April 2021

The Drive for Automation

A view of the near-term potential of autonomous road transport

CATAPULT
Connected Places

Contents

1 Executive Summary

There is a drive to deliver to market Connected and Autonomous Vehicles (CAVs) that are fully responsible for driving within specified environments, known as Level 4 CAVs (L4 CAV).

Behind this drive is the economic power of L4 CAV vehicles, the market for CAVs in the UK is forecast to be worth £41.7bn in 2035[1] with most of this value an outcome of these Level 4 vehicles.

Further motivation for this drive is the potential L4 CAV has to deliver significant social and environmental impacts[2]. In particular, L4 CAV could contribute to the decarbonisation of transport, an essential part of achieving the UK's 2050 Net Zero target.

Achieving a timely arrival at this intended destination for L4 CAV will require some careful navigation because:

- There are several types of L4 CAV, each creating different economic, environmental, and social impacts. Guiding the course of industry development will help to reach a favourable destination.
- There are significant complex barriers to overcome in developing CAV capabilities, gaining assurance, developing trust, and building co-operation between stakeholders. Ensuring that experience from CAV activities is captured to grow the CAV ecosystem will accelerate the drive to market.

Several steps must be taken in bringing L4 CAV products to market. Significant time and investment is required to complete these steps, because L4 CAV are highly complex and involve the integration of several emerging technologies and intelligent learning software systems. L4 CAVs are safety critical, with potential risks to the public so a high level of assurance is required involving extensive testing and regulatory approvals.

Whilst much work has been undertaken within the CAV ecosystem to date, further work is required particularly in relation to the following priority areas:

- **Policy** - needs to keep pace and support the rapid technological developments and support the various business and operational models that may be utilised.
- **Governance** - creation of codes and practice to enable the approval L4 CAV on roads and provide guidelines for supporting development and assurance.
- **Collaboration & shared knowledge** - continued requirement to build a culture of collaboration and sharing within the ecosystem to ensure the UK is at the forefront of further technical innovations.

1 (Catapult, 2020)
2 (CCAV, 2020)

2 The Road We've Travelled

LUTZ Pathfinder
CAV R&D project with industry & academia to deliver the world's first autonomous vehicle demonstrator in a public space.

UK Autodrive
Largescale, multi-organisation consortia trials of connected and automated vehicle technology to support the introduction of self-driving vehicles into the UK.

FLOURISH
Multi-sector collaboration to developing services and capabilities by linking user needs and system requirements to maximise the benefits of CAVs.

Auto Valet Parking
R&D programme into AVP technology concluding in a successful demonstration in November 2020.

MuCCA
Development of a next generation driver aid that aimed to avoid multi-car collisions on motorways.

HumanDrive
Project delivering the single longest and most complex journey by an autonomous vehicle on UK roads. Additionally involved the use of AI to implement intelligent driving to enhance the user experience.

ServCity
Launched in 02 to help cities solve how they can harness the latest autonomous vehicle technologies and successfully incorporate them into a complex urban environment.

ACCRA
Development of a system capable of allowing remote control of a vehicles energy management system to ensure it is running in zero emissions mode whilst in a designated Dynamic Control Zone.

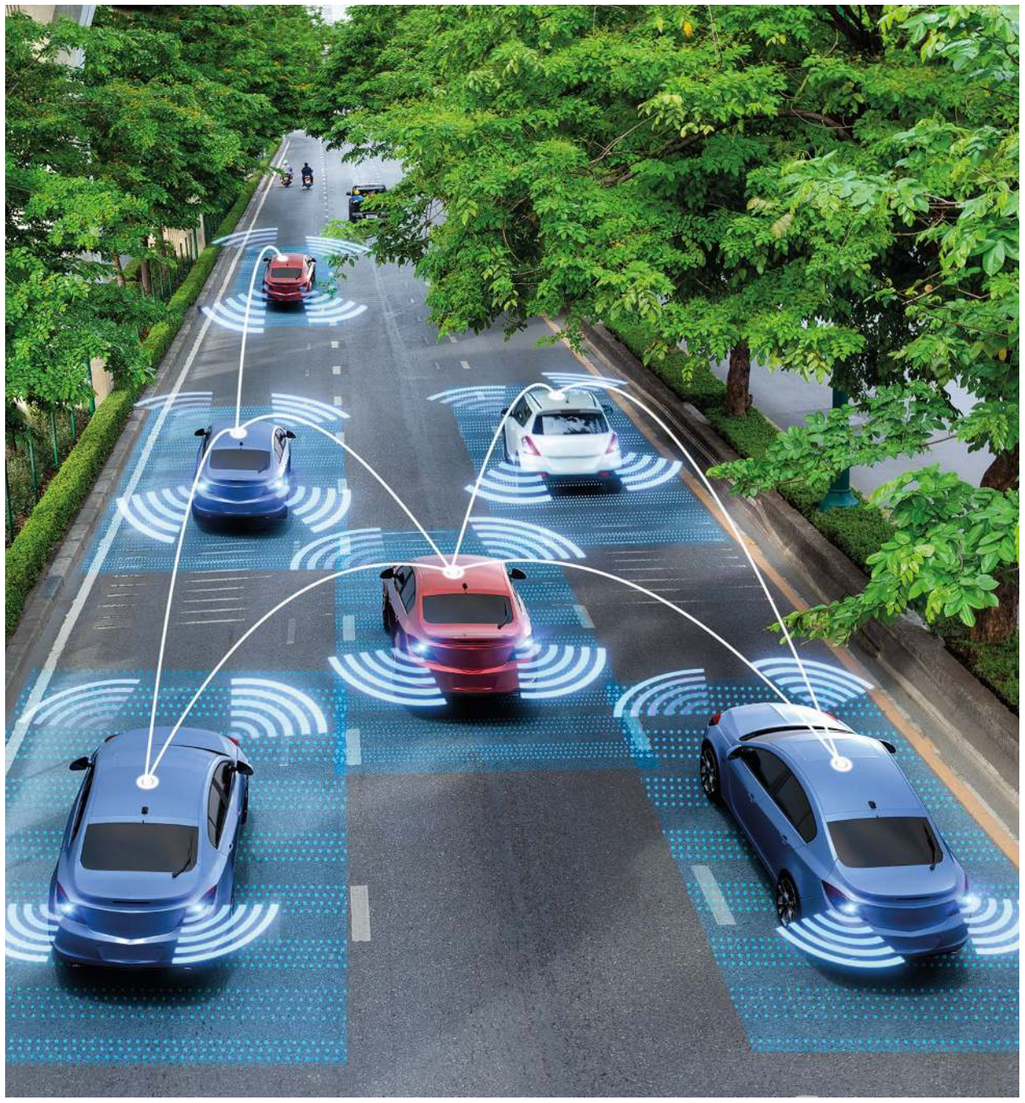
MERGE Greenwich
Simulation of how passengers could cut their transport costs and journey times by sharing driverless or AV with other passengers, and how a service can be designed to complement existing public transport services.

VeriCAV
Automated creation of countless simulation scenarios of varying complexity and then automatically analyse the CAV performance (ie. how safe, how well was road etiquette observed etc).

MUSICC
MUSICC has delivered a system to store and share a library of scenarios, which launched for beta testing in July 2019, and was released as open source software in April 2020.

CertiCAV
Developing a high-level framework for assuring the safety of CAVs, working in collaboration with WMG, University of Warwick, and supported by a broad industry engagement programme.

LUTZ Pathfinder
UKAutodrive
flourish
Auto Valet Parking
ACCRA
MuCCA
HUMAN DRIVE
ServCity
merge GREENWICH
VeriCAV
MUSICC Multi User Scenario Catalogue for Connected Autonomous Vehicles
CertiCAV

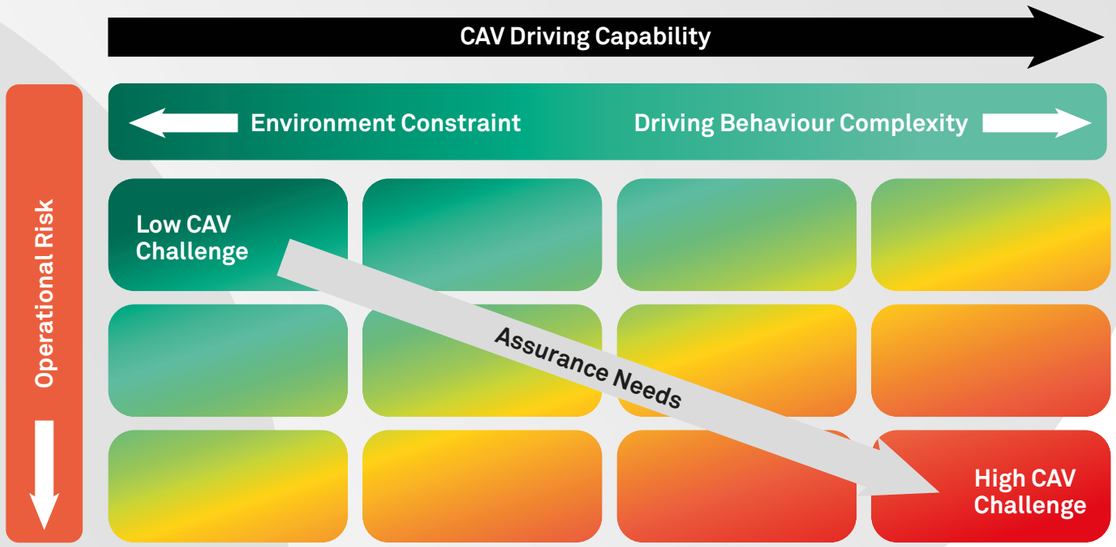


3 Navigating L4 CAV

Through our experience of CAV projects including safety management of the HumanDrive[3], and MuCCA[4] projects we have developed an understanding of the challenges associated with these steps.

However, there is a diversity of L4 CAV types ranging from warehouse cargo robots, to urban automated taxis; which has a huge effect on the development challenges. The magnitude of the barriers to be overcome by these steps depends on the driving challenges that are specific to the type of L4 CAV:

- The constraint of the environment being driven in
  - What the CAV needs to perceive from its surroundings impacts the sensing and artificial capabilities that need to be developed
  - Reliably replicating human-like interpretation of other road users and their intentions is not yet solved by AI
- The complexity of the driving behaviour
  - The extent of manoeuvres and decisions made by the CAV impacts the scale of defining and validating the CAV behaviour software
  - Justifying the interpretation of complex driving codes in diverse set of situations is a huge development challenge and also raises complex ethical and regulatory issues
- The potential safety risk of operations
  - The operation of CAVs in public spaces is safety critical
  - When factors such as operational speed increases and interaction with vulnerable road users, so does the potential consequence of failures
  - Where deaths are possible, the level of scrutiny is high

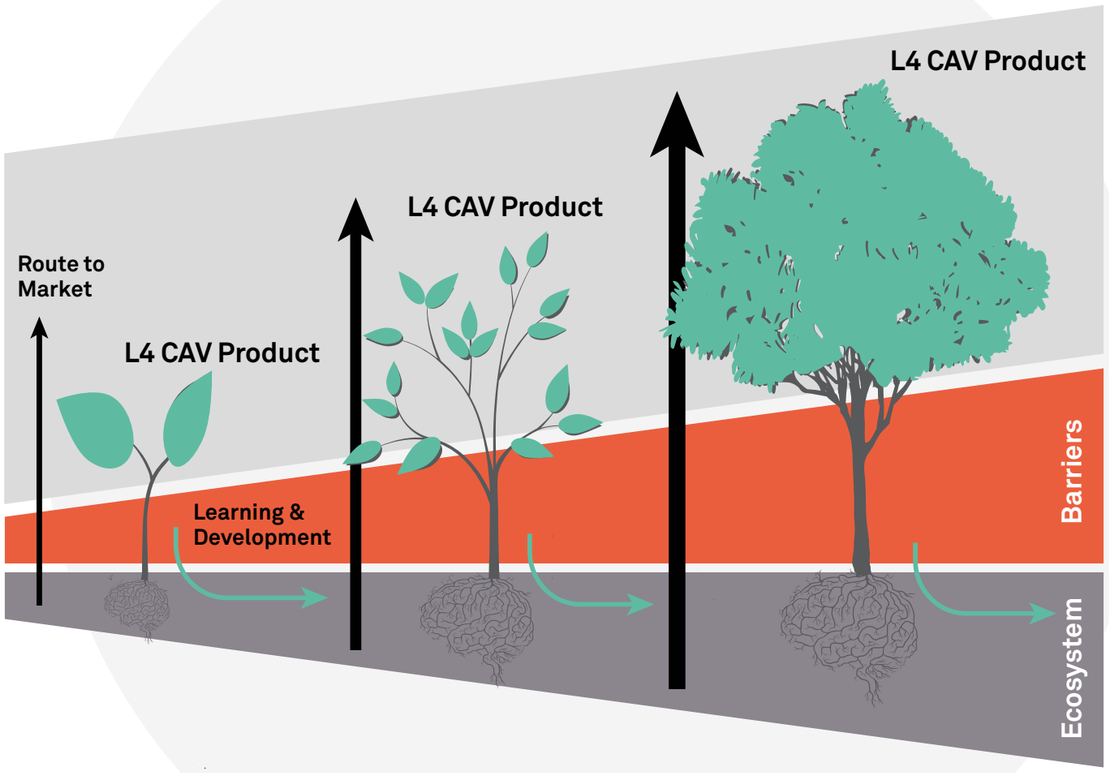


These factors impact the capabilities and the assurances required before release to market.

Overcoming these barriers is enabled by the CAV ecosystem. This is the backbone of technology, knowhow, governance, and relationships that supports the development and delivery of CAVs. Through our work with VeriCAV[5] consortium project, an architecture to address the important task of virtual verification of L4 CAV was developed, however it is acknowledged that further work is required to fully implement this.

CPC and DfT's CertiCAV[6] project studied the assurance of L4 CAVs in detail to support the UK's CAVPASS programme. Key findings were the fundamental importance in developing practice and governance, such as the development of CAV behavioural requirements and guidelines, to enable the rollout of L4 CAVs.

3 (HumanDrive consortium, 2020)
4 (Connected Places Catapult, 2020)
5 (Connected Places Catapult, 2020)
6 (Connected Places Catapult, 2020)



From this relationship we observe that:

- The types of L4 CAV products that can handle more diverse environments and have higher driving capabilities are attractive in their potential economic and environmental impact. However, their route to market must overcome significant barriers and must be supported by a mature CAV ecosystem that will take time to develop.

The types of L4 CAV that are more constrained in their use can be brought to market earlier are the key driving force behind growing the ecosystem by feeding back learning and development into the CAV ecosystem.

To explore we've identified the key types of L4 CAV and assessed their route to market, relationships with **Barriers** and **Ecosystem** and their economic and environmental impact. These factors are summarised below:

Barriers
- Technology
- Infrastructure
- Liability & assurance
- Lack of clarity of business/ownership models
- Public trust in the system
- Skills within the workforce
- Industry prioritisation as a result of COVID, BREXIT and electrification

Benefits
- Improved personal / social mobility (quality, cost, time, congestion and access)
- Improved road safety
- Supporting decarbonisation
- Industry has already committed undertaken significant developments
- Upskilling the workforce
- Increased productivity (e.g. through working from cars)
- Supporting SMEs scale up through disruptive technologies
- Increased data capture (vehicle and people)
- Improved movement of goods

Potential Drawbacks
- Possible loss of jobs
- Dependence on infrastructure
- Possible reduction in active mobility
- Possible mode shift away from environmentally friendly modes such as trains

As a result, we identified four key categories of L4 CAV opportunities, as follows:

- **Controlled area driving**
- **Driving Assistant**
- **Driving as a service**
- **Intelligent mobility**

These are explored in more depth in the following sections.

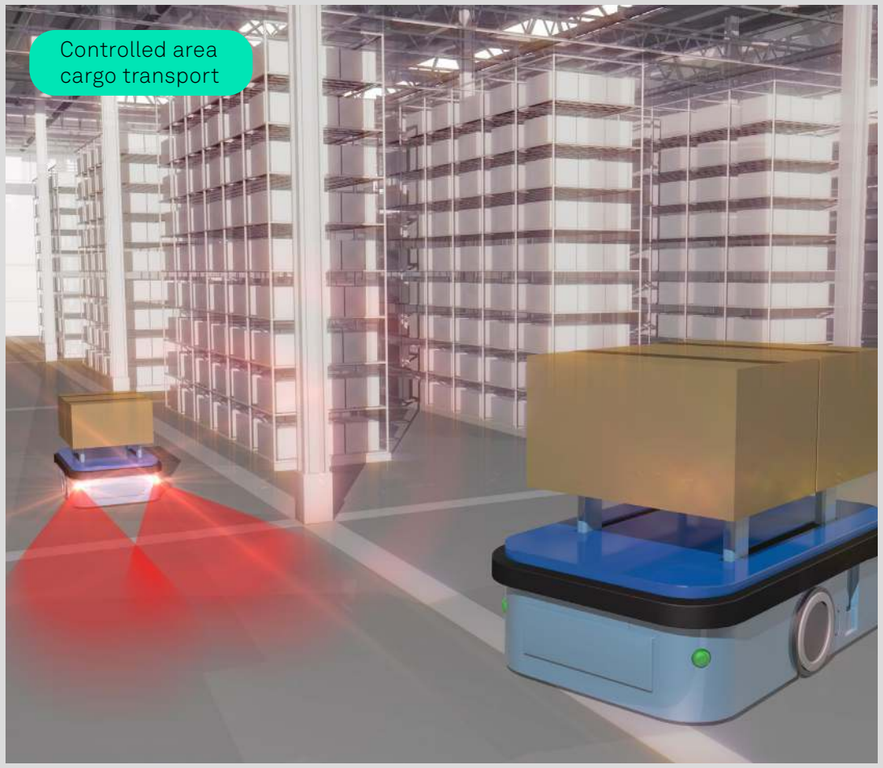
3.1

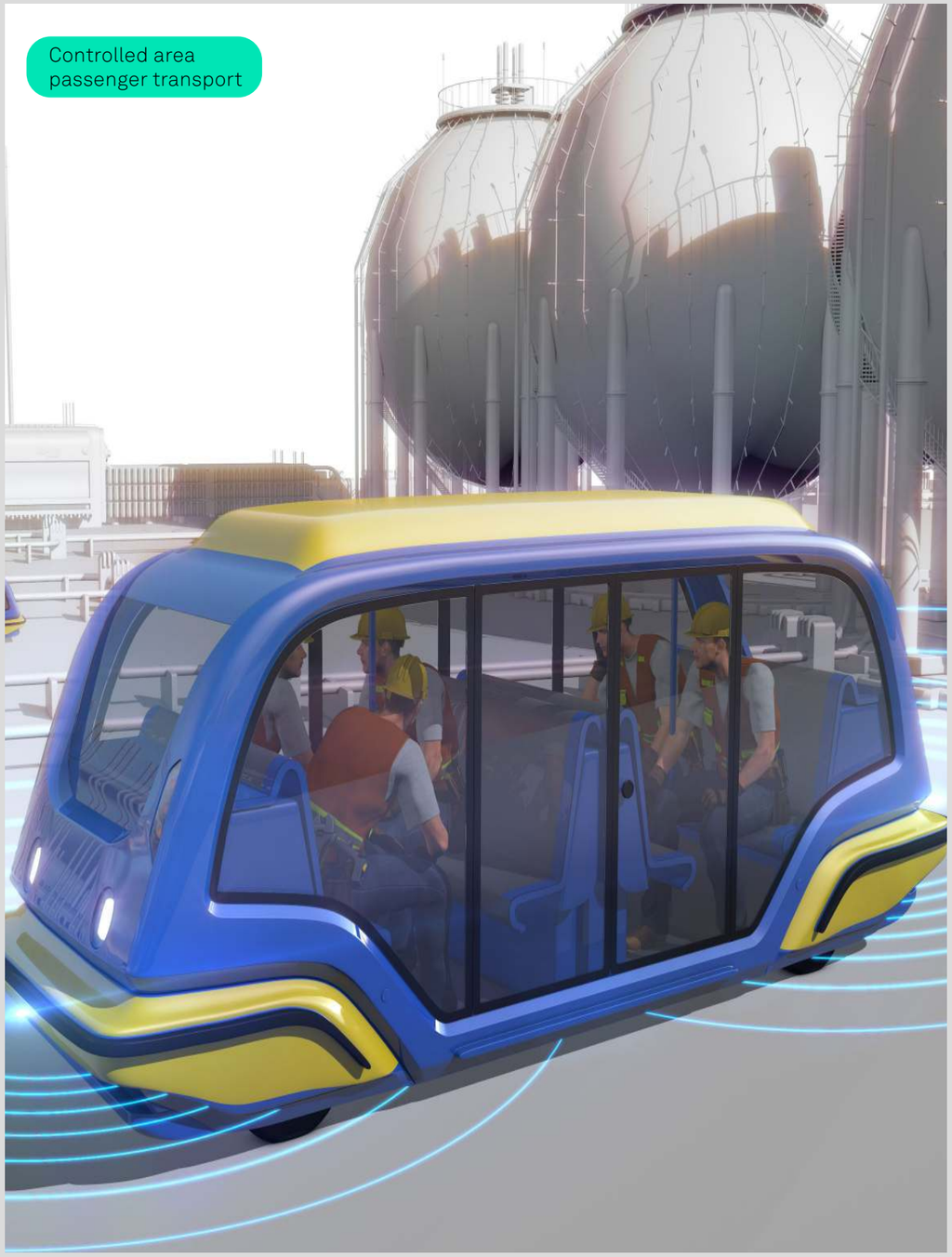
Controlled area driving

Using CAVs to transport people and goods in controlled private areas such as warehouses, ports, and factories. As the operators have control over the operating environment and actors this substantially reduces the CAV challenges compared to operating in public spaces.

Outlook and opportunity

- This application is already disrupting the logistics market (Amazon, Ocado).
- Passenger and freight transport applications are in limited use, or operations development, e.g. in ports and factories (Volvo Vera, Ultra Global, EasyMile, Navya).
- Currently access is largely limited to large enterprise due to the significant rollout R&D required.
- Investing in developing common practices would increase the market base, accelerate the development of capabilities, and draw upon experience from this sector into growing the CAV ecosystem.





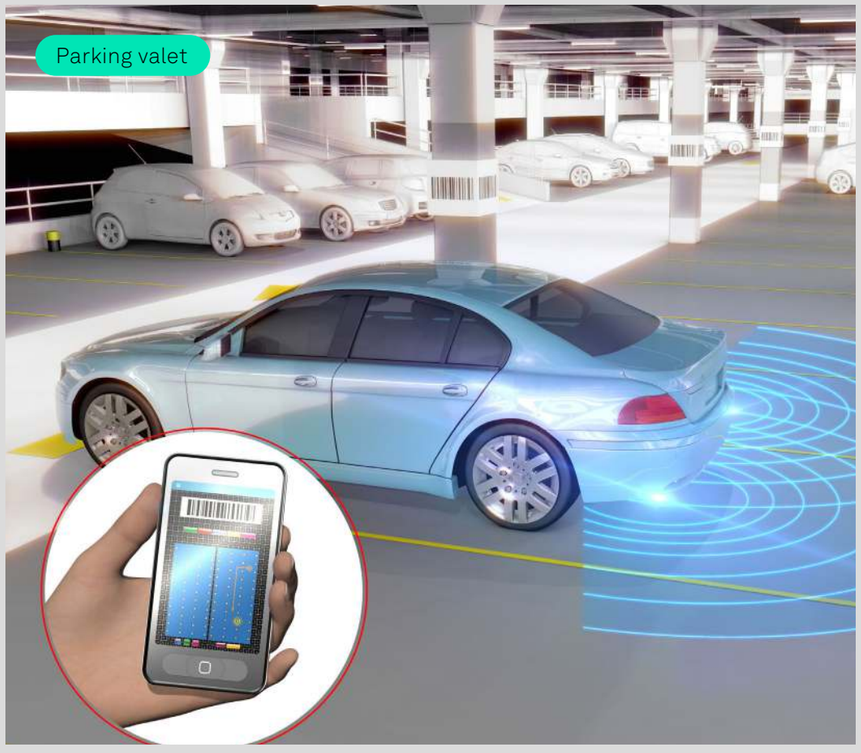
3.2

Driving Assistant

CAVs that can take-over from the human driver to perform a particular driving task within specific environments..

Outlook and opportunity

- Progress is being driven by major automotive manufactures, with a large market potential.
- The UK has relatively limited OEM and tier 1 conducting R&D in this area, which presents a challenge to UK job growth CAV R&D and component manufacturing that needs to be managed.
- The time to market varies based on the challenges related to each driving function. Parking valet has been trialled and is in small scale operation. However, overcoming assurance challenges to realise motorway chauffeur is likely to take significantly longer even though the approval of regulations for Automated Lane Keeping System (ALKS) traffic jam assist has laid the foundations.
- The environmental impact of this opportunity is relatively limited.
- The CPC report '*The CAV Decarbonisation Paradox*[7]' forecasted that the rollout of motorway chauffeur driving assistant may increase carbon emissions.
- The CPC report on *Autonomous Valet Parking*[8] found benefits for user convenience, but not for the environment.
- We forecast that the development of L4 CAV driving assistants will continue to be governed by the international automotive industry. This may be influenced and monitored through international standards committees to plan infrastructure and governance to benefit from these features when they are rolled out to vehicle fleets.



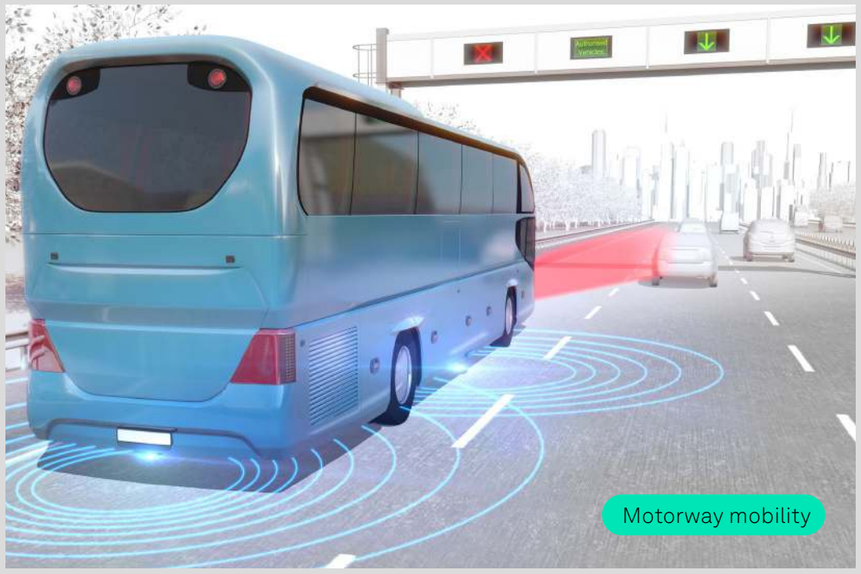
7 (Connected Places Catapult, 2020)
8 (Connected Places Catapult, 2018)

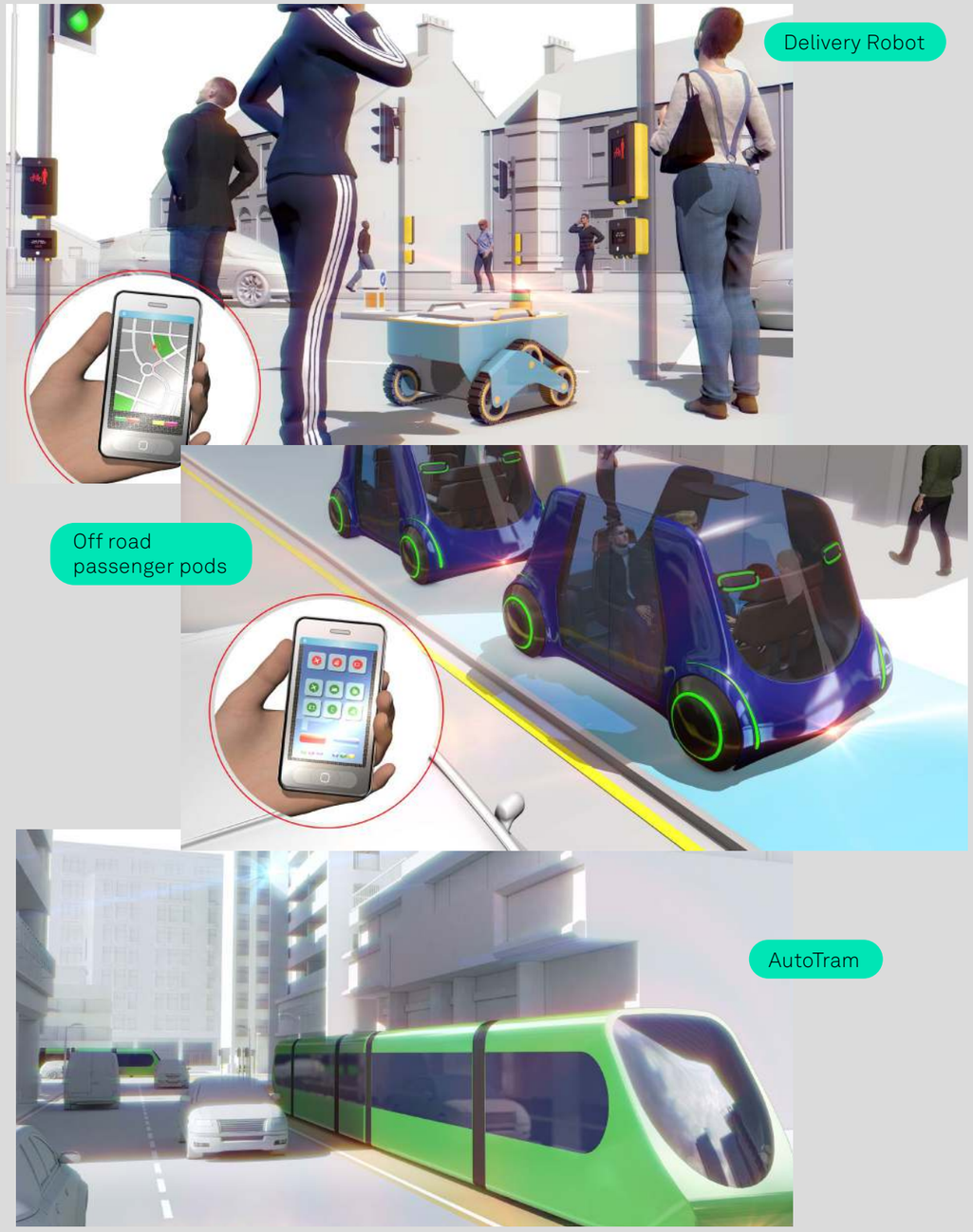
3.3 Driving as a Service

CAVs that provide confined, but complete journey driving as a service, for freight or passenger transport.

Outlook and opportunity

- Last mile small freight delivery is in operations development (Starship).
- Small scale off and on road passenger pods have been demonstrated (Aurrigo).
- There is a diversity of types of use within this opportunity, however in common they all have a close relationship with transport planning strategy.
- Significant potential to improve the environment. The CPC report '*The CAV Decarbonisation Paradox*[9]' forecasts this opportunity would reduce carbon emissions through increased vehicle sharing, and reduced emissions per vehicle mile travelled.
- Would disrupt the transport industry, resulting in new skilled job creation. However, there would be a reduction in traditional vehicle driving jobs.
- This opportunity has the potential to shape the transport, economic and environmental landscape. It would be benefit to plan which types of this opportunity support current policies and guide developments on this route.
- The service provided by these CAVs is relatively confined, which may limit the market size. However, delivering these in the medium term will grow the CAV ecosystem and enable longer term opportunities with broader markets and impacts to be realised.





9 (Connected Places Catapult, 2020)

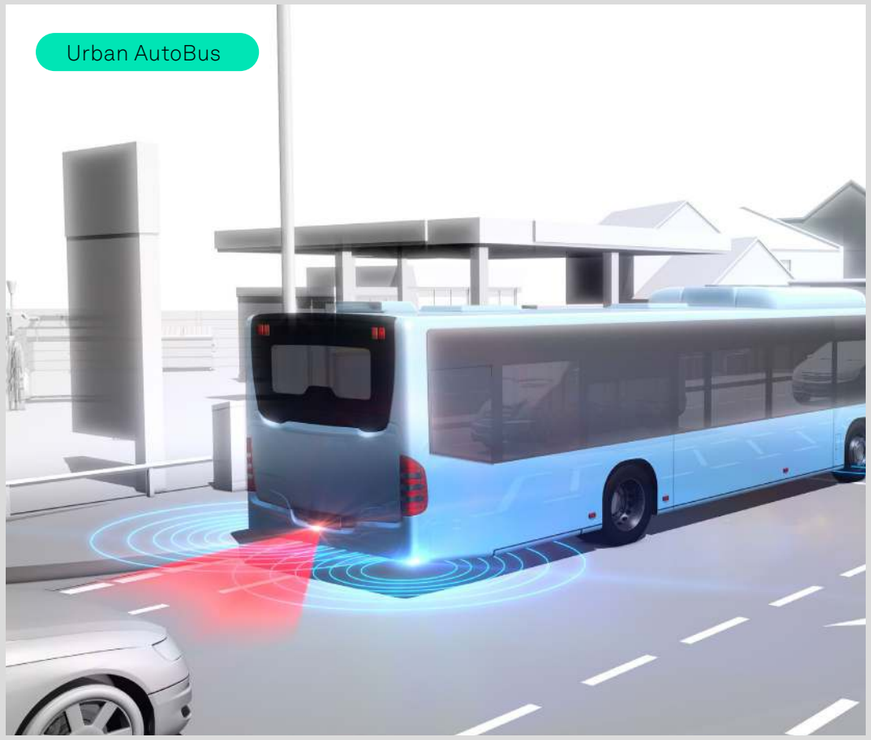
3.4

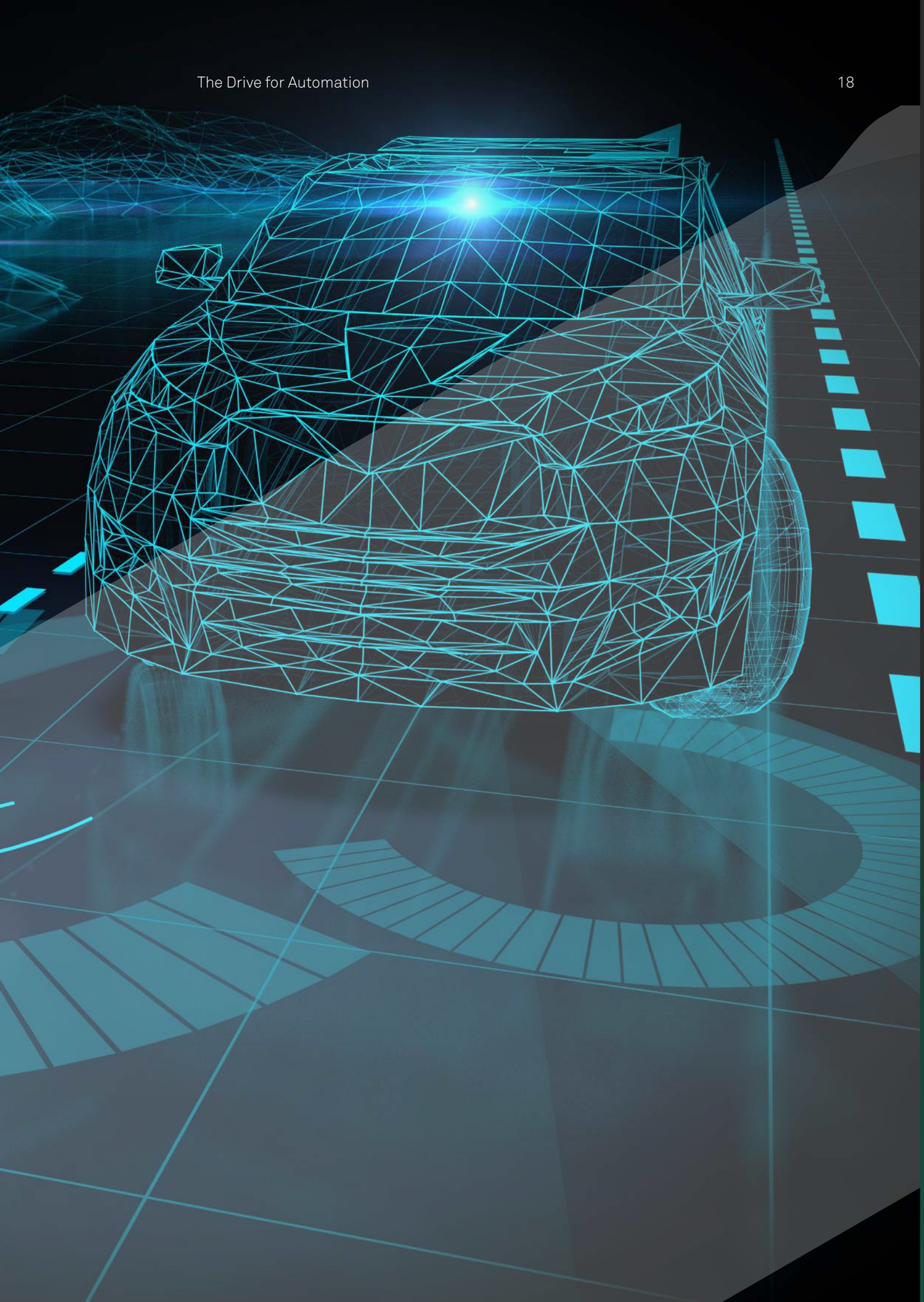
Intelligent Mobility

Longer term application of L4 CAV capable of providing versatile end-to-end journey transport.

Outlook and opportunity

- Active development in developing mobility as a service products (Wayve) and supporting software and tooling (Oxbotica, Five).
- This opportunity represents a levelling up of the driving as a service opportunity and multiplying the transport, economic and environmental impacts.
- Bringing to market requires long term development, and investment. The CAV ecosystem must be grown to enable products to be brought to market.
- This opportunity has the potential to significantly reshape the transport, technology, and manufacturing industries; and furthermore, how we live and travel in the longer term. There are benefits in strategising long term plans on which types of this opportunity support policies and guide developments on this route, including medium term stepping stone projects.





4 Conclusions

The future of L4 CAV is economically important – forecast to represent the majority of a £41.7bn UK CAV market in 2035[10].

There are different types of L4 CAV that are important to recognise due to:

- The challenges involved in bringing them to market, those with lower driving capabilities and have lower operational risk can be delivered in the shorter term, while those with higher capabilities and risks require a long term build-up of knowhow.
- Their environmental impacts, types providing 'driving as a service' lower carbon emissions, however types providing functions in personal use vehicles may increase carbon emissions

To maximise the benefits of the CAV revolution the UK needs to focus on opportunities geared towards L4 CAV. Each area of categorisation that we have considered provides opportunities to deliver incremental benefits to the UK.

Products within the 'Controlled area driving' and 'Driving assist' categories are typically further developed than the other categories but deliver fewer overall benefits. 'Driving as a Service' and 'Intelligent Mobility' bring the greatest economic, environmental, and societal benefits. However, 'Intelligent Mobility' products require significant investment and are a much longer-term prospect. Therefore, 'Driving as a Service' products provide an opportunity to deliver L4 CAV to the mass market, whilst delivering benefits to the UK and continuing to build a shared body of knowledge.

To fully exploit the 'Driving as a Service' products it is essential regulators, technology developers and service providers come together to build the CAV ecosystem which enables the development and implementation of such products. Whilst much work has been undertaken within the CAV ecosystem to date, further work is required particularly in relation to the following priority areas:

- **Policy** - needs to keep pace and support the rapid technological developments and support the various business and operational models that may be utilised.
- **Governance** - creation of codes and practice to enable the approval of L4 CAVs on roads and provide guidelines for supporting development and assurance.
- **Collaboration & shared knowledge** - continued requirement to build a culture of collaboration and sharing within the ecosystem to ensure the UK is at the forefront of further technical innovations.

[10] (Catapult, 2020)

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