NATIONAL ENGINEERING POLICY CENTRE

Royal Academy of Engineering

The journey to an autonomous transport system: identifying challenges across multiple modes

Summary of a roundtable discussion

December 2020

As part of the National Engineering Policy Centre's (NEPC) project on Safety and Ethics of Autonomous Systems, we brought together individuals from across a range of different transport modes and disciplines to discuss and debate the latest state of play in autonomy and the issues arising. This 'transport deep dive' summarises the range and diversity of views and discussions captured at this roundtable and sets out some important questions for consideration.

The issues we uncovered are complex and many questions still remain. By publishing this paper now we hope to move this debate forward by stimulating thinking about how these challenges can be tackled. We think it is important to highlight the cross-cutting challenges that exist to decision-makers and regulators that can open up opportunities for further cross-modal collaboration.

In parallel, this paper is also aimed at encouraging engineering developers to share insights and identify co-benefits across modes. Transport is the focus of our first sector deep dive, with further deep dives in health and care and social media to follow. Our aim is to build our evidence base to develop a wider understanding across different sectors, so that we can make recommendations to support the safe and ethical development and deployment of autonomous systems across the UK.

Executive Summary

The *Safety and ethics of autonomous systems* project overview outlined a need for further sectoral exploration of the role autonomous systems could play. This output is the first of a series of sector specific deep dives.

To investigate the opportunities and challenges to develop an autonomous transport network, the National Engineering Policy Centre (NEPC) held a roundtable. This **looked at modes including road, air, sea and rail** and brought together a range of expert stakeholders from technical, legal and policy perspectives.

Autonomous systems can create safer, more efficient and lower carbon transportation systems. Realising these benefits is dependent on how the future transport system is envisioned, engineered, and implemented. Numerous challenges need to be overcome before widespread deployment is possible.

This summary sets out the current technological state of the art, domain challenges such as decision-making time and software ownership, and cross-cutting challenges such as safety assurance, ethical considerations and public perception. It also highlights several enabling factors: skills, infrastructure, legislation, interoperability, and culture change, (Figure 1).

bcs The Chartered Institute for IT
Engineering Council
IAgrE
IET The Institution of Engineering and Technology
Institute of Marine Engineering, Science & Technology
Institution of Mechanical Engineers
Royal Aeronautical Society

Figure 1:
Considering transport in the context of the framework presented in the project overview1 (Annex A) emphasises some of the current challenges and their interdependent nature.

The expectations from an autonomous transport system are yet to be defined in terms of safety and service provision. **Public acceptability across transport modes will have different challenges** depending on how the public interacts with it, the complexity of environment and degree of industry unionisation.

Interoperability between different modes, systems and the surrounding infrastructure is vital to maximise the benefits beyond modal silos. With increasing interconnectedness **greater oversight is required to be able to attribute responsibility, improve transparency and information sharing**.

Developing technologies and services that are **trustworthy, ethical and inclusive will require extensive consultation**, multidisciplinary collaboration and culture change. Whether societal expectations should be a consideration for systems decision-making processes for autonomous transport has to be decided.

Technical challenges focus on the need for new validation and verification techniques alongside simulation and real world trials to assure safe and timely decision-making. This can further be supported by secure connective infrastructure.

Common frameworks will be required to support engineers to make ethical decisions. As driverless transport evolves the **future technical and ethical competencies need to be defined to equip engineers with the skills required to be responsible professionals**.

Real-world trials also help identify gaps in UK and international regulation, legislation and insurance models. **Collaborative and agile development of the regulatory environment** will help these to be future proofed. Regulators need to be equipped with the complex technical skills to challenge and assess compliance.

The COVID-19 pandemic has highlighted new needs for these technologies that were not previously anticipated. This has accelerated innovation in autonomous systems for the delivery of goods. Deploying these technologies will inevitably highlight new challenges and ways to overcome them. Depending on their success, this may influence public trust for autonomous systems in transport so, despite the need, these innovations should be deployed in a considered manner.

Introduction

To build on a cross-sectoral understanding of some of the challenges associated with autonomous systems[2] a series of sector deep dives set out to explore what is unique about how autonomous systems are developing in each sector: the specific challenges to safe and ethical deployment; and identification of opportunities and emerging good practice.

On 15 January, the NEPC held a roundtable discussion on the development of autonomous systems in transport. This **looked across different transport modes including road, air, sea, and rail**; bringing together experts with technical, legal and policy perspectives.

This paper explores several questions including:

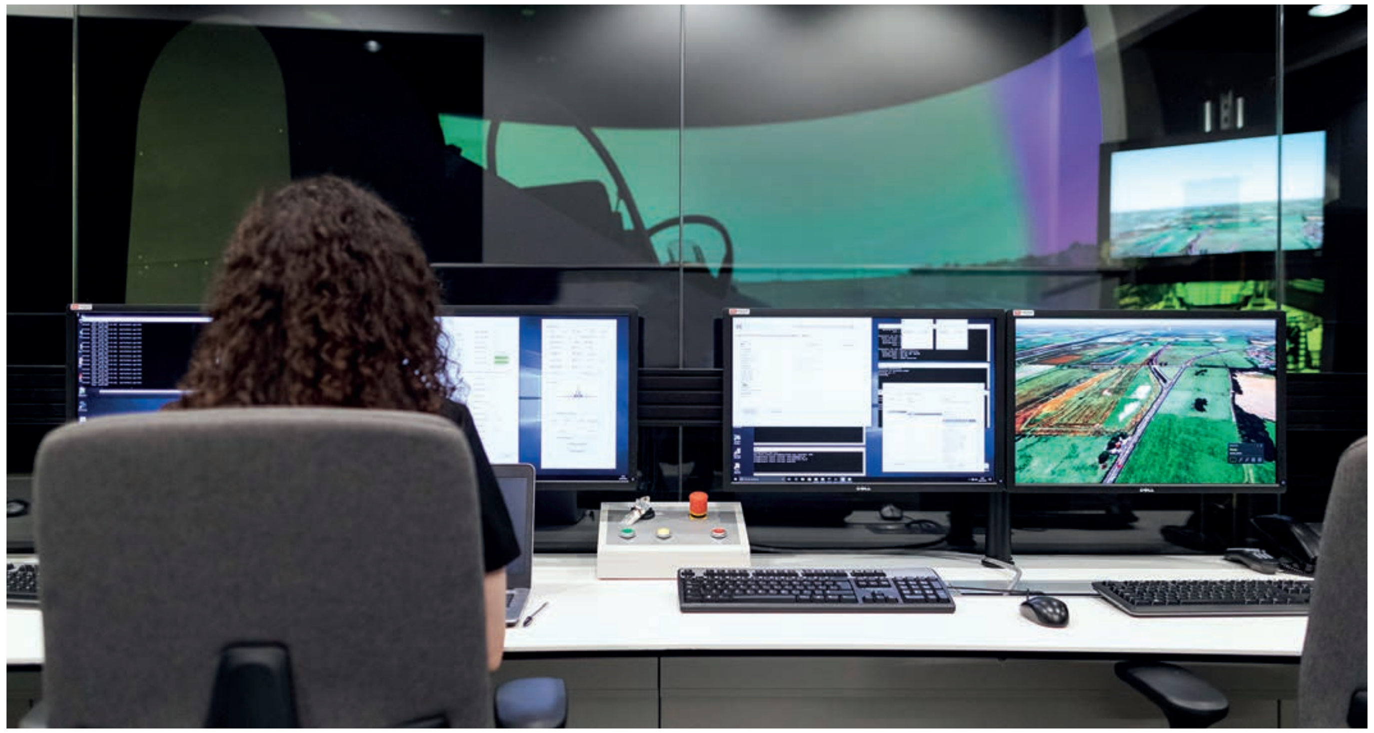
- **how do the modes compare?**
- **accelerating innovation during the COVID-19 pandemic**
- **how can safety be assured?**
- **how safe is safe enough?**
- **what are the ethical considerations?**
- **what are the enabling factors?**
- **what might influence public perceptions?**

Developing and deploying autonomous systems for transportation is challenging. There is **complexity associated with the physical and social operating environment, the existing supply chain, and the requirement for real-time decision-making**.

There is significant automation of many functions across the current transport system, but this technology is deterministic, meaning that the same inputs always result in the same outputs. This includes cruise control in vehicles, automatic door closing on trains and fly-by-wire software in aeroplanes. **Increasing autonomy poses new challenges as these systems are adaptive and able to make decisions based on the specific circumstances**; this means that the same inputs will not always result in the same outputs.

Maximising the benefits of these advancing technologies will require **full integration across the different modes of the transport system** and a careful and considered approach to deployment.

Autonomous systems can be a cross-cutting technology but there is limited knowledge sharing across the modes of transport. While the technological state of the art and drivers for innovation vary **there is an opportunity for cross-modal learning for engineers, regulators and legislators** to ensure safe and ethical development and deployment of autonomous systems.



How do the modes compare?

	Road	**Air**	**Sea**	**Rail**
Presence of automation	Modern cars already come with different degrees of automated functions from simple cruise control to more advanced lane changing and self-parking capabilities.	A significant amount of air travel is already highly automated. The pilot is typically responsible for supervising the automation and take-off and landing procedures.	Maritime platforms are traditionally viewed as 'hands-on' with regards to engineering intervention. In relation to safety and crewing, governance is largely done via international regulations that stipulate who has responsibility and how often inspections, for example, must take place.	The Docklands Light Railway has operated without a physical driver since 1987. Several London Underground services are partially automated: starting and stopping controlled by software and operators required to identify when it is safe to close the doors.
Drivers of progress	Potential safety improvements and a supportive policy environment have resulted in a sense of inevitability about the arrival of autonomous vehicles. Increasingly the opportunities for autonomous freight are accelerating the case for development.	Autonomous flight requires adjustments to many parts of the system grouped together as urban air mobility (UAM). Advancements in UAM are driven by increasing urbanisation, technological advancement and pilot shortages.	The development of autonomous surface ships has been driven by reducing running costs and taking people out of harm's way. Removing people from the vessel also allows ships to be redesigned, reducing weight and improving the environmental performance. Issues regarding CAPEX, maintaining safety through life and ensuring a supply of skilled professionals still need to be addressed.	Rail automation has focused on reducing operating costs, increased service reliability and throughput to allow for greater capacity. The railway industry has focused on the Digital Railway programme to update the signalling, train control technology and connectivity to improve the management of the trains and infrastructure.
Where are developments being made?	Self-driving cars are being developed by classic automotive original equipment manufacturers (OEMs) and university spin-outs are developing autonomy software. The capability of this software is advancing fast.	UAM requires value chain transformation to provide the new aircraft designs, flight operations for vertical take-off and landing (VTOL) planes, ground infrastructure, and unmanned traffic management systems. Elements of this system have been tested in isolation such as VTOL autonomous passenger demonstrators, but there is much further development needed. It is anticipated that many of these challenges can be overcome with the technology development in delivery drones.	Some operational risks can be mitigated by removing onboard crew. As such, some sectors of the maritime industry are adopting the use of uncrewed vessels. These are equipped with the ability to carry out remote control interventions, combined with the use of some autonomous systems as a more flexible, cost-effective and safer alternative for gathering critical data about the ocean.[3] Autonomous underwater vehicles are already being used for deep-sea exploration and pipeline inspection.	For Crossrail, a hybrid service of heavy rail and mass transit, the aim is for the train to turn around autonomously at the end of the track while the driver is walking to the other end of the platform. This reduces the turnaround time resulting from engaging a second engine.

	Road	**Air**	**Sea**	**Rail**
Current state of the art	Cars operating autonomously with oversight from safety drivers are being trialled in cities across the UK today.[5] In February 2020, a Nissan Leaf's 230-mile self-navigated journey on UK roads received significant media coverage for making the longest and most complex autonomous journey.[6] These trials have been supported by the Automated and Electric Vehicles Act 2018, which allowed these vehicles to be insured[7] and the Centre for Connected and Autonomous Vehicles Code of Practice.[8]	In January 2020, Airbus reported its first automated vision-based take-off.[9] To take this to the next stage, industry is currently developing strategies for the future of UAM. In Singapore 25kg autonomous drones have been trialled over densely populated areas delivering goods from ship to shore in defined aerial corridors.[10] However, to become widely operational, further work is required to deploy operations beyond visual line of sight in unsegregated airspace.[11]	Maritime autonomy is in the demonstration phase focusing on trials for international journeys. In the UK, collaboration with the Maritime and Coastguard Agency allowed an uncrewed vessel controlled from an operation centre in the UK to make the journey between the UK and Belgium in 2019.[12] In Finland, a ship successfully completed a partly autonomous journey through national waters, controlled by technology but with the master always in command and able to revert to remote control from a shore operator, if required.[13]	Industries such as Thales are researching and developing more autonomous mass transport systems, planning to learn from how self-driving vehicles have overcome challenges like computational heating.[14] The hope is that these systems will enable more flexible timetabling and smoother, more efficient journeys.
Example of mode specific challenges?	**Decision-making time** The complexity of the surrounding environment will influence the complexity of the system. On the road there are many interacting players and the challenge for the self-driving car is to anticipate their behaviours (Figure 3). To characterise the situation and assess the potential risk, a large volume of data must be processed. There is minimal time available for decision-making and introspection.	**Demonstrator permissions** Permissions for autonomous system demonstrations can vary depending on the mode. The UK Ministry of Defence (MoD) reportedly carried out testing for an Airbus Zephyr unmanned drone in Australia as gaining authorisation in the UK proved challenging. The results from the Australian assessment were not recognised by the UK and a new clearance process was required, doubling the cost and efforts. **There is a need for better recognition of international test procedures and the development on common standards based on best practice**.	**Connectivity** Maintaining secure connectivity and communications over long-range journeys is a challenge that needs to be overcome to ensure efficient and safe international operations. Multiple wireless systems are needed for resilience and 5G communications networks could provide important enabling infrastructure if proved to be applicable for safety critical operations.	**Software ownership** The software ownership can affect the pace of change. In current autonomous vehicle demonstrators, it can take just six hours to make a change to the software and apply this to the test fleet. By comparison, the outsourcing process in rail is reported to result in an eight-week software development cycle with a further 17 weeks to ensure the functional safety of the software. **For public procurement, the ownership of the software algorithms needs to be considered carefully**.

Accelerating innovation during the COVID-19 pandemic

The UK lockdown has highlighted the important role that autonomous systems could play. Testing and feasibility studies are being funded to speed up innovation to support future deployment.

In the UK, UK Research and Innovation (UKRI) has funded developers with autonomous systems that can support delivery and logistics, monitoring, and disinfection (Table 1).[15] These aren't transport applications specifically but demonstrate how this technology can create opportunities to highlight public benefit and build trust, paving the way for future advances in transport applications.

For more advanced innovations, the increased need for goods to be delivered has seen a surge in demand for the services of pavement delivery robots, such as Starship Technologies operating in Milton Keynes.[16] Similarly in the US, Nuro, a self-driving delivery van, was recently granted a fixed-term regulatory exemption enabling it to operate on the roads autonomously without features that allow a driver take control.[17]

Table 1.
UKRI projects funding the development of autonomous systems

Application	Organisation	Project
Delivery and logistics	Academy of Robotics	Semi-autonomous last-mile delivery in which medicines can be delivered from pharmacies to care homes without human contact.
	Toshiba Research Europe	Fleet of logistics robots capable of autonomously coordinating delivery of vital supplies in ad-hoc arenas.
	Skyfarer Ltd	Feasibility study for a platform that allows any organisation to access an ecosystem of drones, to then be used to distribute medication, blood, test kits, food and digital devices.
	Hybrid Drones Ltd	Aiming to autonomously carry a maximum payload of 100kg, over a distance of 10km, within 10 minutes.
Crowd monitoring	Level five supplies Ltd	Unmanned aerial vehicle (UAV) crowd-monitoring tool measures the location of people in open spaces, covering up to 30,000 sq m (line of sight) per system.
Disinfection	Unmanned life	Fleet of autonomous drones and robots to disinfect large spaces, both indoors and outdoors.

Cross-cutting themes

Despite recent progress across the modes there are many common challenges, including assuring safety and trustworthiness, managing complexity, and oversight.

How can safety be assured?

As different components of autonomous transport software and hardware are integrated, dependencies will be created between these elements. This means that testing components in isolation is not representative of the system. Instead **autonomous systems must be tested together and validated as a whole**, through a variety of mechanisms.

Success is dependent on **correct characterisation of system behaviour in different scenarios**. Validation of these requirements is a real challenge but it is critical to ensure confidence that the right behaviours have been identified for the system at the point where an action is committed.

Software has historically been assured with formal methods, mathematical proofs that the system behaves as designed. However, as the code is continuously being updated and the complexity of the code grows to millions of lines, the applicability of traditional formal methods is limited. Other methods of developing self-driving software rely on end-to-end machine learning, for which formal methods cannot currently be applied. **Engineers have a vital role in developing the new methods of verification that are required to replace formal methods**.

For self-driving cars there has been a recognition that **classical, functional safety assessments do not apply for autonomous systems**, as failure mechanisms are more complex than electronic system malfunctions. This has resulted in a new thinking around **safety for example, safety of the intended functionality philosophy** (SOTIF)[18] **and responsibility-sensitive safety methodology** (RSS).[19]

SOTIF aims to deal with uncertainty by defining standards that demonstrate that the system would never get itself into an accident without an external actor making a significant error.

RSS is a formal, mathematical model to measure a vehicles behaviour in terms of responsibility and caution. It assesses performance for safe distancing, lane changing, giving way, increased caution for limited visibility and the response to a dangerous scenario.

In the UK, the approach to assuring safety and security will be supported by the development of CAV PASS, a system to support trials without a human and novel vehicle types.[20] Similar techniques may be applicable to other modes.

Testing in real-world scenarios is a vital component (Figure 2). It provides an understanding of the technical performance, deployment on roads, rails, airways or

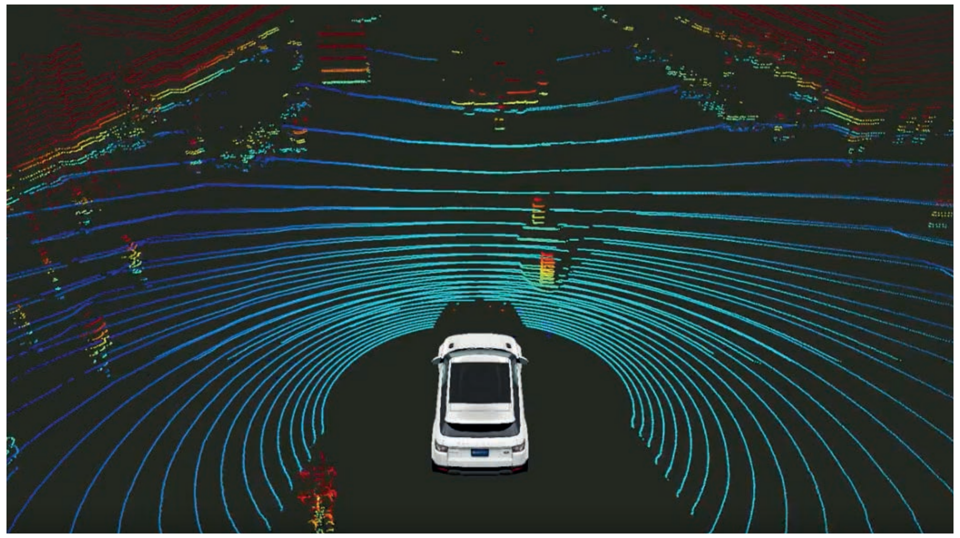


Figure 2.
Oxbotica software characterising the environment

international waters and helps to **identify the gaps in existing regulation legislation and insurance**. In vehicles, this has also highlighted inconsistencies between vehicle decision-making and human expectations. It is also important that transport autonomous systems can operate safely and effectively in mixed environments alongside humans.

There is an additional role for simulation for which artificial intelligence is being used to create a wide range of scenarios for systems to be tested in. This allows combinations of weathers, environments and reflections to be varied to create new scenarios that have not been experienced before. **Opportunities should be taken to embed the experiences and expectations of the safety operators within the testing** to test the performance. These approaches enable testing of the software in new scenarios that are comparable to the real world.

A safe by design philosophy needs to be embedded for autonomous systems. This is already common practice in existing passenger planes, other modes are also building for redundancy to ensure that if elements should fail or be physically disrupted there will be alternative routes to maintain the necessary functionality.

When these systems operate even more autonomously, making more decisions without oversight, existing safety cases will only provide assurance to a certain point. **A decision must be actively made to pursue this next level of autonomy informed by the public, industry and policymakers**. If this is decided, new methods will be required to cope with the step-change of fully removing the human from the loop.

Figure 3.
Multiple uncertainties on the road that create a complex environment for future self-driving road vehicles.

How safe is safe enough?

The code of practice for autonomous vehicles outlines the safety expectations but industry is going beyond compliance[8], aspiring to higher safety standards. However, the details of what **the market will expect for road vehicles are yet to be defined**.

For aerospace, these initial safety expectations have not been set out, instead industry and regulators are working together to identify an approach. **Across the modes, collaborative deliberation is required to define safety standards**, and stakeholders who will be directly and indirectly affected should be consulted.

As technology is relied upon further there is a question as to whether the safety expectations should be the same across modes. The risk is typically framed in micromorts: on the road the acceptable risk is pitched at 10^{-7} based on the idea that the addition of vehicles should not affect the mortality rate of a typical healthy youth. However, providing proof of this is difficult prior to wide scale use.

While there are challenges to assuring safety there are areas where **autonomous systems could provide transformative safety improvements**. A report by TRL predicted that if 8% to 19% of the total car fleet was autonomous by 2040, up to 650 fatal and serious injury collisions could be prevented annually.[21] Another industry with opportunities for safety improvements is fishing, which has reported 79 fatalities and 572 injuries on UK fishing vessels between 2008 and 2018.[22]

What are the ethical considerations?

Many of the ethical discussions held in the public domain focus on the trolley problem (Figure 4). This can help to engage the population in the idea of delegating a decision to a machine and to discuss the burden of intervention. However, the specific problem posed is a no-win scenario and an ability to accurately predict has been assumed.

For each decision an autonomous transport system must understand where it is, what's around it and what that might do, and **identify the least harmful action in the time available**. The available time to decide varies depending on the mode of transport.

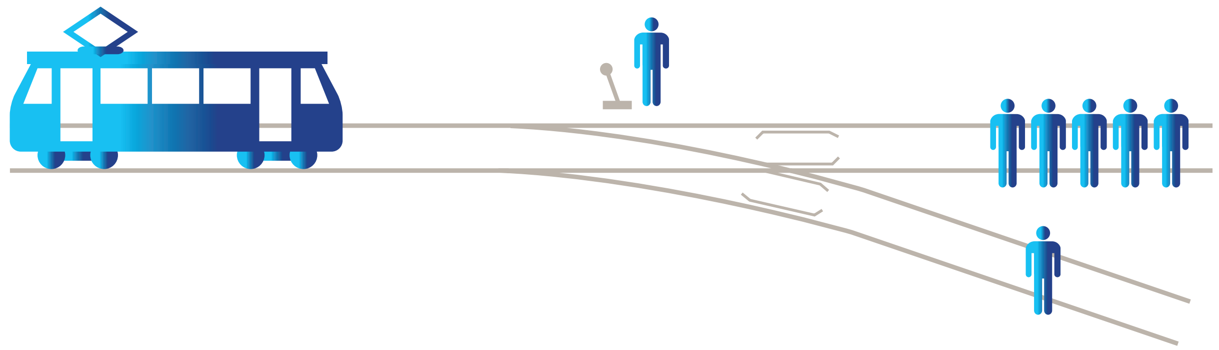
For the programmer many of the ethical issues are safety issues and the safest action isn't always the most socially acceptable. There is a question whether the soft rules of the road, which are embedded with **societal expectations, should be a layer on the systems decision-making process**. In vehicles, unexpected behaviours can have knock-on effects for other road users, which is also likely to apply to the maritime conventions. This asks the question whether it is ethical for a self-driving car to reduce the risk of knock-on consequences rather than being perceived as 'unsafe' when taking the statistically safest action. Just as drivers are not homogenous, one safety driver may not flag the same risk as another, so rationalising these views into a definitive action is a challenge. There may be a need for **frameworks that support engineers to make these ethically charged decisions**. To what extent can considerations of ethical by design be embedded in the safety assurance process to ensure compliance?

There are further wider ethical considerations in **how these systems are deployed**, with questions such as;

- The balance between investment in mass transit systems or individual mobility.
- Autonomous systems present significant potential for lower-carbon transport but this will depend on how they are operationalised, how can the environmental impact have a similar weighting to safety?
- Are the business models driving these technologies fair and sustainable?
- Who will own the data that is collected and who profits from the understanding of passenger preferences?
- The impact on certain individuals and social groups also needs to be considered. For example, if there is an aversion to full autonomy on ships, a halfway step may be to include one or two individuals onboard in a form of human-autonomy teaming. Such isolation can have major implications for an individual's mental health and these harms need to be considered alongside physical safety.

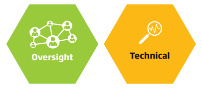
Figure 4.
The Trolley problem

The trolley problem is an ethical thought experiment that presents no-win moral dilemmas that ask whether you would take action in order to sacrifice one person to save a larger number.



What are the enabling factors?

Infrastructure



Across the transport modes, **benefits would be enabled faster with the right infrastructure provision**. Connectivity is one example, as smart environments can increase the understanding a system has of its environment. If modelling the environment was an option so that different actors could communicate, uncertainty would be diminished, reducing the complexity of computational decisions made by individual autonomous systems.

In maritime, port infrastructure is important. Australia has two ports, which operate autonomously and have showcased many benefits across safety, productivity and efficiency. **Investment in public infrastructure needs to deliver benefit for society as well as industry as they bear the cost**. For the Finnish demonstrator, new land-based infrastructure was required involving creation of a new safety case, which came at significant expense.

To scale, efficient drone delivery of goods from ship to shore will require specific infrastructure. For its Singapore trial, Airbus installed several parcel stations across the city for the drone to land and manage the parcels.

Integration with legacy systems is a known challenge for autonomous systems. Both air and rail must integrate with existing air traffic management and automatic train supervision systems to manage the throughput safely and effectively. These systems will be improved by better use of data and real-time monitoring and prediction.

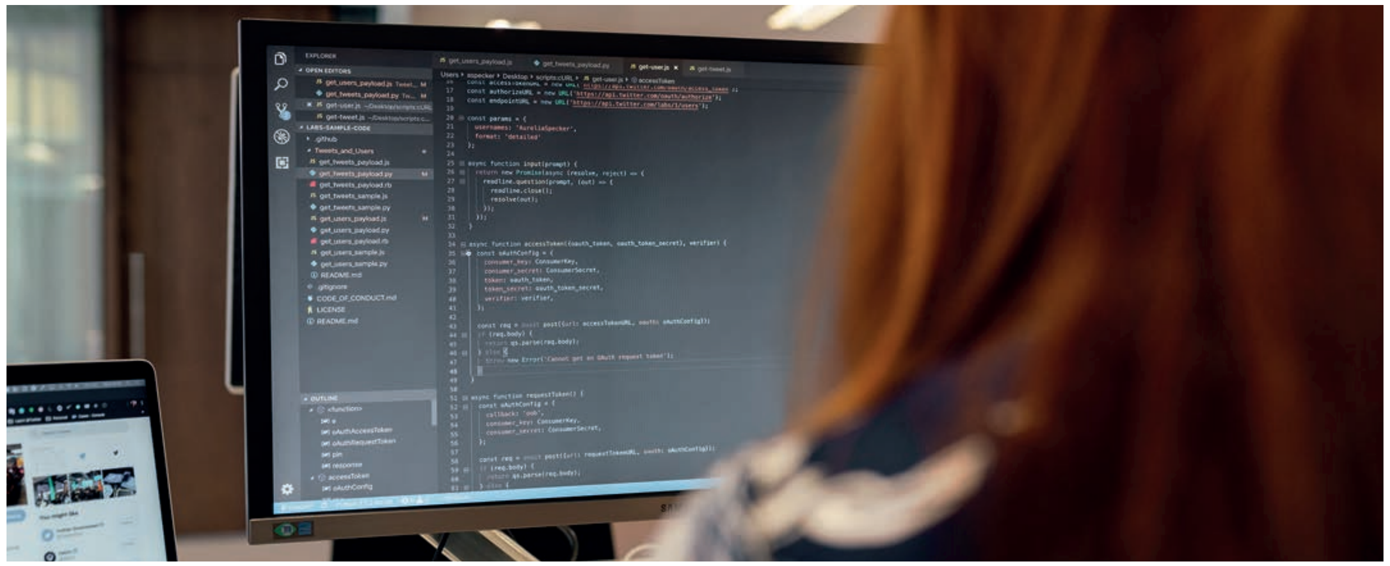
Skills

Across the modes, there are skills gaps for technology, regulation and legislation. There may be a **role for a competency framework that could apply across the different transport domains to identify the future skills needs**. However, there are already challenges to identifying current competencies for software engineering. This should be accompanied by a training needs assessment that considers both hard and soft skills.

The speed of technological progress makes it difficult to ensure that regulators have enough understanding to be able to competently assess compliance. As with previous technology evolutions, competing with industry for a limited pool of skilled professionals will affect regulatory capacity.

Legislation

The pace of change is likely to be affected by whether the operations are national or international. Global regulation and legislation are necessary components to enable autonomy across modes, especially for maritime and aerospace industries. The International Maritime



Organization is exploring areas where regulation needs to adapt, and international agreement on formal regulation is not likely to happen soon. **There may be an opportunity for the UK to take to lead and write a version of international regulations as a starting point for international dialogue**.

There is a challenge to futureproof legislation in such as fast-moving field. Early trials can help to identify the legislative gaps. However, these are driven by industry demands and often limited in scope.

For SEA-KIT's journey from the UK to Belgium (Figure 5) a bi-lateral agreement was required, involving extensive consultation and legal input. This demonstration highlighted the lack of an alternative for a Load Line Certificate despite the fact that the vessel was exempt, which has initiated the development of new certification documents.

Legally the issue of responsibility is a barrier. The Automated and Electric Vehicles Act 2018 took a 'soft law' approach to allow a self-driving vehicle to be insured and used on public roads. If an accident occurs, insurance companies will cover the damages initially, but this still requires a fair distribution of residual risk. Across autonomous systems the complexity of the system creates substantial challenges for understanding the root cause of failure or error. **There is a need for transparency and information sharing to allow responsibility to be attributable**.

If an accident were to take place, criminal law would be unlikely to prosecute an individual engineer, as they would not be considered mentally culpable. However, responsibility still matters to the public, especially when a machine is at fault.

Interoperability

Interoperability between the different modes and systems is vital to maximise the benefits. Common standards between modes could enable this integration across the transport sector. Facilitating interoperability becomes difficult in the international context, as the degree of acceptability will vary from country to country.

A disconnect exists between the different modes of transport, which reflects historical silos within government. The future mobility Industrial Strategy Grand Challenge has a role to enable this coordination. It is also important to ensure alignment with artificial intelligence policies emerging from Department for Digital, Culture, Media and Sport or recommendations from the Centre for Data Ethics and Innovation **to create a holistic regulatory environment**.

Figure 5.
SEA-KIT uncrewed vessel

Culture

There are many challenges facing autonomous transport and no single organisation can solve them all. This is encouraging a **more open and collaborative culture of developers, regulators and insurers working together with publics** to ensure safe and ethical deployment of autonomous systems. Initiatives funded by the Regulators' Pioneer Fund and Centre for Connected and Autonomous Vehicles are actively supporting this collaboration.

There are existing UK codes of conduct to support the testing of autonomous surface ships and self-driving vehicles. These are considered to set a minimum standard, with some developers going significantly above the requirements, moving towards anticipated market expectations.

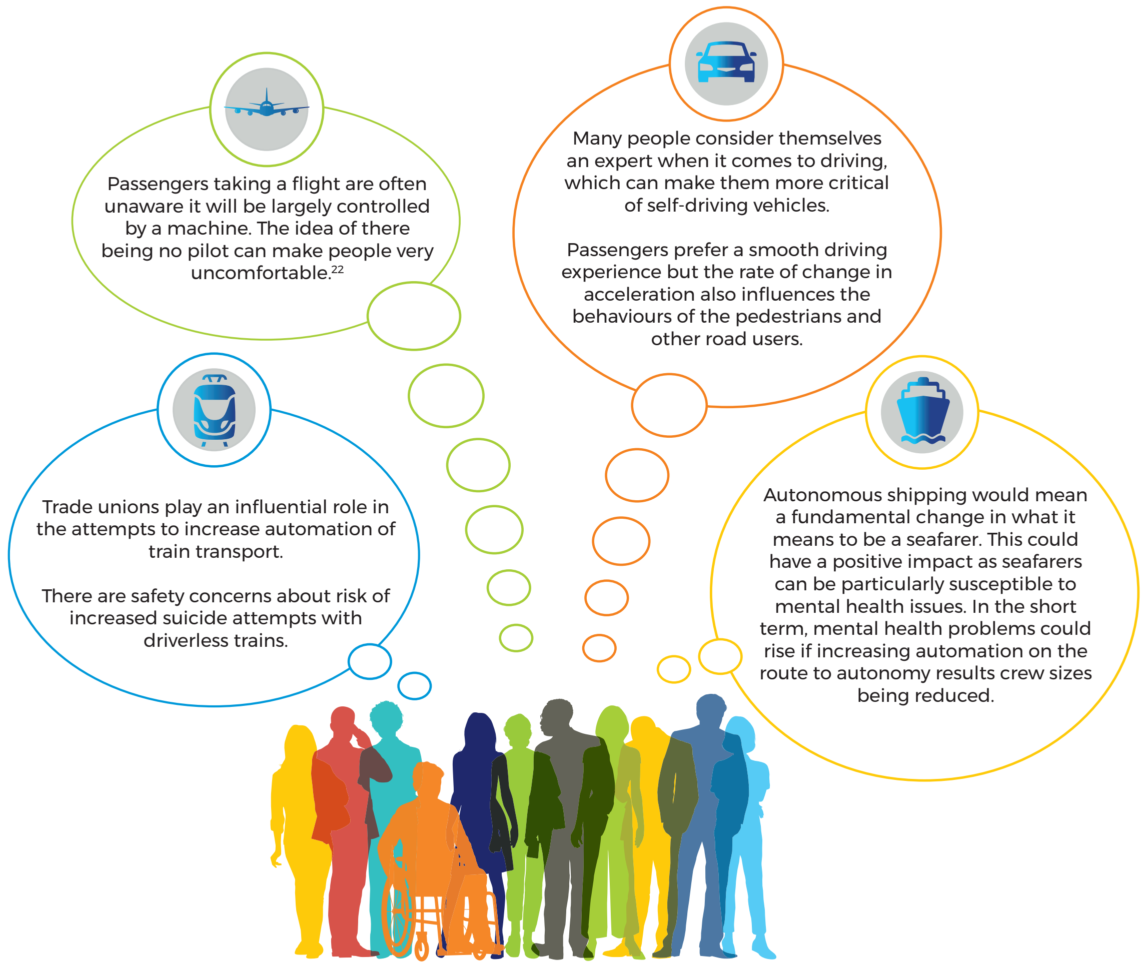
What might influence public perceptions?

One of the biggest obstacles to overcome with autonomy across transport modes is public acceptance. The press has a significant role to play in how this technology is presented and the job loss narratives can create fear and apprehension.

The government's narrative also influences public perception. Government aspirations for UK leadership in autonomous transport may be associated with a relaxed regulatory approach.

There are further specific challenges depending on the mode (Figure 6).

Figure 6.
Considerations that may influence stakeholder perceptions in different modes



Conclusion

The multimodal perspectives brought together through this transport deep dive roundtable highlights the need for a much more joined up and collaborative approach to autonomous systems development and deployment across transport domains. There are co-benefits that can be amplified through the design and development of an integrated, interoperable transport and infrastructure system. Making sure that end-users and those impacted or displaced by the uptake of this technology are involved in the development and deployment will ensure that benefits are more equitably distributed.

There are still many challenges which remain, spanning **technical, ethical, regulatory, professional, public and oversight areas** of the framework. In certain modes, research and innovation funding and support is helping to address these challenges. For example:

- **research funding** through the Trustworthy Autonomous Systems Strategic Priorities Fund will start to answer the technical verification and validation questions
- **technology demonstrators** in Future Flight and Self-Driving Vehicles Challenges (supported by the Industrial Strategy Challenge Fund) and the Connected Places Catapult are laying the groundwork for the necessary regulatory, ethical and logistical conditions
- **regulatory collaboration** is being enabled through mechanisms like the Regulators Pioneer Fund, which supports the Maritime and Coastal Agency, and the collaborative programmes Centre for Connected and Autonomous Vehicles (CCAV).

These initiatives are welcome and are step in the right direction. However, there is still more to do, and still areas where more targeted support would be beneficial, including:

- **foster cross collaboration between modes and disciplines**, to enable experience sharing and learning from a range of perspectives and to make collective decisions that merit public support and ensure alignment across infrastructure, levelling up and decarbonisation agendas
- **develop a training pipeline that creates, reskills and upskills** the engineering profession to develop, deploy and maintain these autonomous transport solutions throughout their lifetimes while simultaneously evolving and maintaining technical and ethical competencies
- **establish the oversight mechanisms** to attribute responsibility and improve transparency and information sharing across the whole transport system.

Next steps

This is the first of a series of sectoral deep dives, further evidence gathering is planned for health and care and social media. By exploring the evidence base across three very different sectors, we aim to better understand the technology context behind each one, identify common challenges, and make recommendations that cut across sectors to support safe and ethical development and deployment of autonomous systems.

The NEPC will continue to publish the proceedings and insights as they emerge to feed into the debate. If you are interested in learning more please contact NEPC@raeng.org.uk

or visit our webpage:
www.raeng.org.uk/policy/safety-and-ethics-ofautonomous-systems

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Annex A:

Framework summarising the cross-sectoral challenges faced by autonomous systems

NATIONAL ENGINEERING POLICY CENTRE

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