilities of drones (eg geo-fencing)?
- Should liability for UAVs be established as it has been in the AVs sector?

Safety

Risks to manned aircraft (helicopters and airplanes)

One of the biggest challenges is making sure that drones operate safely alongside manned aircraft and beyond visual line of sight (BVLoS) systems. In 2017, out of 113 incidents reported in UK airspace, 93 were caused by drones. In 2018, this number increased to 125 out of 139 incidents. In 2019, there was a small decrease in incidents caused by drones – 91 out of 125 all number of incidents – compared to 2018 (UK Airprox Board, 2019).

The consequences of airplanes colliding with a drone are not fully known yet, which may be because drones vary in size and design and so the potential damage they could cause would also vary. For example, a drone hit a plane's wing in Canada, but only minor damage was caused. In the US, a drone caused damage to the main rotor blade of a military helicopter (BBC,2017). The DfT in 2016 commissioned a study into the effects of collisions of piloted drones with manned aircraft (MAA, BALPA and DfT, 2016). Computing tests showed drones could cause significant damage to manned airplanes under certain circumstances.

Plans for a commercial drone corridor, allowing drones to operate safely using a "detect and avoid" system that prevents the drone from coming into conflict with another aircraft, is on the horizon (BBC, 2020a). There is a question as to whether UAVs could be integrated into the national airspace domain by using this system. It's worth noting, however, that these corridor tests are being conducted in a closely monitored environment, and so the risk of collision is reduced compared to a real-world environment.

Individual safety

The safe operation of drones does not only apply to situations in shared airspace. They can also cause accidents, damage to property, and fatal injuries when there is a system failure or lack of safety features. For example, in 2016, an 18-month-old boy lost an eye after being hit by a drone (BBC, 2015). Although the legislation places the responsibility on operators to ensure safe operations away from airplanes, people and buildings, there is a question of whether people should be responsible when technology does not behave as intended.

Malicious use

While drones can be used for many practical purposes – including surveillance, delivering packages, tackling wildfires and monitoring natural resources – they can also be used for malicious purposes. There have already been some examples where the illegal use of drones has caused disruptions and economic loss (see Box 2).

Best. et al. (2020: 7-8) provided the STRIDE Threat Taxonomy for identifying possible cyber threats arising from malicious use of drones. Table 5 below presents the definitions of the different types of threats adopted from Best et al. (2020)

Box 2: Examples of malicious use of drones

In 2018, Gatwick airport was closed for two days after two drones were spotted flying near the airport. Despite the deployment of police using counter-drone technology, no offender was identified. As a result, the government published the Counter-Unmanned Aircraft Strategy in 2019, giving police more power to fight the illegal use of drones, as well as introducing new regulations.

There were several incidents where drones were used to deliver drugs to prisons in the UK between 2016 and 2018. In 2018, following the most significant investigations of this kind, 15 members of an organised criminal gang were sentenced. The delivered illegal substances contributed to violence and crimes within prisons.

Source: Home Office (2019)

TABLE 5 THE STRIDE THREAT TAXONOMY WITH DEFINITIONS

S	**Spoofing:** Violations of authentication protocols, an attacker might pretend that they are something or someone else.
T	**Tampering:** Making modifications to the system.
R	**Repudiation:** An attacker refuses to take responsibility for actions.
I	**Information disclosure:** Releasing information without proper credentials.
D	**Denial of service:** Making unavailable service that is required for the system to to function properly.
E	**Elevation of privilege:** Performing an action that one is not authorised to do.

Public acceptance

Awareness of drones and their application

Public dialogue on drone use in the UK (DfT and MoD, 2016) suggests that awareness of drone technology is limited. People associate drones mainly with military use and have negative views towards them. Nesta's study from December 2017 showed that only 30 per cent of UK responders had a good understanding of the possible uses of drones. In 2018, DfT (2018) conducted a public attitudes survey. The findings showed limited awareness of potential applications for drones; the public mainly knows them for leisure use (71 per cent) and in a military context (70 cent) (DfT, 2018:2).

However, public perceptions can change after being exposed to the technology. For example, DfT and MoD (2016) found that participants had a more positive perception at the end of the study.

In 2019, the UK government, announced awareness campaigns in response to the public's limited understanding of drone technology (House of Commons and Science and Technology Committee, 2019: 4).

Privacy concerns

Privacy is a significant concern expressed by the public. DfT and MoD (2016: 4) found that worries about privacy were linked to a negative view of drones, among other things. A public attitude survey conducted by DfT (2018) showed that more than half (59 per cent) of respondents mentioned privacy issues as a concern. In Nesta's 2017 study, privacy was also the biggest concern, cited by 74 per cent of responders.

The unintended consequences of commercial drones

Different aircraft manufacturers are developing flying taxis and urban air mobility (UAM) (Evtol, 2019). One issue here is around noise. As Torija Martinez (2020) noticed, smaller drones produce a different sound than civil aircraft. Torija Martinez and Li (2016) found that drone sounds are considered less acceptable than civil aircraft noise. This is due to the fact that drones fly at lower altitudes (in areas that are not exposed to aircraft noise) and produce a high-pitched noise (Torija Martinez, 2020). In Canberra, drone delivery trials were launched and divided residents. While some residents reported issues with noise, privacy and wildlife, the others pointed out the convenience of getting quicker deliveries (ABC News, 2018).

It is predicted that drones will improve productivity by automating routine tasks in different sectors, such as deliveries, emergency responses, supporting search and rescue etc., and uptake of drone technology could bring £16bn net cost savings (PwC, 2021; DfT, 2019). However, less is known about how introducing commercial drones will impact the job market and other businesses.

The UK government's activities

Participants in the public dialogue in 2016 were concerned about not being able to trace and identify a drone's users in the case of an accident or invasion of privacy (DfT and MoD, 2016). They suggested common strategies to address their concerns: registration, mandatory training, technological solutions, and raising awareness and education.

The government responded to some of these concerns by implementing regulations such as the requirement of taking a competency test, and registration of small, unmanned aircraft (a drone between 250g-20kg) (House of Commons and Science and Technology Committee, 2019: 8). The CAA and NATS introduced The Drone Code to help people to understand regulations, and created an application called Drone Assist to understand safety rules. However, it might be necessary to listen to more diverse views, compare opinions between different groups (age, sex, place of living), as well as understand people's views on the certain application of autonomous systems in airspace (eg delivery drones, flying taxis).

Unmanned aerial vehicles: Public acceptance and possible research areas

- Listening to more diverse views.
- Understanding of citizens' expectations and visions of drone use.
- Understanding people's views on specific applications of autonomous systems in airspace (eg flying taxis, delivery drones).
- Understanding differences between different socio-demographic groups.
- Developing tools for tracking changes in public acceptance.

Unmanned surface vehicles

Background

It has been noted there has been less political activity and progress in developing USVs. One of the reasons may be the complex regulatory environment and ambiguity whether a person is required onboard. The government established MARLab in 2019. The report issued by MARLab concluded that existing regulations are slowing down innovation in the maritime sector (MCA, 2020). The expectation is that USVs would eliminate human error. Various studies showed that human errors in the maritime sector are the main causes of accidents. However, similar to AVs, it is difficult to know how safe or safer USVs are going to be. The introduction of USVs might bring different safety issues (eg cybersecurity issues). It was also not investigated what people think in general about autonomous vessels and their potential applications. However, unlike in other sectors (AVs and UAVs), the government put forward clear plans for reskilling the existing workforce and attracting new talent (DfT, 2019c).

Regulation

Various United Nations (UN) agencies regulate the shipping industry – mainly the International Maritime Organization (IMO). UK and EU legislation also influence the maritime sector (MCA, 2012). Businesses developing autonomous vessels need to interpret different regulatory frameworks, specifically the Regulations for the Prevention of Collisions at Sea 1972 (COLREGs). For example, COLREG Rule Five states that:

> *"Every vessel shall at all times maintain a proper look-out by sight and hearing as well as by all available means appropriate in the prevailing circumstances and conditions so as to make a full appraisal of the situation and the risk of collision."*

Whereas Rule Two requires:

> *"Nothing in these Rules shall exonerate any vessel, or the owner, master or crew thereof, from the consequences of any neglect to comply with these Rules or of the neglect of any precaution which may be required by the ordinary practice of seamen, or by the special circumstances of the case."*

Therefore, questions that arise from these rules when developing USVs are: is attendance onboard required? Can "a proper look out" be replaced by autonomous systems? How can the technology know what precaution is required "...by the ordinary practice of seamen"? And who will be liable for the accident caused by a fault in the autonomous system?

Challenges in the regulatory framework are approached from two distinct perspectives. One view is pushing for developing systems that comply with the COLREGs legal framework (Varas et al., 2017; Du et al., 2020; Naeem et al., 2016). The other focuses on advising changes in the regulatory framework or replacing existing rules (eg Zhou, et al. 2020; Ringbom et al. 2020).

Rolls Royce's MAXCMAS project (Machine Executable Collision Regulations for Marine Autonomous Systems) claims that they developed a COLREG-compliant ship collision avoidance algorithm in partnership with other partners. Although there are many other developments with considerations of COLREGs, this project suggests addressing "multiple target ships and multiple COLREGs rules" (Varas et al., 2017:3). On the other hand, for example, Zhou et al. (2020) suggest that Rule Two of COLREGs should be expanded and include liability in case of an accident caused by USVs.

Another regulatory issue arises from the fact that there is no formal international definition of a ship. For example, in France, a ship is defined as: "any floating craft, built and manned for maritime merchant navigation, or for fishing, or for yachting and dedicated to it" (Code des transports, 2021). While in the UK, the Merchant Shipping Act 1995, section 313(1) defines a ship as "every description of vessel used in navigation". In this case, USVs could fall under the category of definition of a ship under English law, but not in French law (UK P&I, 2019: 4). This poses a challenge considering that any ship is subjected to the law of flag – the sailors and vessels are subject to the state's law whose flag they fly – and the coastal or port state jurisdictions. The lack of uniform definition could lead to USVs being recognised as ships in one country but not in others (ibid.). It is, therefore, not surprising that the first USVs might be developed inside national borders, where regulators could introduce change to the existing frameworks or provide more flexible non-binding solutions. In fact, Maritime UK published an Industry Code of Practice for MASS (Maritime UK, 2020). Apart from this, the government established MARLab in 2019, whose purpose is to pioneer innovative regulatory approaches to USVs (Dft, 2019e).

Safety

USVs are expected to minimise the human error caused by fatigue, inadequate information, and other factors. In fact, most studies that investigate maritime accidents find that they are mainly caused by human error (eg Berg et al., 2013; Porathe et al., 2018). However, there is a question of whether autonomous ships can eliminate human error when solely relying on computers for operation. For example, what security systems should be in a place where there is a total electric breakdown (eg a fire on a ship)? In a situation like this, a person on a board could still signal a problem by using a satellite phone or the navigation status on the top of the mast. Or one could argue that in complex situations issues should be dealt with by a remote operation. However, can a ship with a backup operator based somewhere else be called fully autonomous?

Although USVs should be safer than human-crewed ships, they might introduce new types of accidents. Risk assessments were mentioned in the research papers to identify accidents that might arise (eg Kim et al. 2020). There are several potential risks associated with the introduction of USVs:

- **Cybersecurity threats:** In 2016, IMO identified a list of potential cyber-risks: cargo handling and management systems; propulsion and machinery management and power control systems; access and control systems; and communication systems (IMO, 2016).

- **Failure of systems:** Failure of key operational systems required for autonomous operations.

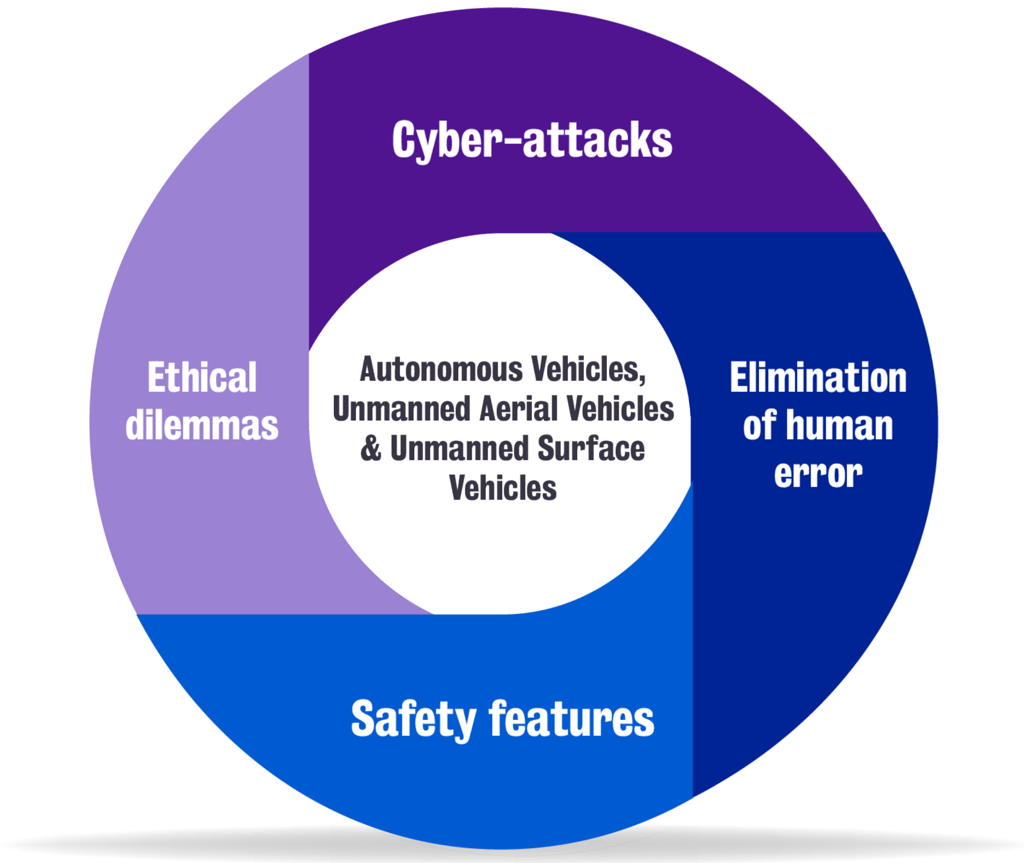
- **The difficulty of recognising an accident:** Failure or delay in identifying possible accidents.

- **Threat against port security:** The weaponisation of autonomous ships

Source: Potential risks listed by Kim et al. 2002, adopted from Komianos 2018

The challenges of USVs in terms of safety can be viewed from the same perspectives of drones and driverless cars, as these industries face similar issues (eg cybersecurity, safety features). Some lessons from self-driving cars and drones can be applied to USVs. Figure 1 below shows possible overlapping issues in all sectors that try to introduce autonomous systems. However, this list is not exhaustive

FIGURE 2: SAFETY IN AUTONOMOUS VEHICLES: SUMMARY OF ISSUES AND QUESTIONS



Public acceptance

Public acceptance of USVs has not been extensively studied in comparison to AVs or UAVs. The main concern that has been identified is the impact of automation on jobs in the maritime sector (eg Kim et al. 2020; Pribyl and Weigel, 2018). A shortage of seafarers has already been observed, and this shortage is expected to increase in the coming years. For example, Lloyd's Register et al. (2017) predict a significant decrease in qualified mariners from 2025. Although the wide adoption of USVs could probably address the issue of deficit in mariners, it is expected that human presence might be still required, for example in the role of on-shore operators (Pribyl and Weigel, 2018: 23). Lloyd's Register et al. (2017) predicts that monitoring autonomous ships will require a new set of skills, including technical and digital competencies.

The International Transport Federation and the International Federation of Shipmasters' Associations published a report indicating that more than 80 per cent of seafarers expressed their anxiety about possible job losses (The Maritime Executive, 2018).

The UK government recognises the importance of reskilling the existing workforce and attracting new talent. The Maritime 2050: People route map sets out a long-term strategy with a people-centred approach to technology and innovation policy (DfT, 2019c). Nonetheless, it is unclear what society thinks in general about autonomous ships.

Conclusion

The aim of this report was to compare policy developments in each autonomous vehicle sector and point to areas for further research or exploration. In general, the UK government has been more proactive in providing testing facilities and working towards a regulatory framework for autonomous vehicles. The government's expectations are that shared and connected AVs will reduce collisions, pollution and make transport more inclusive for all people by providing greater transport choices (eg DfT, 2019). However, this argument is based on the idea that AVs will be both shared and connected, going beyond the intention of a self-driving car alone. It is also less apparent how AVs will be used in cities and towns where policies at the city and national level aim to promote walking and cycling as the preferred option for shorter journeys.

Although public acceptance is key in the commercial deployment of this technology, little consideration has been given to the impact on jobs, and to how disruptive this technology is going to be for businesses and society. This stands in contrast to the maritime industry. DfT (2019c) published a roadmap for reskilling the workforce, attracting new talent, and take a people-centred approach to developing new autonomous ship technologies. In fact, the paradox of autonomous systems – where the development of highly complex autonomous systems is linked with the increased demand for highly skilled people – seems to have been overlooked by the government when looking at the introduction of autonomous systems on public roads. Little consideration has also been given to the fact that AVs can increase the unemployment rate in other sectors involving driving as a primary skill set. The government needs to make plans to address both issues: the need for highly skilled people and the rise of unemployment in other groups less likely to benefit from the introduction of AVs.

The potential of commercial application of UAVs BVLoS also requires more exploration by the UK government. In contrast to AV regulation, the government takes a controlled approach towards regulating drones. In particular, it may be prudent to create a regulatory framework for the development of fully autonomous drones that operate in cities. While this technology does offer many positives, there also needs to be a thorough consideration of the negative impacts it may cause, particularly in relation to public safety.

References

ABC news (2018) *Whining drones bringing burritos and coffee are bitterly dividing Canberra residents*. Available from: https://www.abc.net.au/news/2018-11-09/noise-from-drone-delivery-service-divides-canberra-residents/10484044. Accessed 01/05/2021.

Accenture Research (2011) *Embedded Software Consumer Pulse Survey* [online] Available from https://newsroom.accenture.com/content/1101/files/EmbeddedSoftware-Overall.pdf Accessed 23/02/2021.

Adams, T. (2015) 2020 - The year you become a permanent backseat driver. *Observer 13th*. Tech monthly, p. 32-3.

Anderson, J. M., Nidhi, K., Stanley, K. D., Sorensen, P., Samaras, C., & Oluwatola, O. A. (2014) *Autonomous vehicle technology: A guide for policymakers*. Santa Monica, CA: Rand Corporation.

Automated and Electric Vehicles Act 2018. 2018 c. 18.

Baxter, G. *et al.* (2012) The ironies of automation: still going strong at 30? *In: Proceedings of the 30th European Conference on Cognitive Ergonomics (ECCE '12)*. Association for Computing Machinery, New York, NY, USA, 65–71. DOI:https://doi.org/10.1145/2448136.2448149

BBC (2015) *Toddler's eyeball sliced in half by drone propeller.* Available from: https://www.bbc.co.uk/news/uk-england-hereford-worcester-34936739. Accessed 23/02/2021.

BBC (2017) *Drone collisions 'worse than bird strikes for planes'*. Available from: https://www.bbc.co.uk/news/technology-42238115. Accessed 10/02/2021.

BBC (2019) *UK wants fully autonomous cars on road.* Available from: *https://www.bbc.co.uk/news/technology-47144449*. Accessed 10/02/2021.

BBC (2020) *Uber's self-driving operator charged over fatal crash*. Available from: https://www.bbc.co.uk/news/technology-54175359. Accessed 23/02/2020.

BBC (2020a) *Commercial drone sky highway 'could open this year.* Available from: https://www.bbc.co.uk/news/uk-england-berkshire-54266680?intlink_from_url=https://www.bbc.co.uk/news/localnews/6620293-yateley/30&link_location=live-reporting-story. Accessed 23/02/2021.

BBC (2020b) *Drone users face new rules across Europe and UK.* Available from: https://www.bbc.co.uk/news/technology-55424729. Accessed 23/02/2021.

BBC (2021) *'Self-driving' cars to be allowed on UK roads this year*. Available from: https://www.bbc.co.uk/news/technology-56906145. Accessed 11/08/2021

Berg, N. *et al.* (2013) *The impact of ship crews on maritime safety*. Kouvola: Publications of the Centre for Maritime Studies, University of Turku. Available at: https://www.semanticscholar.org/paper/THE-IMPACT-OF-SHIP-CREWS-ON-MARITIME-SAFETY-Berg-Storg%C3%A5rd/b8f7fbeebff8828ddf6bd8e5d4a9a18895e6a8e2. Accessed 26/04/2021.

Best, K.L. *et al.* (2020) *How to Analyze the Cyber Threat from Drones: Background, Analysis Frameworks, and Analysis Tools*. RAND Corporation. Available from: https://www.rand.org/pubs/research_reports/RR2972.html. Accessed 23/02/2021.
Boeglin, J. (2015) The costs of self-driving cars: Reconciling freedom and privacy with tort liability in autonomous vehicle regulation. *Yale Journal of Law & Technology*, 17, article 4, 171.

Boucher, P. (2016) 'You Wouldn't have Your Granny Using Them': Drawing Boundaries Between Acceptable and Unacceptable Applications of Civil Drones. *Sci Eng Ethics* Vol. 22, pp. 1391–1418. DOI: https://doi.org/10.1007/s11948-015-9720-7

CAA (2015) *An introduction to unmanned aircraft systems*. Available from: https://www.caa.co.uk/Consumers/Unmanned-aircraft/Our-role/An-introduction-to-unmanned-aircraft-systems/ Accessed 15/04/2021.

CAA (2019) *The Drone and Model Aircraft Code*. Available from: https://register-drones.caa.co.uk/drone-code. Accessed 22/02/2021.

CAA (2020) *Innovation Hub Beyond Visual Line of Sight in Non-Segregated Airspace Fundamental Principles & Terminology*. Available from: https://publicapps.caa.co.uk/docs/33/CAP%201861%20-%20BVLOS%20Fundamentals%20v2.pdf. Accessed 19/08/2021.

CAA (2020a) *UK regulations*. Available from: https://info.caa.co.uk/uk-regulations/. Accessed 19/08/2021.

CAA (2021) *Certified Category. Guidance on regulations for the Certified Category*. Available from: https://www.caa.co.uk/Commercial-industry/Aircraft/Unmanned-aircraft/Certified-Category/. Accessed 11/08/2021

CAA (2021a) *Flying in the open category*. Available from: https://www.caa.co.uk/Consumers/Unmanned-aircraft/Recreational-drones/Flying-in-the-open-category/. Accessed 11/08/2021

CAA (2021b) *The Drone and Model Aircraft Code*. Available from: https://register-drones.caa.co.uk/drone-code/protecting-peoples-privacy Accessed 11/08/2021.

CAA (2021c) *Registering to use a drone or model aircraft*. Available from: https://register-drones.caa.co.uk/individual. Accessed 11/08/2021.

Catapult (2017) Market forecast for connected and autonomous vehicles. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/642813/15780_TSC_Market_Forecast_for_CAV_Report_FINAL.pdf. Accessed 22/02/2021

Cavoli, C. *et al.* (2017) *Social and behavioural questions associated with Automated Vehicles. A Literature Review*, London: Department for Transport.

CCAV (2020) *Safe Use of Automated Driving Systems Call for Evidence* (August 2020) (Call for Evidence). Available from: https://www.gov.uk/government/consultations/safe-use-of-automated-lane-keeping-system-on-gbmotorways-call-for-evidence. Accessed 11/08/2021.

CCAV, BEIS and DfT (2021) *Code of Practice: Automated vehicle trialling*. Available from: https://www.gov.uk/government/publications/trialling-automated-vehicle-technologies-in-public/code-of-practice-automated-vehicle-trialling. Accessed 22/02/2021.

Christian, A. W. and Cabell R. (2017) *Initial Investigation into the Psychoacoustic Properties of Small Unmanned Aerial System Noise*. Available from: https://doi.org/10.2514/6.2017-4051. Accessed 22/02/2021.

Civil Aviation Act 1982 s76.2. Available from: https://www.legislation.gov.uk/ukpga/1982/16/section/76 . Accessed 22/02/2021.

Conventions on the International Regulations for Preventing Collision at Sea (COLREGs), The International Maritime Organization (IMO) (1972)

Davies, A. (2018) *How Do Self-Driving Cars See? (And How Do They SeeMe)?* Available from: https://www.wired.com/story/the-know-it-alls-how-do-self-driving-cars-see/. Accessed 10/02/2021.

DfT (2018) *Transport and Technology: Public Attitudes Tracker*. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/752240/transport-and-transport-technology-public-attitudes-tracker-wave-1-and-2-report.pdf. Accessed 23/02/2021.

DfT (2019) *Future of Mobility: urban strategy*. Available from: https://www.gov.uk/government/publications/future-of-mobility-urban-strategy. Accessed 15/04/2021.

DfT (2019a) *Future of Transport: rural strategy – call for evidence*. Available from: https://www.gov.uk/government/consultations/future-of-transport-rural-strategy-call-for-evidence. Accessed 22/02/2021

DfT (2019b) *The future of transport in towns and cities.* Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/940344/urban-transport-report-easy-read.pdf. Accessed 22/02/2021

DfT (2019c) *Maritime 2050 People Route Map*. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/872270/Maritime_2050_-_People_route_map.pdf. Accessed 22/02/2021.

DfT (2019d) *Taking Flight: The Future of Drones in the UK Government Response*. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/937275/future-of-drones-in-uk-consultation-response-web.pdf Accessed 22/02/2021

DfT (2019e) *Technology and Innovation in UK Maritime: The case of Autonomy.* Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/877630/technology-innovation-route-map-document.pdf Accessed 23/02/2021

DfT (2019f) *Maritime 2050 People Route Map*. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/872270/Maritime_2050_-_People_route_map.pdf . Accessed 23/02/2021.

DfT (2020) *Future of Transport Regulatory Review Summary of Responses.* Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/938347/FoT-Regulatory-Review-Summary-of-Responses-Accessible.pdf. Accessed 22/02/2021.

DfT (2020a) *Taxi and Private Hire Vehicle Statistics, England: 2020*. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/944680/taxi-and-private-hire-vehicle-statistics-2020.pdf. Accessed 22/02/2021.

DfT and MoD (2016) *Public dialogue on drone use in the UK*. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/579550/drones-uk-public-dialogue.pdf Accessed 22/02/2021. Accessed 19/04/2021.

DfT *et al.* (2019) *CAV public acceptability dialogue*. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/

file/951094/cav-public-acceptability-dialogue-engagement.pdf. Accessed 19/04/2021.

DfT *et al.* (2019a) *CAV public acceptability dialogue – appendices.* Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/951095/cav-public-acceptability-dialogue-engagement-report_appendices.pdf. Accessed 19/04/2021

DfT *et al.* (2021) Government paves the way for self-driving vehicles on UK roads. Available from: https://www.gov.uk/government/news/government-paves-the-way-for-self-driving-vehicles-on-uk-roads. Accessed 30/04/2021.

DroneSafe (2021) *Airport and other airfield restrictions*. Available from: https://drone-safe.uk/restrictions/. Accessed 30/06/2021.

Du, L. *et al.* (2020) A COLREG-compliant ship collision alert system for stand-on vessels. *Ocean Engeering*. Vol. 218. DOI: https://doi.org/10.1016/j.oceaneng.2020.107866

EASA (2021) *Easy Access Rules for Unmanned Aircraft Systems (Regulation (EU) 2019/947 and Regulation (EU) 2019/945).* Available from: https://www.easa.europa.eu/document-library/easy-access-rules/easy-access-rules-unmanned-aircraft-systems-regulation-eu. Accessed 23/02/2021.

Evtol (2019) *Urban air mobility concepts showcased at NBAA.* Available from: https://evtol.com/news/urban-air-mobility-concepts-showcased-nbaa/. Accessed 01/05/2021

Fagnant, D. J. Kockelman, K. (2015) Preparing a nation for autonomous vehicles: opportunities, barriers and policy recommendations. Transp. Res. Part A: Policy Pract.,Vol. 77, pp. 167-181.

Felski, A. and Karolina Zwolak, K. (2020) The Ocean-Going Autonomous Ship—Challenges and Threats. *J. Mar. Sci. Eng.* Vol. 8(41). DOI: http://dx.doi.org/10.3390/jmse8010041

Glancy, D. J. (2012). Privacy in autonomous vehicles. *Santa Clara Law Review*, Vol. 52(4), pp. 1171–1239.

Hannon, E. *et al.*, (2019) *An integrated perspective on the future of mobility. McKinsey & Company*. Available from: https://www.mckinsey.com/~/media/mckinsey/business%20functions/sustainability/our%20insights/the%20road%20to%20seamless%20urban%20mobility/an-integrated-perspective-on-the-future-of-mobility-part-3-vf.pdf Accessed 23/02/2021.

Haylen, A. (2019) *Civilian Drones*, Briefing paper CBP 7734, House of Commons Library, February 2019

HM Government (2017) *The key principles of vehicle cyber security for connected and automated vehicles*. Available from: https://www.gov.uk/government/publications/principles-of-cyber-security-for-connected-and-automated-vehicles/the-key-principles-of-vehicle-cyber-security-for-connected-and-automated-vehicles Accessed 10/02/2021.

HM Government (2018) *Beyond the horizon: The future of UK aviation*. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/698247/next-steps-towards-an-aviation-strategy.pdf. Accessed 22/02/2021.

HM Government (2019) *UK Counter-Unmanned Aircraft Strategy*. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/840793/Counter-Unmanned_Aircraft_Strategy.pdf. Accessed 15/04/2021.

Hohenberger, Christoph & Spörrle, Matthias & Welpe, Isabell M., (2017) Not fearless, but self-enhanced: The effects of anxiety on the willingness to use autonomous cars depend on individual levels of self-enhancement. *Technological Forecasting and Social Change*, *Elsevier*, vol. 116(C), pp. 40-52.

Hohenberger, C. Spörrle, M., Welpe, I. M. (2016) How and why do men and women differ in their willingness to use automated cars? The influence of emotions across different age groups.*Transp. Res. Part A*, 94, pp. 374-385, 10.1016/j.tra.2016.09.022

Home Office (2019) Counter-Unmanned Aircraft Strategy. Available from: https://www.gov.uk/government/publications/uk-counter-unmanned-aircraft-strategy/table#part-1-introduction. Accessed 22/02/2021.

House of Commons and Science and Technology Committee (2019) *Commercial and recreational drone use in the UK: Twenty-Second Report of Session 2017–19*. Available from: ttps://publications.parliament.uk/pa/cm201719/cmselect/cmsctech/2021/2021.pdf. Accessed 23/02/2021.

IMO (2016) *Interim guidelines on maritime cyber risk management*. Available from: https://www.gard.no/Content/21323229/MSC.1-Circ.1526.pdf. Accessed 23/02/2021.

International Transport Forum (2015) Automated and Autonomous Driving. Regulation under uncertainty. *OECD*. Available at: http://www.itfoecd.org/sites/default/files/docs/15cpb_autonomousdriving.pdf Accessed 15/04/2021.

Ipolitics (2018) *Automated cars could kill wide range of jobs: internal documents*. Available from: https://ipolitics.ca/2018/10/15/automated-cars-could-kill-wide-range-of-jobs-federal-documents-say/. Accessed 17/08/2021.

Kalra, N. and Paddock, S.M. (2016) Driving to Safety: How Many Miles of Driving Would It Take to Demonstrate Autonomous Vehicle Reliability?. Santa Monica, CA: RAND Corporation. Available from: https://www.rand.org/pubs/research_reports/RR1478.html. Accessed 14/12/2021

Kersley, A. (2021) The slow collapse of Amazon's drone delivery dream. Wired. *8th August*. Available from: https://www.wired.co.uk/article/amazon-drone-delivery-prime-air. Accessed 12/08/2021.

Kim, M. *et al.* (2020) Autonomous shipping and its impact on regulations, technologies, and industries. *Journal of International Maritime Safety, Environmental Affairs, and Shipping*. Vol. 4(2), pp. 17-25. DOI: https://doi.org/10.1080/25725084.2020.1779427

KPMG (2020) *Autonomous Vehicles Readiness Index*. Available from: https://assets.kpmg/content/dam/kpmg/uk/pdf/2020/07/2020-autonomous-vehicles-readiness-index.pdf. Accessed 10/02/2021.

Kyriakidis, M., Happee, R., & De Winter, J. C. F. (2015). Public opinion on automated driving: Results of an international questionnaire among 5000 respondents. *Transportation Research Part F: Traffic Psychology and Behaviour*, *32*(July), 127–140. https://doi.org/10.1016/j.trf.2015.04.014

Law Commission (2019) Automated Vehicles: Consultation Paper 2 on Passenger Services and Public Transport. Available from: https://s3-eu-west-2.amazonaws.

com/lawcom-prod-storage-11jsxou24uy7q/uploads/2019/10/Automated-Vehicles-Consultation-Paper-final.pdf. Accessed 22/02/2021

Law Commission (2020) Consultation Paper 3 -a regulatory framework for automated vehicles. Available from: https://www.lawcom.gov.uk/project/automated-vehicles/ Accessed 22/02/2021

Lee, C. Ward, C., Raue, M., D'Ambrosio, L., Coughlin, J.F (2017) Age differences in acceptance of self-driving cars: a survey of perceptions and attitudes. In: Zhou,I. and Salvendy, G. (Eds.) *Human aspects of it for the aged population. Aging, design and user experience*, Springer, London, pp. 3-13

Levin, T. (2020) IBM will send an autonomous research vessel across the Atlantic next year. *Business Insider*. 20th Sep. Available from: https://www.businessinsider.com/ibm-transatlantic-autonomous-research-vessel-ship-across-atlantic-ocean-mayflower-2020-9?r=US&IR=T Accessed 15/04/2021.

Library of Congress (2019) *Regulation of Drones: United Kingdom*. Available from: https://www.loc.gov/law/help/regulation-of-drones/united-kingdom.php#_ftn46. Accessed 23/02/2021.

Liu, P., Zhang, Y., He, Z. (2019) The effect of population age on the acceptable safety of self-driving vehicles. *Reliab. Eng. Syst. Saf*. Vol. 185,pp. 341–347

Lloyds Register *et al.* (2017) *Global Marine Technology Trends 2030: Autonomous Systems* . Available from: https://www.lr.org/en/insights/global-marine-trends-2030/global-marine-technology-trends-2030. Accessed 26/04/2021.

MAA, BALPA, and Dft (2016) *Small Remotely Piloted Aircraft Systems (drones) Mid-Air Collision Study*. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/918811/small-remotely-piloted-aircraft-systems-drones-mid-air-collision-study.pdf. Accessed 23/02/2021.

Maritime Autonomous Surface Ships UK Code of Practice (2018) *Maritime Autonomous Surface Ships UK Code of Practice*. Available from: https://www.maritimeuk. org/media-centre/publications/maritime-autonomous-surface-ships-uk-code-practice/. Accessed 15/04/2021.

Maritime UK (2020) *Maritime Autonomous Ship Systems (MASS) UK Industry Conduct Principles and Code of Practice*. Available from: https://www.maritimeuk.org/priorities/innovation/maritime-uk-autonomous-systems-regulatory-working-group/mass-uk-industry-conduct-principles-and-code-practice/. Accessed 23/04/2021.

MCA (2012) *Shipping industry regulations*. Available from: https://www.gov.uk/guidance/shipping-industry-regulation. Accessed 22/02/2021.

MCA (2020) *Maritime Autonomy Regulation Lab (MARLab) Report.* Available from: https://www.gov.uk/government/publications/maritime-autonomy-regulation-lab-marlab-report/maritime-autonomy-regulation-lab-marlab-report. Accessed 22/02/2021.

Mehmet, S. (2020) DfT calls for evidence as part of future of mobility review. *Intelligent Transport*. 16th March.

Merchant Shipping Act 1995

MoD and MAA (2017) Drones: how to fly them safely and legally. Available from: https://www.gov.uk/government/news/drones-are-you-flying-yours-safely-and-legally. Accessed 10/02/2021

Moreno (2020) *Will autonomous ships be the "downfall" of the shipping sector.* Available from: https://www.equaltimes.org/will-autonomous-ships-be-the#.YDTpwuj7Tcs. Accessed 10/02/2021

Naeem, W. *et al.* (2016) A Reactive COLREGs-Compliant Navigation Strategy for Autonomous Maritime Navigation. *IFAC-PapersOnLine*, Vol. 49(23), pp. 207-213.

National Counter Terrorism Security Office (2020) *Countering Threats from Unmanned Aerial Systems (C-UAS)*. Available from: https://www.gov.uk/government/publications/crowded-places-guidance/countering-threats-from-unmanned-aerial-systems-c-uas. Accessed 22/02/2021.

Nesta (2017) Drones in our cities by 2020, predict a quarter of people - rising to half by 2024. Available from: https://www.nesta.org.uk/press-release/drones-in-our-cities-by-2020-predict-a-quarter-of-people-rising-to-half-by-2024/. Accessed 23/02/2021.

NESTA (2018) *Flying High: The future of drone technology in UK cities*. Available from: https://www.nesta.org.uk/report/flying-high-challenge-future-of-drone-technology-in-uk-cities/exploring-urban-drone-integration/ Accessed 15/04/2021.

Nuttall, C. (2021) Self-driving cars turn off hype highway. *Financial Times*. 4th Jan.

Payre, W., Cestac, J., & Delhomme, P. (2014). Intention to use a fully automated car: Attitudes and a priori acceptability. *Transportation Research Part F: Traffic Psychology and Behaviour*. Vol. 27,pp. 252–263.DOI: http://dx.doi.org/10.1016/j.trf.2014.04.009.

Porathe, T. *et al.* (2014) Situation Awareness in Remote Control Centres for Unmanned Ships. In: *Proceedings of Human Factors in Ship Design & Operation.*

Porathe, T *et al.* (2018) At Least as Safe as Manned Shipping? Autonomous Shipping, Safety and "Human Error". Safety and Reliability – Safe Societies in a Changing World .In: *Proceedings of the 27th European Safety and Reliability Conference* (ESREL 2018), Trondheim, Norway.

Pospiech, P. (2018*) Scandinavia is pioneer in autonomous shipping. Veus-shipping*. Available from: https://veus-shipping.com/2018/12/scandinavia-is-pioneer-in-autonomous-shipping/. Accessed 11/06/2021.

Pribyl, S.T. and Weigel, A. M. (2018) Autonomous Vessels: How an Emerging Disruptive Technology is poised to impact the maritime industry much sooner than anticipated. *The Journal of Robotics, Artificial Intelligence & Law*. Vol.1, pp. 17–25

PwC (2021) *Skies without limit: Drones – taking the UK's economy to new heights. Available from*: https://www.pwc.co.uk//intelligent-digital/drones/Drones-impact-on-the-UK-economy-FINAL.pdf

Reuters (2021) *Air taxi startup Volocopter gains key production certification*. Available from: from:https://www.reuters.com/business/aerospace-defense/air-taxi-startup-volocopter-gains-key-production-certification-2021-07-06/ Accessed 16/08/2021

Ringbom, H. *et al.* (2020) *Charting Regulatory Frameworks for Maritime Autonomous Surface Ship Testing, Pilots, and Commercial Deployments*. Ministry of the Transport and Communications. Available from: https://julkaisut.valtioneuvosto.fi/handle/10024/162560. Accessed 23/04/2021.

Rolls-Royce (n.d.) *Autonomous ships: The next step*. Available from: https://www.rolls-royce.com/~/media/Files/R/Rolls-Royce/documents/%20customers/marine/ship-intel/rr-ship-intel-aawa-8pg.pdf Accessed 15/04/2021.

SAE (2019) SAE *Standards News: J3016 automated-driving graphic update*. Available from: https://www.sae.org/news/2019/01/sae-updates-j3016-automated-driving-graphic. Accessed 15/04/2021

Schoettle, B. and Sivak, M. (2014) *A survey of public opinion about autonomous and self-driving vehicles in the US, the UK and Australia*. Michigan: University of Michigan.

Shalev-Schwartz, S., Shammah, S. & Shashua, A. (2017) *On a Formal Model of Safe and Scalable Self-driving Cars*, arXiv preprint arXiv:1708.06374.

Shuttleworth, J. (2019) *SAE standards news: j3016 automated-driving graphic update*. Available from: https://www.sae.org/news/2019/01/sae-updates-j3016-automated-driving-graphic. Accessed 22/02/2021.

Sifted (2021) *UK's first flying taxi hub to be built in Coventry*. Available from: https://sifted.eu/articles/uk-flying-taxi-hub-coventry/. Accessed 22/07/2021.

Royal Navy (2021) Drone swarms support Commando Forces trials in a first for the UK's armed forces. Available from: https://www.royalnavy.mod.uk/news-and-latest-activity/news/2021/july/17/210715-autonomous-advance-force-4. Accessed 22/07/2021.

Thales (2019) *White Paper Making driving as safe as flying in an autonomous world.* Available from: https://www.thalesgroup.com/sites/default/files/database/document/2019-01/19589%20%E2%80%93%20TCC%20Making%20driving%20White%20Paper%20v1.pdf . Accessed 10/02/2021.

The Maritime Executive (2018) *CS: Seafarers Won't Lose Jobs to Automation Yet.* Available from: https://www.maritime-executive.com/article/ics-seafarers-won-t-lose-jobs-to-automation-yet. Accessed 26/04/2021.

The Maritime Executive (2021) *ICS: Seafarers Won't Lose Jobs to Automation Yet*. Available from: https://www.maritime-executive.com/article/ics-seafarers-won-t-lose-jobs-to-automation-yet. Accessed 23/02/2021.

The Register (2021) *Cyberlaw experts: Take back control. No, we're not talking about Brexit. It's Automated Lane Keeping Systems*. Available from: https://www.theregister.com/2021/07/16/automated_lane_keeping_systems_feature/. Accessed 20/08/2021.

The Waymo team (2021) Welcoming our first riders in San Francisco. Available from: https://blog.waymo.com/2021/08/welcoming-our-first-riders-in-san.html. Accessed 24/08/2021.

Topham, G. (2021) 'Peak hype': why the driverless car revolution has stalled. *The Guardian.* 3rd Jan.

Torija Martinez, A. J. (2020) Make drones sound less annoying by factoring in humans at the design stage. *The Conversation*. 21st Dec.

Torija Martinez, A.J., and Li, Z. (2016) *Metrics for assessing the perception of drone noise*. Available from: http://usir.salford.ac.uk/id/eprint/59114/1/000018.pdf. Accessed 22/02/2021

UK Airprox Board (n.d.) *Airprox involving UAS Drones*. Available from: https://

www.airproxboard.org.uk/Reports-and-analysis/Statistics/Airprox-involving-UAS-Drones/. Accessed 22/02/2021.

UK Autodrive (2016) *The moral algorithm how to set the moral compass for autonomous vehicles*. Available from: https://gowlingwlg.com/getmedia/30384809-9eb3-4750-9061-f11351557b45/the_moral_algorithm.pdf.xml?ext=.pdf Accessed 22/02/2021.

UK Drone Delivery Group (2020) *The commercialisation of the UK civil air drone industry. An industry White Paper presented to the UK government*. Available from: https://drive.google.com/file/d/1yNzX5ZFaARHlPplh9f8mup-lyLg5GGY4/view. Accessed 22/02/2021

UK Government (2019) *Promoting the UK's world-class global maritime offer: Trade and Investment 5-year plan*. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/833816/Maritime_5-year_Plan_Accessible.pdf Accessed 22/02/2021. Accessed 22/02/2021.

UK P&I (2019) *Legal Briefing Sharing the Club's legal expertise and experience*. Available from: https://www.ukpandi.com/-/media/files/imports/13108/briefings/37135---legal_briefing_autonomous_shipping_web.pdf. Accessed 23/04/2021.

UK Space Agency (2020) *Space Agency backs space-enabled drones to deliver Covid-19 testing kits.* Available from: https://www.gov.uk/government/news/space-agency-backs-space-enabled-drones-to-deliver-covid-19-testing-kits. Accessed 28/04/2021

UK Space Agency (2020) *Space Agency backs space-enabled drones to deliver Covid-19 testing kits*. Available from: https://www.gov.uk/government/news/space-agency-backs-space-enabled-drones-to-deliver-covid-19-testing-kits. Accessed 22/02/2021.

Vakil *et al.*, (2019) Self-Driving Cars: Balancing Safety and Data Privacy Considerations. *White & Case*. 04th Nov. Available from: https://www.whitecase.com/news/media/self-driving-cars-balancing-safety-and-data-privacy-considerations. Accessed 14/06/2021.

Varas, J. M. *et al.* (2017). MAXCMAS project: Autonomous COLREGs compliant ship navigation. *In Proceedings of the 16th Conference on Computer Applications and Information Technology in the Maritime Industries* (COMPIT), pp. 454-464.

Wadud, Z., MacKenzie, D., Leiby, P. (2016) Help or hindrance? The travel, energy and carbon impacts of highly automated vehicles. *Transp. Res. Part A: Policy Pract.*, Vol. 86, pp. 1-18

Zenzic (2020) *UK Connected and Automated Mobility Roadmap to 2030: CAM Creators Update*. Available from: https://zenzic.io/roadmap/. Accessed 22/02/2021

Zhou, X. *et al.* (2020) A Study of the Application Barriers to the Use of Autonomous Ships Posed by the Good Seamanship Requirement of COLREGs.*Journal of Navigation.* Vol. 73(3), pp. 710-725. DOI:10.1017/S0373463319000924

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