Innovate UK

AUGUST 2021

UK TRANSPORT VISION **2050:** investing in the future of mobility

Foreword

Welcome to our 2050 transport vision. We set out in the following pages our thoughts on the changes, challenges and opportunities that will confront the UK's transport sector over the next 30 years.

It is a time of incredible change for transport. UK and global net zero targets, greater connectivity and digitalisation, automation and changing consumer habits all present significant challenges for transport industries. Rising to meet these challenges offers great opportunities for economic growth and for societal benefit – a cleaner environment, and unique and more efficient ways for us all to get around and to deliver goods. In these pages we aim to foster a better understanding of what lies in the future so we can anticipate the opportunities and make the most of them.

We are the UK's innovation agency, and we aim to inspire, involve and invest.

We want to inspire you by demonstrating the opportunities that lie ahead of us. We have already involved many of you in helping us to put this vision together. We want to involve you much more in the years ahead. That means working together to realise these great opportunities. We also invite challenge where you think we have not got it right. This vision is a living document. We will update it as thinking evolves.

Above all, the vision will help us to shape our decisions on what to support and where to invest in the coming years, and we hope it will do the same for you.

I would like to thank all those who have helped us to produce this vision, including our partners at UK Research and Innovation (UKRI), the Department for Business, Energy and Industrial Strategy, KTN, Connected Places Catapult, and Department for Transport, and our partners in industry. We look forward to working with you all to meet the challenges, shape the future transport system, and realise the great opportunities that we see in the years ahead.

Indro Mukerjee
Chief Executive | Innovate UK

Executive summary

Transport is fundamental to the daily movement, trade and communication of people, organisations and goods across the globe. Transportation and transport manufacturing generated over £109 billion added value for the UK in 2019, 5.5% of the total UK output. Transport also accounted for 27% of the UK's Green House Gas emissions in 2019. Digitalisation, greater connectivity, the journey to net zero, changing customer needs and new ways of getting about and delivering goods are all placing fresh demands on transport.

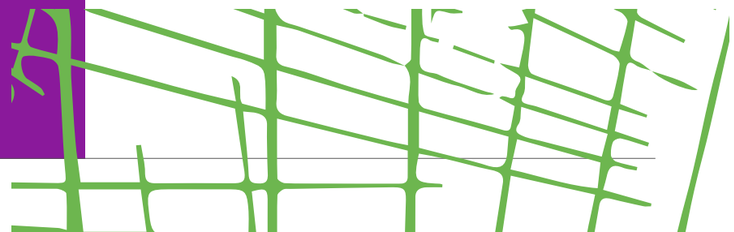
The importance of transport means the UK must respond to the challenges and opportunities represented by these significant changes. We at Innovate UK and our partners have invested £4.5 billion in innovative transport projects since 2007. This investment will continue to shape transport in the UK for many years.

This vision document has grown out of extensive research into the future of transport and out of consultation with our partners in both the public and private sectors. It takes a view of where we will be by 2050 and outlines the likely steps along the way to achieving this. Our aim is to gather UK government and industry around a single vision that will inform the way we all invest in the future of transport to deliver economic growth and societal benefit. It is also to provoke debate. We recognise that this is one vision and others may come to a different conclusion. We welcome challenge that leads to constructive conversation and we will update the vision to reflect the latest thinking as time goes on.

Vision for UK transport 2050

Our vision is for a 2050 transport system that enables the movement of people and goods from one location to another through seamless, safe, net zero, connected, cost effective, accessible and reliable means.

The transport system will maximise use of UK design, innovation, manufacturing and deployment. Industry will provide high-quality and skilled employment and remain a major contributor to UK GDP and to UK innovation.



Pathways to 2050

We have identified **six key areas** where steps need to be taken to achieve the 2050 vision:

- **travel and transport demand**
- **connectivity**
- **energy vectors**
- **autonomy**
- **business models**
- **infrastructure**

We have set out a pathway in each of these areas that lays out a central assumption of the future and the steps and timescales on the road to achieving that future. The pathways are briefly described below and detailed versions can be viewed in the main body of the report.

Fundamental, technical and applied research and innovation challenges need to be addressed in all these areas. There is greater certainty about the direction and the needs in some areas than others. The pathways are colour-coded to reflect the level of certainty.

Travel and transport demand –The way people travel and behave will change and this will be accelerated by advances in technology that will improve transport services, reduce costs, and revolutionise business models. We expect to see an increase in the use of most travel modes despite the impact of the COVID-19 pandemic, a push for travel reduction, and a trend towards alternative forms of mobility. There will be some shifts in travel use between modes, for example less bus use and more use of shared services and some shift from road and rail freight to short-sea shipping. Walking and cycling is expected to grow as is the use of electric bicycles and scooters. However, it is difficult to predict transport use beyond 2025 because of the large number of variables in future scenarios.

The growth in transport is a challenge to plans to reduce carbon emissions. We expect to see efforts directed towards demand reduction, zero emission technologies, and a shift away from more polluting modes of transport.

Connectivity – Improved communicators and data connectivity will create opportunities for greater efficiency, new services for travellers, and new business products and amenities. We expect all road vehicles to be capable of fully cooperative driving by 2050. Road maintenance, traffic planning and routing, traffic management, refuelling systems, freight operations, train operations and air traffic management will all benefit significantly.

Energy vectors –The move to net zero by 2050 will require a complete shift from fossil fuels to sustainably produced electricity, hydrogen and other alternatives and a switch to supply chains producing the new powertrains. Fossil fuels will still be the dominant energy vector in 2025, and even 2030. However, electric will need to be the dominant vector by 2050 if we are to achieve net zero. We also expect hydrogen to be a significant vector for heavy goods vehicles, buses and aircraft by 2050.

Autonomy – Autonomy will make road vehicles smarter, create opportunities for new services such as last-mile delivery by drone and deliver fully autonomous urban transport. We anticipate that the urban transport system, air transport, rail freight, ferries to and from UK islands and 90% of motorway HGVs will be fully autonomous by 2050.

Business models – Advances in technology and new government policies will transform business models and lead to bundling of services, better use of resources and mass customisation. The growth of online retail, improved logistics, use of drones, greater understanding of insurance and risk and improved connectivity will all have an impact on business models.

Infrastructure – UK transport's consumption of petroleum products will fall by over 90% by 2050 and be replaced by electricity, hydrogen, ammonia and sustainable fuels. This will create significant new business opportunities for fuel and energy generation, production and distribution. Greater connectivity will remove the need for some infrastructure such as motorway gantries.

International benchmarking

We are looking in detail at the relative strengths of the UK transport sector to determine where the UK can best devote its efforts in meeting the challenges and opportunities identified in the pathways. The results of this study will be published in autumn 2021.

The route ahead

Changes to the transport system over the next 30 years present significant challenges and great opportunities for the UK transport sector. We have identified where we see the main changes coming as we move towards 2050.

We will use this vision and our assessment of the UK's relative strengths to determine where we invest our efforts over the coming years. We hope it will also inform and guide our partners in the public sector and in industry when they are making their investment decisions.

Contents

Introduction

Transport enables mobility, communication, trade and other forms of exchange between people. Improving it has a big societal impact.

Good transport helps people to get jobs, access services and enjoy social activities [1]. Transportation and transport manufacturing generated over £109 billion added value for the UK in 2019, 5.5% of the total UK output [2] and efficient transport impacts almost all other UK businesses. Transport also remains the largest source of Green House Gas emissions in the UK, accounting for 27% in 2019 [3]. Transport industries tend to adopt innovative technologies that drive efficiency, change for good and a forward-looking inclusive society in the UK and internationally.

Increasing digitalisation and connectivity, the drive towards zero emissions and sustainability, and a greater appreciation for travellers' needs are placing increasing demands on transport systems. The focus on walking and cycling and the arrival of new means of transport, such as electric bicycles, scooters and cargo bikes, are having an impact beyond people's health and the planning of urban environments. These changes create challenges and opportunities for those who deliver and use transport. The development and adoption of innovative products and services are increasingly important for UK competitiveness and in delivering value and providing accessibility to all.

Transport's wide-reaching impact and the high level of change make it an area of major importance to UK government and industry. There is opportunity for substantial societal benefit, environmental gains and economic growth. This is recognised in the Department for Transport (DfT) science and transport decarbonisation plans [4] and in the government commitment to raise investment in research and development, including through its UK Research and Development Roadmap [5].

Putting forward a vision

We are putting forward a vision of UK transport in 2050 and outlining the steps to achieving this. This is relevant to anyone investing in the future of transport to make an economic return and to deliver societal and environmental benefit. The vision is tailored to UK challenges and opportunities, but is also a strong indicator of global trends. The UK transport system must interact and work as part of a global system. Our aim is to bring together UK government and industry around a single common vision for the expected future of UK transport. We intend this vision as an exercise in thought leadership. It is available on the UKRI website, and we will update it regularly to reflect the pace of change in transport. The vision complements government policy documents, building on these and drawing on current evidence to provide specifics about the likely future.

We will also examine UK and international capabilities in current and future transport supply chains to indicate clearly where UK strengths lie relative to other leading nations. We will draw conclusions on areas that offer greatest impact of investment, where global opportunity aligns with UK strengths, or where follow-on work is needed to develop the case for strategic interventions in line with wider government policy.

Our vision will inform future Innovate UK strategies and activity, including decisions on where we focus our efforts and our discussions with partners about the UK approach. This information can help others (e.g. industry, UK government – including arm's length bodies) in their decision-making to help us align investments and enable the UK to gain the economic, environmental and societal benefits more quickly and at the appropriate value for money.

We recognise that others may come to different conclusions based on different evidence. We welcome challenge to this vision that leads to constructive conversations on how to align ourselves or acknowledge our differences and will reflect this in future versions of the vision.

What do we mean by transport?

Transport vision 2050 encompasses only the use of vehicles, fuels/energy vectors and supporting infrastructure to move people and goods and an assessment of what is needed to support the future transport system, including amounts and sources of energy, levels of connectivity, and data services. The document details the expected vehicles or vessel fleets in service at particular points in the timelines, rather than the latest models being sold.

We do not include the construction, manufacture or recycling of vehicles, production of fuels/energy vectors or heavy infrastructure. We recognise the need to work with constructors, manufacturers and recyclers. However, we need to define some boundaries on scope. Similarly, we do not include workforce skills and training. This is an area that requires broader consideration beyond transport alone.

UKRI Innovate UK

Innovate UK is the UK's innovation agency.
We have a strong business focus. We drive growth by working with organisations to de-risk, enable and support innovation. This gives us a unique vantage point. We can tap into knowledge across a wide range of sectors, not only in transport. We, and our partners, have supported investment of £4.5 billion in transport[6]. **Understanding and shaping the future is a critical part of our role.**

We have sought input into this transport vision from across our network, including from UKRI (including Engineering and Physical Sciences Research Council and Economic and Social Research Council), KTN, Connected Places Catapult, Department for Transport, Department for Business, Energy and Industrial Strategy, Maritime and Coastguard Agency and industry representatives.

This vision is based on extensive research including input from over 200 contributors from industry, government and academia.

Vision for UK transport 2050

Our vision is for a 2050 transport system that enables the movement of people and goods from one location to another through **seamless**, **safe**, **net zero**, **connected**, **cost effective**, **accessible** and **reliable means**.

The UK transport system will be recognised as a world leader in design, innovation, manufacturing and deployment. Industry will provide high-quality and skilled employment and continue to be a major contributor to UK GDP.

MEETING SOCIETAL AND TRANSPORT USER NEEDS

The 2050 traveller will experience a connected, cost-effective, accessible and reliable transport system. Transport will be accessible to people of all ages, locations and abilities. Comfort, convenience and perceived status will be critical in influencing user decisions. Transport will be an integrated, energy efficient, intermodal system, taking travellers from door-to-door in an efficient, safe, affordable and sustainable manner, offering an acceptable level of choice. Travellers will be fully connected with work or leisure activities during the entire journey. They will be as productive as at other times and able to maximise the value of time spent travelling. Travellers will experience near 100% reliability and arrive on time. Freight distribution will be more efficient and competitive.

> **Travellers will experience near 100% reliability and arrive on time**

SEAMLESS TRANSITION OF PEOPLE AND GOODS

The 2050 UK transport system will be fully integrated, providing interconnected mobility that allows the seamless and sustainable transition of people and goods from one location to another, regardless of the methods or modes used. This includes both movements within the UK and those made on overseas legs of journeys to and from the UK. Today's challenges in linking transport modes will be removed, and transport, energy and infrastructure will be optimised to deliver the best system.

NET ZERO EMISSIONS

Almost all transport will be zero emission at point of use in 2050, and the remainder offset. Emissions from the manufacture of transport solutions will be zero or offset. Raw materials will be sustainably sourced and products will be designed for resource efficiency, remanufacture and recycling to create a circular economy.

SAFE, SECURE AND RESILIENT

Deaths and serious injuries from transport-related incidents will be reduced to near zero in 2050 through systems to protect travellers and other users. When incidents do occur, technology will be reliable enough to redirect traffic and provide real-time information to both incident-response teams and those travelling. Standards will also ensure safety and interoperability of transport products and services across modes, regions and data sources. Data, including personal data, will be protected, and systems will be secure from cyber-attack. The transport network and supporting systems will include enough back-up to ensure reliability and confidence.

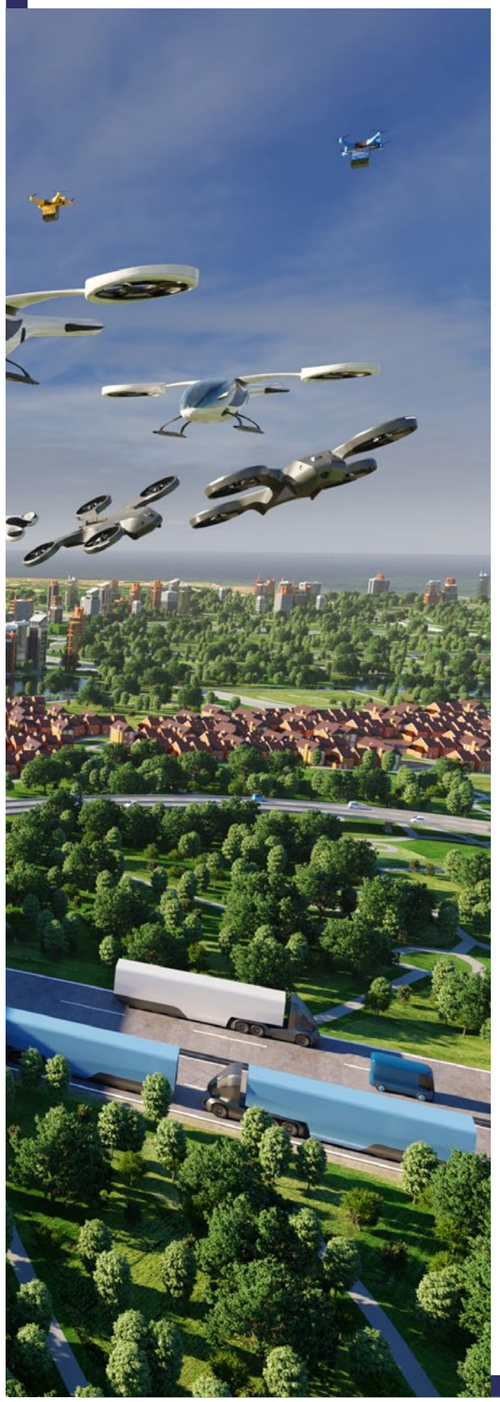
> **Transport-related deaths and serious injuries will be reduced to near zero in 2050**

ECONOMIC CONTRIBUTION

A world-leading, reliable and cost effective transport system in 2050 makes the UK a more attractive place to travel to or do business and drives economic growth, exports and (new) jobs. It is underpinned by the global leadership of UK companies in research and development, manufacturing and delivery of transport systems, infrastructure, and resilient and secure supply chains.

The pathways to 2050

We have identified **six key areas** where steps need to be taken to achieve the 2050 vision. They are:



- TRAVEL AND TRANSPORT DEMAND
- CONNECTIVITY
- ENERGY VECTORS
- AUTONOMY
- BUSINESS MODELS
- INFRASTRUCTURE

We identified these areas following a wide-ranging review and have drawn up a pathway for each one. The pathways set out our expectations in the timeframe between 2021 and 2050 and draw on referenced sources and our own key assumptions based on our sector knowledge and input from a wide range of stakeholders.

We have reviewed different scenarios for each key area but have included only a single scenario that we consider the most likely path and outcome. We will keep this under review and update it as needed in future versions.

The pathways lay out a central assumption for the future and the routes to it. Our certainty and confidence in some routes and solutions is greater than others. Areas of higher confidence in a destination or route should provide greater certainty for investors in the system. Where our certainty is lower, there is a higher chance that the ultimate solutions and routes will be different to those we have identified. We will update the pathway accordingly as new information becomes available. The shadings in Figure 1 show how we represent our level of certainty in the pathways. The pathways contain many abbreviations for the sake of brevity. A list of common abbreviations can be found in Annex 1.

There are fundamental, technical and applied research and innovation challenges that need to be tackled across and within each pathway and transport mode even where there is more certainty.

We have broken the transport system down into these areas. However, we recognise that there is significant interaction between pathways. A holistic approach is clearly needed to keep the UK on the path to 2050.

Figure 1 – Certainty key used in each pathway

high | med | low | speculative

Travel and transport demand

The way people travel and behave will change and this will be accelerated by advances in technology that will improve transport services, reduce costs and revolutionise business models.

These changes could result in an unsustainable transport system if smart policies and interventions are not implemented in a holistic way. Understanding innovation and the impacts of innovative products and services as they are deployed is key to an optimised transport system.

Predicting travel and transport demand beyond 2025 with confidence is challenging. The sector's size and the huge number of variables creates a melting pot of possible scenarios. However, by using available references and informed opinion we have presented one possible scenario to encourage debate and draw our conclusions.

Population growth and rising GDP have historically resulted in a greater demand for mobility. The emergence of COVID-19 [7], a greater push for reducing travel [36] and alternative forms of mobility ought to be challenging this trend. However, most sources predict an increase in most travel modes both in the UK and globally [32, 35, 40] under current approaches.

Aviation – Passenger numbers in 2021 are expected to be down by between 1.9 and 2.2 billion (42% and 48%) compared to 2019, a revenue loss of between US$276 billion and US$315 billion [1]. Passenger demand is expected to recover by the mid-2020s and then grow 1.4% a year to 2050. These figures assume demand management measures are not implemented to drive sustainability. We expect international air freight to grow 5.5% a year to 2030 and then 4.5% a year to 2050. However, volumes will remain comparatively low given its high cost in comparison to shipping, rail or road freight. Advanced air mobility (AAM) – air transportation services for people and/or cargo using revolutionary new aircraft – is forecast to be worth US$510 billion by 2040 [51] and there will be 76,000 operational drones by 2030 [5]. We expect AAM will first be adopted for freight delivery and remote inspections, with passenger-carrying services adopted by 2030.

Micromobility and Active Travel – Active travel (walking and cycling) has risen during the pandemic [18], and we expect to see long-term behaviour change. Over a quarter of YouGov survey respondents were quite likely or very likely to cycle or use e-cycles, with the figure rising to 30% for walking, both figures up on pre-pandemic levels [42]. These changing attitudes are recognised in the Department for Transport's Gear Change [21] strategy, which aims for 50% of all journeys in urban areas in England to be cycled or walked by 2030. Micromobility – use of electric and human-powered vehicles under 200kg and with speeds restricted to under 25mph – will be prevalent in urban areas from 2025 and provide a transport option for all trips under 8km [23]. Micromobilty will also complement public transport by offering a viable option for the first and last mile of the journey [52]. Striking a balance between promoting active travel, with its health benefits, and use of micromobility will be necessary.

> **Advanced aircraft able to take off and land vertically will be carrying passengers by 2030**

Maritime – Shipping accounts for 95% of international freight arriving in the UK [9] – 419.1 million tonnes of goods were handled in 2020-21 (a fall of 11% from the previous year) [11]. Freight is expected to grow in the short to medium term with the advent of new freeports [43] and the associated improvements in efficiency and cost of operations at UK ports [12]. Coastal ports and their interaction with larger hubs will unlock the potential of short shipping for freight movement between 2025 and 2040 [12]. This shift may impact road and rail freight mileage. However, coastal ports will require investment to handle increased freight volumes efficiently [44], and there will be a need for short-distance transfer from port to intended destination by road or rail freight as required.

Rail – There were 388 million rail passenger journeys in Great Britain in 2020-21, less than a quarter of the 1,739 million journeys made in 2019-20 [26]. However, a 2020 national survey suggests that more than 75% of public transport users are willing to regain previous public transport habits if the right precautions are in place [41]. Passengers will continue to use rail, but changing home and office work patterns will impact passenger numbers [45]. The volume of rail freight will grow to more than pre-COVID-19 levels, with government committing to set a new growth target for rail freight. This coincides with wider improvements to the rail network, including in access and flexibility [31]. We expect improved rail links, with freight hubs bringing modal shift to track in some cases.

Bus – Local bus journeys in England were down 50% to 2.12 billion in the year ending December 2020 [46]. Bus use nationally is forecast to decline towards 2040 due to modal shift and increases in shared services. This trend could, however, be bucked if projected reductions in operational costs can be passed on to the customer and bus services grow in quality, frequency and coverage [47].

Road light commercial vehicles (LCV) – LCV traffic fell by 9.1% between 2019 and 2020 [18], but a rise in online sales to 27.9% of all retail sales in 2020 – up from 19.2% in 2019 – means demand for the use of LCVs remains high. This trend towards online sales is set to continue [48]. Government forecasts suggest LCV traffic will grow between 23% and 108% by 2050 [35]. However, disruptive modes that support last-mile delivery, including drones, may remove some LCVs or miles from UK roads by 2040.

Road heavy goods vehicles (HGV) – Truck movements and distance are expected to increase by between 2% and 4% between 2025 and 2030. The advent of high levels of autonomy could lead to a greater percentage increase (up to 12% [35]) given the improved economics. However, truck movements will be focused on highways and the strategic road network. Noise and emissions reductions associated with zero emission capability will improve operations.

> **Total road traffic is forecast to grow by between 17% and 51% between 2015 and 2050**

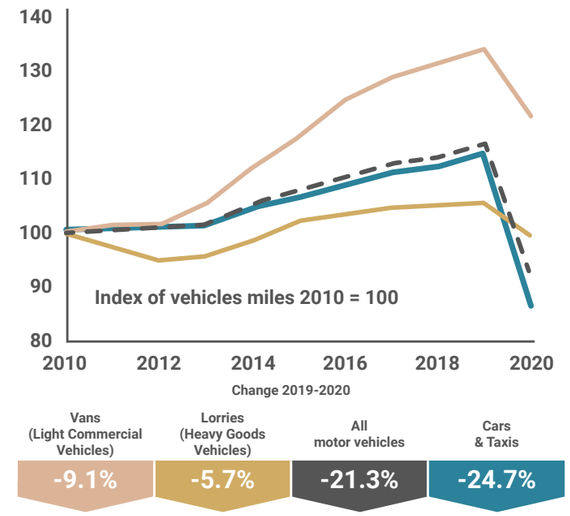
Road cars – Car traffic decreased by 24.7% between 2019 and 2020 [18], but use has quickly rebounded. Total road traffic is forecast to grow by between 17% and 51% between 2015 and 2050 [35] and car traffic by between 11% and 43%. However, changes in car use are notoriously difficult to predict given changes in technology, society and in transport systems, all of which impact behaviour [47]. Autonomy, an increase in shared services and incentives to decongest roads will deliver a "modest" [23] move away from private vehicle ownership. This change may also further reduce reliance on public transport, especially buses, by 2040-2050. While car traffic is projected to increase, the Committee on Climate Change reports that approximately 9% of car miles can be reduced or shifted to lower-carbon modes by 2035, increasing to 17% by 2050 [36]. Private car ownership remains attractive for households, but it is a comparatively inefficient means of travel [47].

Transport policy – The push for zero emission vehicles and modal shift mean alternative tax and subsidy approaches will be needed if overall transport tax revenues are to remain level or increase. This may include road pricing or congestion charges. Any changes to the relatively low global tax regimes for air and maritime transport are likely to require international agreement but are one way to encourage decarbonisation [50].

> **Growing demand for transport is a serious challenge to the UK's plan to reduce carbon-intensive activities by 2050**

It is clear that demand for transport is projected to increase. This is a serious challenge to the UK's plan to reduce carbon-intensive activities by 2050. Demand can be reduced, but there is an equally important role for zero emission technology and modal shift away from more polluting transport modes. Policy change and technology advances that aid behaviour change can increase the shift, such as future decentralised and remote operations reducing the need to travel to work. COVID-19's impact on society's work and leisure patterns could result in longer term emissions benefits through reduced transport demand. Post-pandemic economic recovery packages targeted at decarbonisation and behaviour will greatly accelerate the transition to sustainable transport [40]. Between now and 2050, national and international taxes and subsidies will also be used to influence both societal and business approaches to transport. These will aid the delivery of an optimised transport system.

Figure 2 – Source Department for Transport, Road Traffic Estimates: Great Britain 2020, April 2021



Travel & transport demand pathway

CERTAINTY high | med | low | speculative

Transport modes	Elements	2021 position	By 2025	By 2030	By 2040	By 2050
Air transport	Market Drivers	AAM R&D&I, BVLOS tech trials and piloted drones	Pax AAM available but piloted. Large growth in drone freight delivery.air travel up	Pax AAM available but piloted. Large growth in drone freight delivery	Freight delivery and pax transport drives AAM deployment	Economics drive AAM forward. Intern' air freight remains low vol high price
	Air Mobility Vehicles	Design and development ramping up	Rural routes certified for BVLOS	76k drones in UK airspace [5]	High demand - middle mile deliveries and into rural areas	50% of mode share for delivery
		Investor confidence and consumer interest high [0]	Early Adopters - Gov. and public services [5]	Commercially viable for metro air services - regs in place [6]		Common modal option for Pax
	Civil Aviation	Global pax down to 2.1bn (-48%) from 2019 [1]	International travel back to 2019 levels by 2025 [3]	Passenger numbers approx. 13% higher in 2030 than in 2019 [3]	Passenger numbers approx. 38% higher in 2040 than in 2019 [3]	Passenger numbers approximately 60% higher in 2050 than in 2019 [3]
		Domestic 80% pre-C19 levels by 22	Business travel C19 impact possible [4]			
	International Freight	2020 UK airports handled +2m tonnes, ~500k less than 2019 [39]	Air Freight - high value but very low volume	Estimates put air freight at a 5.5% compound growth rate [7]	Estimates put air freight at a 4.5% compound growth rate [7]	
		Air cargo demand increased in 2021 [2]	Increased demand possible after C19			
Maritime	Market Drivers	Pax travel at historic low. Freight movements hampered by C19 and EU exit	EU Exit offers new way to trade incl. rise of Freeports. Pax travel up	Cruise sector deadline to achieve 40% emission reduction from 2008 levels	Growth in line with Net Zero agenda. Smart tech ensures high demand	Integrated, connected and zero carbon operations
	Passenger	Short sea ferry pax down 63% in 2020 [8]	Pax growth close to pre-pandemic levels [12].	Further shift to responsible cruise travel	Zero emission option for domestic ferry and leisure activities	Ports are multi-modal hub for sustainable transport. Ample connections to onward journey
		No-sail order Mar-Sept 20	Demand for sustainable cruises [13]	Pre C19 pax growth projections resume		
	Freight	95% of goods moved by ships in 2020 [9]	Tonnage +3% dry bulks and containers	Tonnage +8% compared to 20 level [14]	Tonnage +23% compared to 20 level [14]	Tonnage +41% compared to 20 level
		Movements down by 5-10% in 2020 but beginning to recover [10]	Liquid bulk movements down due to less crude oil being shipped [14]	Increase in coastal shipping sees modal shift away from road	Costal ports and their interaction with larger hubs unlock potential of short shipping [16]	Crude oil movements -43%.
		Total tonnage -11% to 419.1m tonnes (Mar 20 - Mar 21) [11]	Freeports increase trade volume, more vessels in UK waters [15]			Liquified gas +177% compared to 2020 [14]
Micromobility and Active Travel	Market Drivers	C-19 driving active travel and micromobility demand	Public scooter use & shared-vehicle schemes legalised	Urban movements center around walking and cycling	Large-scale improvement in active travel & micromobility infrastructure	Active travel and micromobility embedded into transport system
	Walking	2019 walking = 26% of all trips [27]	Walking displaces other modes post C19	50% of journeys in towns and cities cycled or walked by 2030 [21]	Health, wellbeing and accessibility benefits continue to result in high levels of active travel	
	Cycling	Cycling 45% above 19 levels [17] [18]	Gear Change start showing results [21]			
	Micromobility (all modes)	eScooter trials primed in 30 cities	ebike sales nearly triple by 2023 [22]	+5% user demand over 2025 levels [24]	Micromobility 10% pax mode share	Micromobility (incl. UAVs) serves majority of last-mile deliveries
		+22.5m delivery app users [19] [20]	Journeys <8km travelled by micromobility [23]	Complementary to public transport [52]	Micromobility 30% of urban deliveries [25]	
Rail	Market Drivers	Covid continues to present major demand challenges	Covid's impact still felt. Some freight increases as trade increases	Use of sunk (infrastructure) investments. Balance pax and freight [38]	Autonomy, connectivity and business models [38] could see more passengers	Wholesale integration with energy and wider transport system
	Passenger	388m journeys made in 20-21, just 22.3% of 1,739m made in 19/20 [26] [27]	Pax demand still 10% below pre-lockdown levels	Pax rail mode share and demand return to pre-pandemic levels [30]	Pax-km +5% over pre-pandemic levels with mode share +5% [30]	Pax rail mode share and demand flat on 2040 levels [30]
		Commuting mode share 10% [29]				
	Freight	Mode share 9% for freight [29]	Annual growth 2.9% after 2022 [30]	Demand +25% over 2022, mode share to 10% [30]	Demand +65% over 2022, mode share to 12% [30]	Demand +65% over 2022, mode share to 14% [32]
		Freight moved -8.6% in 20/21 [28]		Flexibility and road, air and sea tech advances could hamper demand		Modal competition drives down cost
Road	Market Drivers	OEMs / gov. pledge to zero. TCO of ZEVs decreases. Freight demand up due to trade and consumer behaviour	C19 impact demands. Private car ownership continues upward. Last mile delivery options impact LCVs	gov. push to reduce car travel, but consumers prefer the personalisation, cost and accessibility it offers	Autonomy improves economics of HGVs. Personalised travel and shared vehicles increase	Shift to personalised and on demand. 17% of car journeys replaced or removed - impact forecasts [36]
	Car	2020 car traffic -24.7% from 2019 [18]	+5% increase in demand vs 2015 [35]	'+13% demand vs 2015 [35]	+25% in demand vs 2015 [35]	Cars up to 81% of traffic mileage [35]
		Depression in mobility due to C-19 pandemic is short-lived	C19 legacy - less daily commute and public transport	TCO down and population up	Reduction in TCO, uptake of CAVs and shared services [35]	40% net increase in demand vs 2015 from CAVs and shared services [35]
			Disincentivisation for private car use grows		9% of journeys replaced / removed [36]	Increases in effective road capacity
	Bus & Coaches	Shift away from public transit (bus) [33]	Demand decrease - less commuting and to shift to micromobility	Increased leisure travel difficult to satisfy with public buses	Bus travel down given more mode choice and reduced cost for personalised / private travel	Travel increasingly personalised = significant drop in bus demand
		Covid leaves permanent effects	Business models favouring private and personalised door to door travel	Long distance low cost services continue		Buses retained for routine journeys e.g. commuting
	Freight - Van / Light commercial	Traffic -9.1% from 2019 to 50.5 bvm [18]		'+7% demand compared to 2018 [35]		Growth of between 23% and 108% [35]
		LCVs 11% of total UK traffic [34]	Miles travelled may not reduce due to increased volume of goods			
		Demand may exceed pre c19 levels [33]	Increase in other last mile mode options may limit LCV demand			
	Freight - HGV	Lorry traffic decreased by 5.7% compared to 2019 [18]	Flat to gradual increase in demand of 2% compared to 2018	Flat to gradual increase in demand of 4% compared to 2018 [35]	HGV autonomy switch to HGVs for domestic freight [37]	Increase in demand of up to 12% compared to 2018 [35]
		Demand expected to match/exceed pre covid levels by end of 21 [33]			International RORO up due to improved economies [37]	Distance travelled reduced - influence of wider transport system

Connectivity

Improved communications and connectivity will create opportunities for greater efficiency, new services for travellers and new business products and services.

Connecting transport systems and vehicles through cellular and satellite communications technology will lead to significant efficiency gains and new services for both travellers and freight. Increasing data and digital connectivity will enable new business models and services and unlock significant new economic and social value. Secure connectivity will also be critical to the operation of transport as a national infrastructure.

We expect this to be enabled by widespread 4G connectivity by 2025 and 5G by 2030 [31]. Widespread 7G by 2050 will connect all road vehicles with each other and enable a sophisticated central traffic management system. Road vehicles will offer increasing levels of customer experience with 60% of new vehicles offering personalisation for all occupants (McKinsey Connected Car Customer Expereince level 3) by 2030, and 75% having intelligent decision making by 2050 [30]. Road vehicles will be capable of cooperating with other nearby vehicles to support traffic flow and safety by 2050.

> **Road vehicles will be capable of fully cooperative driving by 2050**

This improved connectivity will be vital for real-time data gathering. It will provide key information for the public sector, industry, travellers and maintenance. For example, real-time data will improve planning of road usage and lead to efficiencies, cost savings and emissions reductions. Developments in connectivity will enable planning simulations using artificial intelligence and machine learning and lead to more efficient traffic management systems. Connectivity and data gathering will underpin the creation of digital twins – real-time digital counterparts of physical objects – that will improve travel planning and routing.

People using active forms of travel, such as cycling and walking, will make more trips in this way as they feel safer, experience better air quality and have more confidence in a connected and informed journey.

It will be normal rather than a novelty for people to use digital channels to plan, book and pay for many different types of mobility services (mobility as a service) as systems become more connected and reliable. The sharing economy will also be embraced as we move from personal vehicle ownership to usership.

Freight movement will be optimised at ports and depots to ensure maximum efficiency in time, miles travelled and of space.

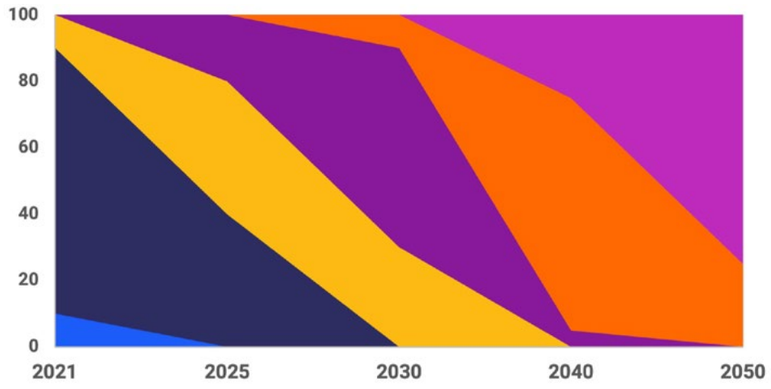
The advanced train protection system, the European Train Control System (ETCS) level 2, will be rolled out on all UK trains by 2040 and 95% of UK mainline rail by 2050 [15].

Autonomous unmanned air traffic management (UTM) has been demonstrated and could be adopted commercially in the 2020s. This will be fully integrated into current air traffic, including commercial flight, by 2050 [43].

All recharging and refuelling systems and vehicles will be fully internet connected by 2030 to maximise energy management for motorists, vehicles and energy networks.

Figure 3 - Connectivity of new vehicle sales, McKinsey Connected Car Customer Experience (C^3X)

Road vehicles will offer increasing levels of customer experience with 60% of new vehicles offering personalisation for all occupants (level 3) by 2030, and 75% having intelligent decision making by 2050.



Connectivity pathway

CERTAINTY high med low speculative

Transport modes	Elements	2021 position	By 2025	By 2030	By 2040	By 2050
All modes	Cellular connectivity	increasing connectivity				
	Satellite, positioning and timing	increasing connectivity				
Air transport	Traffic management	Upgrading air traffic infrastructure [1]	PBN using satellites	Defragmentation of EU Skies [44]	Digital European Sky adopted	
		ADS-B Trials [41]	Airspace systemised [43]	UTM and ATM running together	UTM adopted	
		OTS allows free routing [41]	Digital sharing ATC across airports [45]			
	User connectivity	EAN allows connectivity [42]	Widespread satellite connectivity [3,4,5]	Users routinely connected		
Maritime	Traffic management	Anonymous tracking trials	Shift to digital logistics via IoT	Increased use of AIS and LRIT for tracking	CAV capable vessels for berthing	Individual consignment tracking
		5G unmanned CAV trials [7]	Increased use of IoT devices	Routes optimised for emissions [10]		Port side control for consignments
	User connectivity	Reliance on land based comms	HAPS and Sat comms increase speed	Centre for Smart Shipping established [7]		
		Expensive and unreliable sat comms [12]				
Rail	Traffic Management	GSM-R migrates to packet switching	FRMCS trials start	75% trains fitted with ERTMS/ETCS L2 [15]	100% trains ERTMS/ETCS L2	85% network ERTMS/ETCS (2044) [15]
		ERTMS trials continue	FRMCS roll out	Trackside infrastructure for comms	50% network ERTMS/ETCS L2 (2034) [15]	95% network ERTMS/ETCS (2049) [15]
		Reduce ETCS deployment costs [15]	ERTMS / ETCS level 2 roll out [15]	Trains have wi-fi connectivity	70% network ERTMS/ETCS L2 (2039) [15]	100% network ERTMS/ETCS (2059) [15]
	User connectivity	4G/5G provision location dependent			Lines have trackside coverage	
		Ongoing discussion for national 5G				
Road	Traffic management	C-ITS enabling road safety, efficiency [17]	More C-V2V built in or added on [22]	New cars have V2X / C-V2X capability		Junctions controlled by AI
		No. vehicles with C-V2X increases [18]	Data linked to insurance premiums [23]	Retrofit older models with V2X/C-V2X		AV routes influenced by road authorities
		Vehicles broadcast emergency events [19]	Sensor enabling traffic management [24]	Remote driving capability deployed		
		Use of sensors to monitor traffic [20]	Geospatial info improving data [25]	Sensor tech for informed choice [27]		
		AI traffic management trials in UK [21]				
	User connectivity	4G ubiquitous across network [29]	Many vehicles have connectivity [31]	New vehicles have 5G capability [31]	70% new vehicles meet C3X L4	All new vehicles have 7G
		80% new vehicles meet C3X L1 [30]	40% new vehicles meet C3X L2 [30]	In-vehicle infotainment run on 5G [31]	25% new vehicles meet C3X L5	75% new vehicles meet C3X L5
		10% new vehicles meet C3X L2 [30]	20% new vehicles meet C3X L3 [30]	Trials on 6G commence [34]	New vehicles report status to VOSA [37]	25% new vehicles meet C3X L4
			ALN [32] and AURN data [33]	Automatic switching between 4G/5G	6G rollout by 2035 [36]	
			AV monitoring established	30% new vehicles meet C3X L2 [30]		
			Users informed about route issues	60% new vehicles meet C3X L3 [30]		
				10% new vehicles meet C3X L3 [30]		
Active travel	Traffic management	Sensor tech to enable C-ITS	Improved connectivity	Improved connectivity	Cycling and walking natural choice [38]	Improved connectivity [39]
	User connectivity	Some info avaialble on some routes [40]	Active travel increases [29, 30]	Active travel suppored by real time data		
Maritime	Traffic management	Trials begin	Vehicles outfitted with smart sensors	Urban CAV deliveries commonplace		Majority of micromobility are CAV
	User connectivity	Trials begin		Functional deployment of MaaS 2.0		CAV-enabled on-demand vehicles

Energy vectors

The move to net zero by 2050 will require a complete shift from fossil fuels to sustainably produced electricity, hydrogen and other alternatives, and a switch to supply chains producing the new powertrains.

Liquid fuel, including hydrogen, biofuels and fossil fuels, will still be the dominant energy vector in 2030. This has consequences for policies to decarbonise transport. Most vehicles on the road will be either traditional or hybrid internal combustion engines, including two in three cars and vans, and 85% of HGVs and buses. Nearly 90% of maritime crafts will be powered by liquid fuel. Around 15% of the rail fleet will be diesel-powered. Most air transport will still be using kerosene and only around 10% will be powered by sustainable aviation fuel (SAF) [32].

There will be a major transition to other energy vectors between 2030 and 2050. 80% of inland maritime and 60% of all air transport will use liquid fuels by 2050. Sufficient SAF will be available to power all domestic flights by 2031 and there will be a bigger uptake of power-to-liquid sustainable aviation fuel (e-fuel) by 2036.

Battery electric will power >99% of cars and vans and 50% of HGVs and buses in 2050

Hydrogen-powered aircraft will be commercialised by 2035. Hydrogen will begin as an energy vector for short and medium-range aircraft, although it may be used earlier in smaller commuter aircraft. E-fuels will begin to be the dominant energy vector in air transport by 2040 and hydrogen will power 10% of flights.

Achieving net zero by 2050 means electric will be a dominant energy vector. It will power >99% of cars and vans, 50% of buses, 50% of HGVs, 95% of rail and 100% of micromobility [22]. Hydrogen will also be a major energy vector by 2050. It will fuel 50% of HGVs, 50% of buses, 25% of air transport and 4% of maritime. Autonomous aircraft, drones and regional air travel will mostly be electric/hybrid or hydrogen-powered.

Figure 4 – Energy vectors for road transport sector

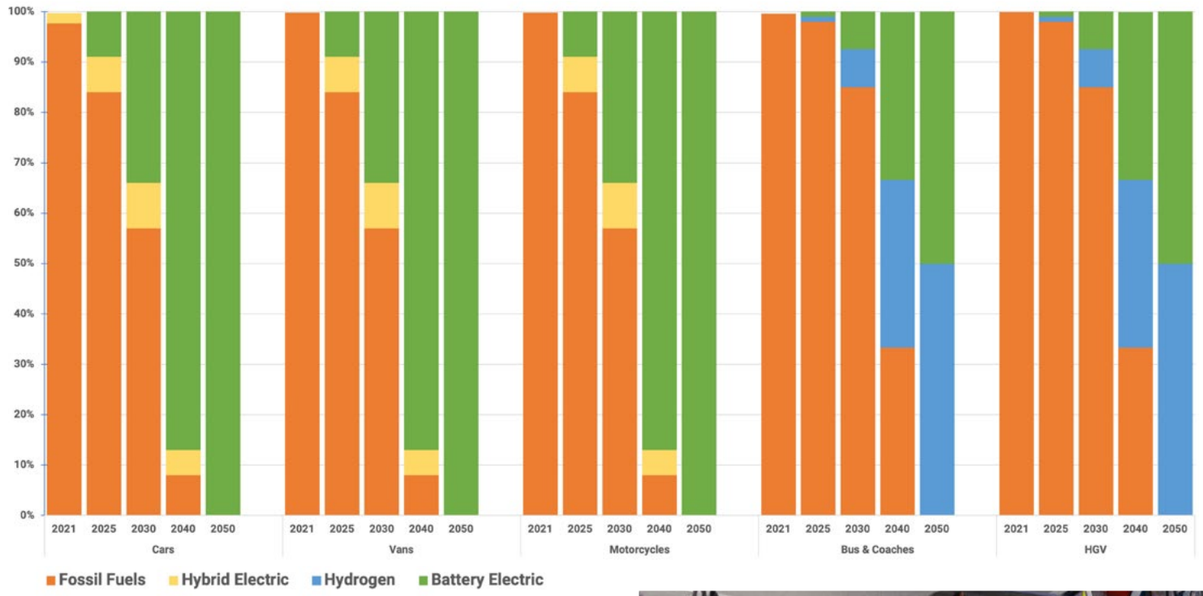
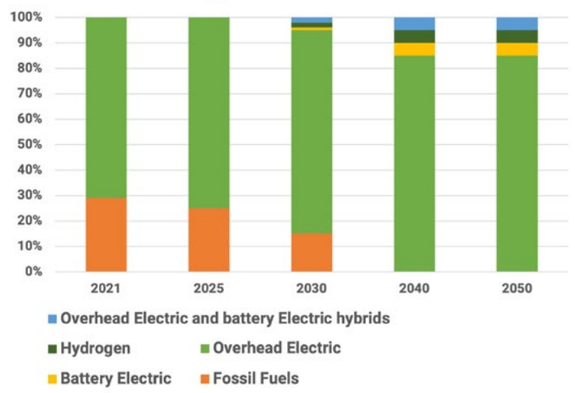


Figure 5 – Energy vectors for rail sector



We expect new sales of cars and vans to be zero emission by 2030, but it will take time to refresh the legacy fleet.

In 2040 >90% of cars will be zero emission as will two in three HGVs. By 2050, all road vehicles will be zero emission.

Energy vectors pathway

CERTAINTY: high | med | low | speculative

Transport modes	Elements	2021 position	By 2025	By 2030	By 2040	By 2050
Air transport	Policy enablers	Early dev of alt. energy vectors	UK SAF mandate implemented	All aircraft certified for 100% SAF	UK SAF industry established	
			CORSIA mandatory for all UK int flights	Sufficient SAF for domestic flights		
			PtL Strategy 2023			
	Advanced Air Mobility (AAM)		>99% battery electric or hydrogen			
	Fuel mix [36-41]	>99% kerosene	>99% kerosene	90% kerosene	70% kerosene	43% kerosene offset [1] [2]
		1% SAF	1% SAF	10% SAF	20% SAF	32% SAF (including some PtL)
			Development of hydrogen powered aviation.	ZE flight demonstrator 2026	10% hydrogen	25% hydrogen for commuter to short-range
	International and domestic		Transaltantic flight 100% SAF demonstrator by 2025	All aircraft certified for 100% SAF by 2030		
			Domestic flight 100% SAF demonstrator by 2023		2031 UK domestic aviation 100% SAF	
			At scale SAF plant by 2025	SAF significant increase in production	Zero-E planes enter into service in 2035	Sufficient SAF to meet >30% UK domestic demand [16]
Maritime	International	Marine diesel & heavy fuel oil (HFO) [11]	BEV for short journeys only	All new ships to be ZE capable		
			TRL3-7 hydrogen & ammonia projects [4]	Wind, biofuel, electro-fuel and H2 demonstrators [6]	Large shift in take up of ZE energy sources from 2030s [5] [15]	All zero emission [3]
	Domestic			40% marine diesel [34]	18% marine diesel [34]	1% marine diesel [34]
	Fuel mix [15]	52% marine diesel [15]	52% Marine diesel [15]	47% low sulphur and heavy fuel oil [15]	33% low sulphur and heavy fuel oil [34]	0% low sulphur and heavy fuel oil [34]
		48% heavy & low sulphur fuel oil [15]	48% low sulphur and heavy fuel oil [15]	4% methanol [34]	10% methanol [34]	26% methanol [34]
				3% shore power [34]	5% shore power [34]	6% shore power [34]
				4% ammonia [34]	30% ammonia [34]	62% ammonia [34]
				2% hydrogen [34]	4% hydrogen [34]	4% hydrogen [34]
Micromobility	Policy enablers	Encourage more active travel	Develop micro-consolidation hubs	Large-scale urban freight consolidation		
		Provide infrastructure		Electric-powered last-mile delivery		
	All modes	E-scooter and e-cargo bike trials ongoing	>99% BEV and active travel modes		100% BEV and active modes	
Rail [7,8,34,35]	Policy enablers	Develop hydrogen and battery solutions	Hydrogen and battery electric trials	Increased electrification of network	Diesel trains removed by 2035-2040	Wholesale integration with energy system
			Manufacture of diesel trains ends	Manufacture of ZE trains only		Net zero rail network [35]
	Fuel mix	71% electric	75% electric	80% electric (inc direct electric and electric diesel hybrids)	85% direct electric	
		25% diesel [10]	29% diesel [10]	15% fossils fuels	electric diesel hybrids phased out	
				2% hydrogen	5% hydrogen	
				2% battery electric hybrids	5% battery electric hybrids	
				1% battery	5% battery	
Road [9,11]	Policy enablers	ICE sales end 2030, hybrids 2035 [10]	ICE de-incentivised	ZEV capability and affordability increased	Shift to ZEV for HGVS [12]	Circular economy for ZEV established
	Cars (2020: 32.9m) [22,22a,3,24,25]	97.6% ICE [9,17]	84% ICE [22,23,24]	57% ICE [22,23,24]	8% ICE [22,23,24]	
		2.1% hybrid [9,17]	7% hybrid [22,23,24]	9% hybrid [22,23,24]	5% hybrid [22,23,24]	
		0.3% BEV [9,17]	9% BEV [22,23,24]	34% BEV [22,23,24]	87% BEV [22,23,24]	100% BEV [22,22a,23,24]
	Vans (LCVs) (2020: 4.3m) [22b,24a]	99.8% ICE [9,18]	84% ICE [9,22b,24a]	57% ICE [9,22b,24a]	8% ICE [9,22b,24a]	
		0.2% BEV [9,18]	9% BEV [9,22b,24a]	34% BEV [9,22b,24a]	87% BEV [9,22b,24a]	100% BEV [9,22b,24a]
			7% hybrid [9,22b,24a]	9% hybrid [9,22b,24a]	5% hybrid [9,22b,24a]	
	Motorcycles (2020: 1.4m) [19,22f]	99.8% ICE [19,22f]	84% ICE [19,22f]	57% ICE [19,22f]	8% ICE [19,22f]	
		0.2% BEV [19,22f]	9% BEV [19,22f]	34% BEV [19,22f]	87% BEV [19,22f]	100% BEV [19,22f]
			7% hybrid [19,22f]	9% hybrid [19,22f]	5% hybrid [19,22f]	
	Bus & coaches (2020: 144k) [22c,22e,25]	99.6% ICE [20]	98% ICE [20,22c,22e,25]	85% ICE [20,22c,22e,25]	33% ICE [20,22c,22e,25]	50% BEV [20,22c,22e,25]
		0.4% BEV [20]	1% BEV [20,22c,22e,25]	7% BEV [20,22c,22e,25]	33% BEV [20,22c,22e,25]	
			1% H2 [20,22c,22e,25]	7% H2 [20,22c,22e,25]	33% H2 [20,22c,22e,25]	50% H2 [20,22c,22e,25]
	HGV (2020: 508k) [22d,24b,29]	99.9% ICE [9,21]	98% ICE [9,22d,24b,29]	85% ICE [9,22d,24b,29]	33% ICE [9,22d,24b,29]	
		0.1% BEV [9,21]	1% BEV [9,22d,24b,29]	7% BEV [9,22d,24b,29]	33% BEV [9,22d,24b,29]	50% BEV [9,22d,24b,29]
			1% H2 [9,22d,24b,29]	7% H2 [9,22d,24b,29]	33% H2 [9,22d,24b,29]	50% H2 [9,22d,24b,29]

Autonomy

Autonomy will make road vehicles smarter, create opportunities for new services such as last-mile delivery by drone, and deliver fully autonomous urban transport.

Automation is being introduced in transport to reduce costs, improve safety or to perform dull, dirty or dangerous human tasks. The balance between these objectives varies across different modes and applications. However, the increased value is universal and the trend clear. Autonomy will be increasingly present and a significant part of the value offering, enabling new services and business models.

Road vehicles are rapidly becoming smarter. We expect to see private vehicles capable of Society of Automotive Engineers level 4 autonomy – operating in driverless mode in limited areas – by 2030 and common by 2035 [26]. They will allow less-able-bodied people to gain or maintain independence. Automated buses and minibuses will undergo trials by 2025 and become commonplace (40% of those in service) by 2035. Low-speed public service vehicles will likely be deployed first.

Automated buses and minibuses will be commonplace by 2035

Use of automated goods vehicles is likely to begin in depots and in motorway platoons before more widespread usage. The UK Heavy Goods Vehicle Platooning (HELM) real-world trials of platooning are scheduled to complete in 2022 [27].

Further trials of autonomous trains will take place on the intercity rail network by 2030. Freight trains and depot-shunting are likely to be the first areas to adopt automated movement. Train automation is highly dependent on rail connectivity and on changing working practices. Automation of maintenance will continue to grow, including use of drones for remote inspection.

The first autonomous commercial air transport flights will take place in new advanced aircraft by 2030. Increasing numbers of last-mile deliveries will be by drones by 2030 [3]. However, although passenger-carrying aircraft can be operated as autonomous vehicles, it is highly likely that they will retain pilots for the foreseeable future.

90% of motorway HGVs will be autonomous by 2050

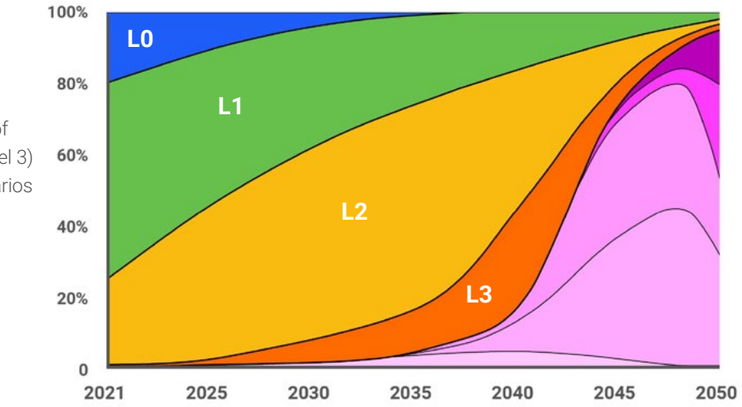
Small-scale autonomous trials will take place on small surface vessels in UK waters by 2030. Automation will be adopted earlier at sea than in harbour. Automation will help smaller vessels to reduce operational costs and reduce risk to life on hazardous routes or missions. Subsea automation will develop from use of remotely operated vehicles.

We anticipate that the urban transport system, air transport, rail freight and ferries to and from UK islands will be fully autonomous by 2050. Some on-board staff will be retained to assist travellers. 90% of motorway HGVs will be autonomous by 2050 and last-mile deliveries in urban and rural areas will increasingly be completed by drone.

Figure 6 – Prediction of percentage of light commercial vehicles (<3.5t) sold with automated functions

Today private vehicles operate with some levels of **driver support**, defined by the Society of Automotive Engineers, level 0-2.

In the future we expect to see private vehicles capable of operating in **driverless mode** in specific scenarios (level 3) by 2025, and operating in driverless mode for all scenarios in limited areas (level 4) by 2030, with those areas expanding over time.



Autonomy pathway

CERTAINTY high med low speculative

Transport modes	Elements	2021 position	By 2025	By 2030	By 2040	By 2050
All modes	Perception & sensing	Technologies with increasing capabilities & reliability (hardware and software) with cost reductions				
	Autonomous control systems	Compute technologies with increasing capabilities (hardware and software) and cost reductions				
	Connectivity & Cyber Security	Increasing connectivity capabilities, evolving cyber threats and cyber security technologies				
Air transport	Airspace management	Upgrading air traffic infrastructure	Advanced network & operation services	ATM data services support CoD [1]	Digital European Sky [2]	
			Cross border free routes [1]	Virtual centres support CoD [1]		
				Change to trajectory based operations		
			UTM system pilot		UTM adopted UK: 2035, internat: 2040	
				Autonomy level 3/5	Autonomy level 4/5	
	Air vehicles	First intracity UAM ops by 2023 [3]	BVLOS passenger UAVs in operation	Drones carrying loads <1 tonnes	Intercity passenger UAVs common [3]	
			City air transport services start [3]	Assisted/autonomous systems certified	UAVs communicate autonomously with UTM	
	Pilots to supervisors		Single pilot operations trial [4]		Single pilot ops, auton separation [1]	
				Autonomous system + human supervisors	Auton. system, no human intervention	
	Ground infrastr. & ops	Auton taxi, take-off & land trials [5]		Auton taxi, take-off & land ops [5]		
					Quantum sensors for poor weather [4]	
	Social acceptance of UAVs	Poor: noise, privacy & environ impacts	Improving, with technology advances	Generally widespread public acceptance		
Maritime	Vessel operation	Unmanned trials underway [6]	Unmanned vessels - deployment	Auton. shipping market £10.33bn [9]		
		5G supports short sea autonomy [6]	Unmanned vessels - surveillance		6G supports surface vessel trials	
		Sat comms for deep sea trials [6]	Unmanned vessels - marine observation			
		Autonomous vessel trials [7,8]				
	Vessel automation in ports		Vessel automat. trials - UK ports [10]		Some automated vessel berthing in port	Automated arrival & berthing common
			Remote pilotage trials	Software pilotage trials	Software pilotage common	
	Port side automation	Automated goods handling at ports [11]	Auton goods transport to / from ports		1st MAFM through a UK port by 2035 [6]	Most ports smart & inter-connected
			Auton passenger transport around ports			
	Standards/Legislation	MASRWG 4th Code of Practice [12]	Updated Code of Practice published	Updated Code of Practice Published	Updated Code of Practice by 2035	
		MARLab report [13]		Centre for Smart Shipping estab.[6]		
		New MASS approved case-by-case		IMO legislation for MASS [14]		Type approval framework for MASS
Rail	Trends	Automation options discussion [15]	Better connectivity -> more automation	In-cab signalling commences	Smart trains adapt to situations [19]	Services adapt to meet demand [19]
		DLR has been driverless since 1987		New operational concepts	ATO (Freight) inc auton. handling [19]	Efficient pass. flow at stations [19]
	Network		FRMCS trials start ~ 2023 [18]	FRMCS on priority routes from 2025	50% network ERTMS/ETCS L2 by 2035 [18]	85% network ERTMS/ETCS L2 by 2045 [18]
					70% network ERTMS/ETCS L2 by 2040 [18]	95% network ERTMS/ETCS L2 by 2050 [18]
	Design & operation	ATO/ETCS trials on UK mainlines [16]	ERTMS / ETCS L2 rollout commences [18]	75% trains ERTMS/ETCS L2 fitted [18]	All trains fitted for ETMS / ETCS L2 [18]	
	Maintenance	Network Rail autonomous inspect'n [17]	Inspecting railways with drones [17]	More auton maint. reduces human risk		
Road	Trends	L4 road trials with safety driver [20]	Advanced road trials: no safety driver	Initial L4 deployments	CAV industry worth £41.7billion [21]	Autonomous usage normal
	MaaS / pods / taxis	Autonomous vehicle trials [22],[23]	Pod road trials, no safety driver		L4 Services common in urban areas	
	HARPS / PSVs	Autonomous bus service trials [25]	Bus depot automation [25]	L4 pods on low complexity routes	L4 rural HARPS deployments	Majority of PSVs are HARPS
				Some L3 capabilities on traditional buses	L4 buses with "captains" not drivers	
	Private vehicles	Initial vehicles with ALKS	Private vehicles with ALKS	L4 trials on series private vehicles.	Self-driving mode on 40% new cars [21]	Self-driving mode on 95% new cars
		AVP trials (off road)	Private vehicles with off-road AVP	Private vehicles with ALKS +	Mid complexity / mid volumes [26]	
		Main automation is ADAS	Improved safety intervention ADAS		High complexity / low volumes [26]	High complexity / high volumes [26]
	Freight	Project HELM UK - platooning [27]	Freight depot automation	Some L3 capabilities on freight vehicles	L4 freight deployment (simple ODD)	
	Standards / legislation	ALKS adoption (2021) [28]	ALKS + consultation (ECE)	"ALKS +" adoption (ECE)	Full AD system approvals (ECE) by 2035	Widespread L4 freight deployments
				Full AD system consultation (ECE)		
		Code of Practice (trials) [30]	Advanced CAM trial approvals by 2023			
		CAVPASS [30]	Low complexity ODD - GBTA	Medium complexity ODD – GBTA 2028	High complexity ODD – GBTA by 2032	
		Scenarios & weather standards in devt	Scenarios & weather standards in GBTA	Complex scenarios agreed by ECE		

Business models

Advances in technology and new government policies will transform business models and lead to bundling of services, better use of resources and mass customisation.

Digitalisation will bring significant commercial opportunities and threats. Advances in robotics and increasing connectivity will alter transport services and bring new business models by 2050. The size of the market for data resulting from greater vehicle connectivity is estimated to be up to US$750 billion by 2030 [26].

Policy, legislation, tax and incentives will significantly shape the future transport system. Businesses will find creative ways to minimise costs and maximise revenues, sharing these benefits with their customers to maximise market share. Creative approaches could all potentially shape future markets including:

- bundling services in a one-stop contract
- maximising use of assets at times of low demand, such as using idle vehicles to transport goods or batteries for grid management
- mass customisation.

Forecasting the most successful business opportunities is extremely challenging, and policymakers and commercial organisations alike will need to react quickly as winners emerge and shape revenue flows. This is reflected in the low confidence rating in most of the forecast.

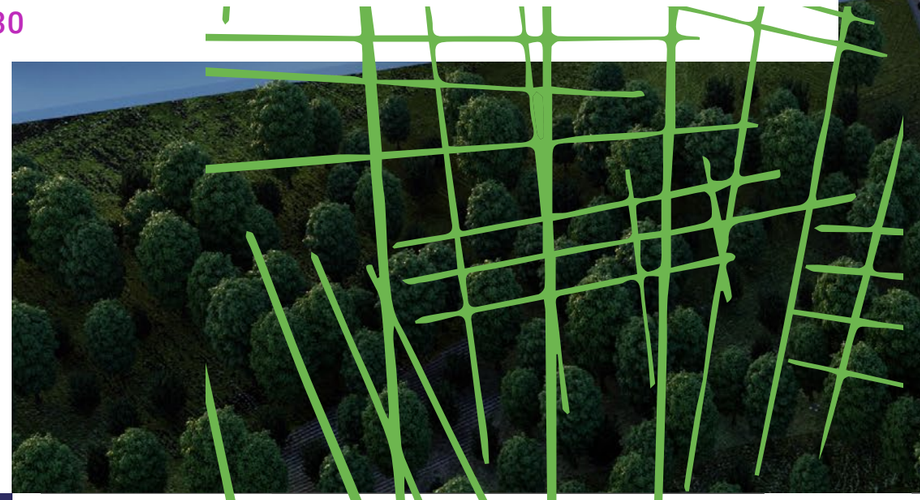
We expect online retail and associated home deliveries will increase from 27.9% in 2020 to over 60% by 2030

We expect online retail and associated home deliveries will increase from 27.9% in 2020 to over 60% by 2030 [7, 8]. About 40% of overall global logistics costs are associated with the last mile [14, 15]. Consumers are demanding faster and more reliable and convenient delivery services. This leads carriers to offer expensive timed, same-day and other traceable services [12, 13]. Industry innovation will continue to reduce the cost and complexity of logistics through measures such as automation of shared storage and distribution systems and increased levels of connectivity [17, 18]. The increased use of commercial drones will also impact the logistics industry [19].

Insurance markets will be disrupted first. Increasing levels of connectivity will allow greater understanding of risk and move the need for insurance away from the user and to the vehicle [1, 4].

Greater connectivity of services and users will increase the use of apps to plan journeys and deliver on-demand personalised services. It will also increase levels of bundled services, including hailing of taxis, ordering of electric bikes and purchase of tickets for buses and trains [6, 9, 10, 11].

Increased data flow and digital twins enabled by increasing connectivity will underpin a number of changes. Cyber security will be critical to delivering a trusted service and creating a significant market opportunity. The global cyber security markets for automotive and aviation will be a combined £12 billion by 2026 [29, 30].



Business models pathway

CERTAINTY high med low speculative

Business model areas		2021 position	By 2025	By 2030	By 2040	By 2050
Retail	Airspace management	2019: 20% of market share [7]	30% market share [8]	63% market share [8]	80% market share	85% market share
	Delivery requirements	Consumer demand for faster, more reliable and convenient delivery services				
		Carriers to offer costly timed, same-day and other traceable services [12, 13]				
	Last mile delivery mode	98% van, <1% bike		20% robot / drone, 78% van, 2% bike	40% robot / drone, 58% van, 2% bike	80% rob/drone, 18% van, 2% bike [14,15]
Insurance	User insurance	Insurance on static risk model	Pay how you drive [1, 4]	AV insurance (cheaper vs human) [1]	Real-time risk insurance [1]	
	Multimodal	Developing market for liabilities on system and service reliability		Increasing market for liabilities on system and service reliability		
	Vehicle insurance			Major shift to insuring vehicles [2,3]	Real-time risk insurance [1]	Real time risk insurance [1]
Circular & resource efficient models	Air Transport [21]	End of use: 80-85% repurposed/recycled	95% repurposed/recycled [23]	100% repurposed/recycled [22]	End of life aircraft material become cheaper than primary materials	
	Rail [24]	Supply chain materials & waste mapped	Embed circular thinking in decision	100% reuse/recycle non-hazardous infra	100% circular processes across network	
	Road [20]	Low levels of circularity	More circularity & efficient asset use	Circularity widely in business models	Full circular value chain & net +ve	
Point of sale	Public, private and shared	Increasing use of apps (with predictive analytics) to plan journey and delivering on demand personalised service				
		Increasing levels of bundled services including hailing taxis, ordered electric bikes, as tickets for buses and trains [6, 9, 10, 11]				
		Reducing car ownership / ability to drive -> increasing fleet operators, with companies repositioning to sell multi modal mobility service rather than products				
Data flow and security	Data flow	Cars 25GB data per hour [27]	AVs 3,600GB data per hour [27]	Digital twin enable services [28]	Real time digital twins enable new business models	
	Cyber security	Global auto market $5.56bn [29], aviation $6.5bn [30]		Cyber in vehicle approval [28]	Continued 10-20% CAGR expected. Critical to national asset	
Revenue and operating model	Enablers	Public policy + technology needed to optimise solution				
	Air Transport [25]	'Hub and spoke' operating model	Consistent operating / revenue model	Consistent operating / revenue model	Increased regional hubs & p2p travel	Int travel at few large airports
		COVID-19 reduced traffic	Traffic returns to pre pandemic level	Pilot distributed aviation	Distributed aviation fully realised	Increased on demand services
	Urban air mobility	Concept	Trials	Trials	Pilot UAM private hire	Early deployment UAM private hire
	Maritime (ferry)	Fixed route & schedule, discrete ticket	Fixed route & schedule, increasing integration of travel pricing		Fixed route & schedule, full integration of pricing – purchasing mobility	
	Maritime (private hire)	On demand door-to-door service, private hire, priced by arrangement				
	Maritime (freight)	Fixed routes & schedule, commercial pricing				
	Micromobility	Initial private hire e-scooter & bike	Wide deployment hire e-scooter & bike	Increasing market for personal scooters (lightweight, high density battery). Impacts fleet scooter market		
		Private payment, not integrated	Private payment, not integrated	Greater integration of mobility pricing		
	Rail	Fixed route & schedule, discrete ticket	Fixed route & schedule, increasing integration of travel pricing		Fixed route & schedule, full integration of pricing – purchasing mobility	
		Product based value chain	Pilot revenue & operating model changes	Services through private partnerships	Service based value chain	
		Some service and utilisation contracts	Block chain enables micro-investment	Block chain secures digital data - individual tailored travel plan & track asset utilisation & maintenance		
	Road (private vehicle)	>90% of cars bought on finance	Peer car share & car club growth		Lower utilisation of private vehicles	
		Revenue from vehicle sale & servicing	Growth in fully serviced vehicles		On demand shared vehicles more affordable and more reliable	
	Road (bus)	Fixed route & schedule, discrete ticket	Intelligent routes & schedule, increasing integration of travel pricing		Intelligent routes & schedule, full integration of mobility pricing	
	Road (taxi)	On demand door-to-door, private and shared, priced per mile / time		Increasing micro transit services	Increasing competition in on demand private vehicles	
		Increasing market for on demand vehicle support - maintenance, cleaning, servicing etc. - brand differentiator and significant revenue source				
		Increasing utilisation of private hire fleet during non peak passenger times, generating value streams from goods services or V2G allowing cost savings to be shared with passengers				

Infrastructure

UK transport's consumption of petroleum products will fall by over 90% by 2050 and be replaced by electricity, hydrogen, ammonia and sustainable fuels. This will create significant new business opportunities for energy generation, production and distribution.

UK transport will consume 60.5 million tonnes of petroleum products in 2021. We expect this to fall to 5.9 million tonnes by 2050. We expect the balance to be made up of other fuels and energy vectors dependent on different modes (Figure 6). This includes 145TWh electricity to support all electric vehicles, which represents 50% of the 2021 UK annual demand. Whilst generation is not expected to be a challenge [57], distribution will require some innovation. Hydrogen, ammonia and sustainable fuel use is forecast to grow exponentially, creating new production and distribution opportunities.

Our forecast reflects efficiency gains in transport solutions but also increasing demand based on the forecasts in 'Travel and transport demand' above. We expect to see:

- 5.7 million tonnes a year equivalent in power-to-liquid and sustainable aviation fuel
- 74TWh of hydrogen for transport, including ammonia for maritime
- 155TWh of electricity for transport.

It is estimated 155TWh of electricity will be needed for transport by 2050

These changes will require significant and rapid development of zero carbon production and distribution on a national scale and international cooperation on supply chains and standards. For example, significant investment is needed to bring in the estimated 280,000 road chargepoints needed by 2030 [32] and the chargepoints needed for the 800km of railway running on battery trains in 2050 [12]. There will also be significant change in the generation and distribution of energy vectors.

It is estimated 280,000 road chargepoints will be needed by 2030

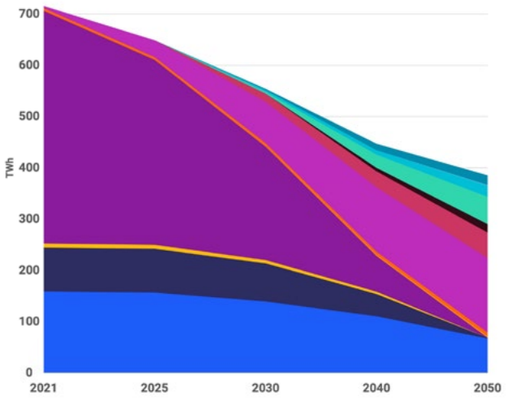
We expect excellent connectivity on all transport to allow travellers to be more productive on the move and improve real-time tracking of goods. Some bespoke transport connectivity infrastructure will deliver significant value, such as digital rail signalling; however, most connectivity is expected to be delivered through cellular or satellite. Low-earth-orbit satellite communications will assist in all transport connectivity, especially in rural or remote areas, including at sea. This increased connectivity will be a key enabler of multiple functions and services across the transport system. All-vehicle connectivity will remove the need for some physical infrastructure such as motorway gantries.

We expect autonomy to place few requirements on infrastructure due to the cost and other burdens on early adopters. It will be applied in a way that adapts to the existing infrastructure.

Figure 7 – Expected changes in energy vectors over time

155 TWh of electricity and 74 TWh of hydrogen are among the energy vectors replacing nearly 55 million tonnes of petroleum products a year by 2050.

With the move from internal combustion engines to more efficient electric powertrain, transport will consume less energy even when taking into account the increase in transport use forecast.



Infrastructure pathway

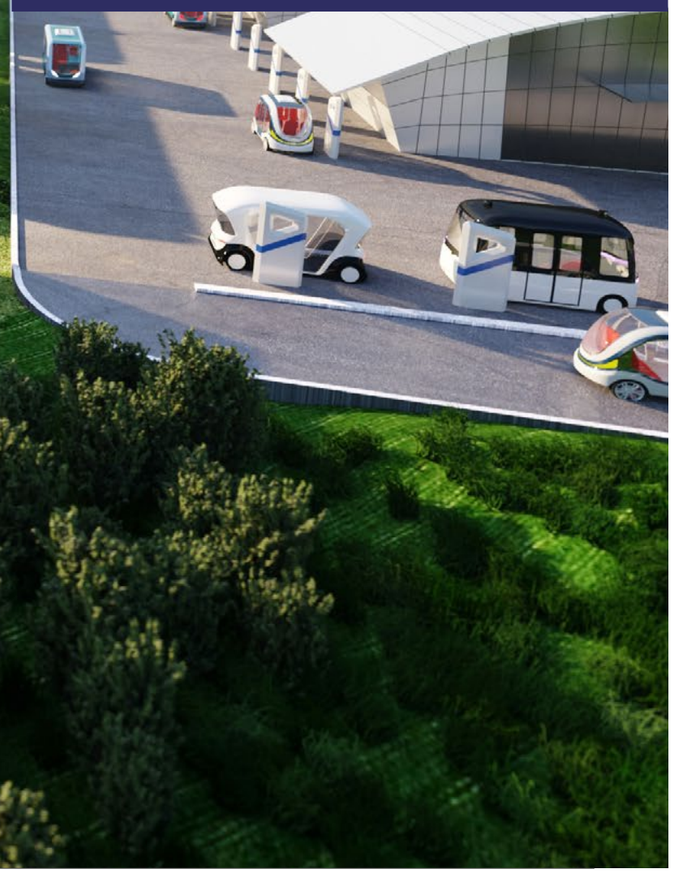
CERTAINTY high med low speculative

Transport modes	Elements	2021 position	By 2025	By 2030	By 2040	By 2050
All mode enablers	Cellular connectivity	Increasing capabilities				
	Satellite / TPNT	Increasing capabilities				
Air transport	Air traffic management	Small scale demo on infrastructure	Improved traffic control for drones	Airspace modernisation [6]	Autonomous traffic control in service	
		Upgrade for future demand [23]	Autonomous traffic control pilots	Re-design of lower airspace [6]		
	Energy / fuel	13.7m tonnes petroleum in 2019 [34]	c13.5m tonnes petroleum products [37]	c12m tonnes petroleum products [37]	c9.5m tonnes petroleum products [37]	c5.8m tonnes petroleum products [37]
		Fossil fuel based kerosene	SAF available at lead airports [6]	Sufficient SAF for domestic flight [6]	UK SAF industry established by 2038 [6]	
			First UK SAF scaled manufacturing [6]	10% of fuel is SAF = 1.4m tonnes [37]	20% of fuel is SAF = 2.7m tonnes	32% of fuel is SAF = 4.3m tonnes [6]
			Hydrogen available at lead airports [6]		10% of fuel is H2 = 1.4m tonnes [6]	25% of fuel is H2 = 3.4m tonnes [6]
			Battery charging at lead airports [6]	Airports substantially electrified		Battery charging at all airports
	Ground support equipment		5% zero emission	20% zero emission	60% zero emission	100% zero emission
	UAM / AAM		Pilot (100s) loading and charging pads	1,000s loading and charging pads	10,000s loading and charging pads	10,000s loading and charging pads
	Other infrastructure		Pilot EV/V2G systems at airports [6]	Pilot charging and maintenance infra	Urban airports/ helipads implemented	
Maritime	Energy / fuel	c7.3m tonnes of petroleum products	c7.9m tonnes of petroleum products	c8.1m tonnes of petroleum products	c3.9m tonnes of petroleum products	c0.1m tonnes of petroleum products
		Marine diesel 160PJ (52%) [58]	Marine diesel 160PJ (52%) [58]	Marine diesel 123PJ (40%) [58]	Marine diesel 55PJ (18%) [58]	Marine diesel 5PJ (c1%) [58]
		Heavy & Low sulphur fuel oil 148 PJ (48%) [58]	Heavy & low sulphur fuel oil 148 PJ (48%) [58]	Heavy & low sulphur fuel oil 148 PJ (48%) [58]	Heavy & low sulphur fuel oil 102 PJ (33%) [58]	Heavy & low sulphur fuel oil 102 PJ [58]
				Methanol 12PJ (4%) [58]	Methanol 31PJ (10%) [58]	Methanol 80PJ (26%) [58]
		Pilot shore-to-ship connections [1]	Shore-side power c60GWh / year [5b]	Shore power 9PJ (3%) =2TWh [58]	Shore power 15PJ (5%) =3TWh [58]	Shore power 22PJ (7%) =5TWh [58]
				Ammonia 12PJ (4%) [58]	Ammonia 92PJ (30%) [58]	Ammonia 191PJ (62%) [58]
				Hydrogen 6PJ (2%) [58]	Hydrogen 12PJ (4%) [58]	Hydrogen 12PJ (4%) [58]
		Limited logistics for alt fuels [2]	Pilot alt fuel for demonstration	Local H2 generation at ports [4]		Widespread logistics for alt fuels
	Other infrastructure	Pilot connected infrastructure	Pilot smart shipping concept [3]			Digital port with central control [3]
		Increased use of IoT to improve flow	Electrification of port equipment [5]		Berthing infrastructure updated	Ports as multi-mode hub [3]
Active travel		c4,000km urban cycle routes in UK [20]			c8,000km urban cycle routes in UK [20]	
		C-ITS for active travel pilot [39,40]	Pilot C-ITS to protect travellers [41]	Aspiration: 50% of trips active [42]		
		Shared cycle hire in most cities [20]	Improving cycling & walking infra [48]	Increasing combotravel [49]		
Micromobility		Micromobility infra near zero [20]	Battery exchange in 50% schemes [20]	25% EV chargers cover mixed vehs [20]	100% of shared MM pair with infra [20]	50% EV chargers cover mixed veh's [20]
			Pilot multimode e-Mobility hubs [20]		50% of private MM pair with infra [20]	1% of urban roads have MM lane [20]
Rail	Traffic management	Conventional signalling [22]	ERTMS / ETCS level 2 roll-out [22]	50% covered by ERTMS / ETCS L2 [22]	70% covered by ERTMS / ETCS L2 [22]	95% covered by ERTMS / ETCS L2 [22]
	User connectivity	No specific user connectivity infra				No specific user connectivity infra
		Pilot line side connectivity [10]	Further pilot line side connectivity			
	Energy / fuel	688,000 tonnes of petroleum [34]	643,000 tonnes of petroleum [36]	554,000 tonnes of petroleum [36]	388,000 tonnes of petroleum [36]	Near zero petroleum [36]
		38% (6,012 STK) track electrified [19]	42% (6,656 STK) track electrified [36]	50% (7,924 STK) track electrified [36]	65% (10300 STK) track electrified [36]	86% (13040 STK) track electrified [12]
				Pilot H2 fuelling deployed		9% of UK railway H2 (1300 STK) [12]
				Pilot battery charging points		5% UK railway battery (800 STK) [12]
		c5,100 GWh electricity consumed [34]	c5,600 GWh electricity consumed [56]	c6,700 GWh electricity consumed [56]	c8,700 GWh electricity consumed [56]	c12,200 GWh electricity consumed [56]
		Negligible levels of H2 consumed [56]	Negligible levels of H2 consumed [56]	Negligible levels of H2 consumed [56]	Negligible levels of H2 consumed [56]	c1,200 GWh H2 consumed [56]
Road	Traffic management	Some localised traffic contol	LEO satellite comms pilot [53]	Widespread satellite comm using LEO	Infra enables PAYG options	
		Pilot sensors to monitor traffic [24]	Widespread sensors manage traffic [27]	Seamless hand-over cellular and satellite		
		Pilot AI traffic management [25]	Geospatial data improves road data [28]	Cellular V2X capabilities expanded	In-vehicle traffic messaging common	AI influence AV and human drivers
	User / other connectivity	No specific user connectivity infra	LEO Satellite comms trials [53]	LEO satellite comms commonplace	Pilot direct vehicle - satellite comms	Widespread direct vehicle sat comms
		4G across most of UK roads [26]	Widespread 4G, some 5G [53]			
	Autonomy	No changes expected to enable autonomous driving - some enablers such as digitisation of road rules [11]				
	Energy / fuel	> 39m tonnes petroleum [34]	c31m tonnes petroleum [35]	c19m tonnes petroleum [35]	c6m tonnes petroleum [35]	Near zero petroleum [35]
		Accounts for 98% road transport [33]				
		4,500 GWh / year for charging [54]	38,000 GWh / year for charging [54]	87,000 GWh / year for charging [54]	134,000 GWh / year for charging [54]	155,000 GWh / year for charging [54]
		36,000 public EV charge points [7,32]	140,000 public charge points [31]	280,000 public charge points [31]	400,000 public charge points [31]	520,000 public charge points [32]
		22% are rapids (>22kW) [7,32]	Approx even 3-7, 22 and 50kW [31]	Increase in 22 and 50kW [31]	Increase in 50kW [32]	
		3% high power (100kW+) [7, 32]		6,000 high-powered (100kW+) [31]	650 ultra-rapid chargers for HGVs [31]	6000 SRN rapid chargers [59]
		Niche volumes of hydrogen [54]	900 GWh hydrogen per year [56]	6,500 GWh hydrogen per year [56]	31,000 GWh hydrogen per year [56]	46,000 GWh hydrogen per year [56]
		12 H2 fuelling stations in UK [14, 15]	53 H2 fuelling stations in UK [17]	185 H2 fuelling stations in UK [18]	250 H2 fuelling stations in UK [31]	300 H2 fuelling stations in UK [20]
		No road catenary infrastructure in UK	Pilot catenary – m'way & city [50, 51]	Catenary <0.1% SRN or city centre [52]	Catenary <0.1% SRN or city centre [52]	Catenary <0.1% SRN or city centre [52]

International benchmarking

A vision of transport in 2050 can only be realised by investing in new and emerging areas where the UK can capture value. We must understand which organisations have the strengths to deliver which part of a future transport system. This helps investors understand where large opportunities align to UK strengths and where they can maximise the impact of their investment. It also helps us to understand where there are strategic reasons to invest, including in areas where the UK may not be strong.

We are carrying out a significant study to gain a detailed understanding of the strengths and weaknesses of the UK transport supply base relative to other nations, and of the threats that may alter the future landscape. We will combine this work with the opportunities identified in the vision and pathways and with other sources when we make our investment decisions. A summary of the project's findings will be published in autumn 2021.



The route ahead

The vision and pathways highlight major new opportunities for economic growth and societal benefit and show how businesses need to adapt and evolve in order to secure market position and grow.

These challenges and opportunities are largely the same across the globe. The major trends we identify are listed below.

Supply chain transformation – The way we power our transport will change radically and bring significant opportunities and risks for powertrain supply chains where 30% of the value of vehicles, aircraft and vessels lies.

> **Innovate UK will work with government and industry to maximise the role of UK companies in future supply chains.**

Energy balance – Use of electricity, hydrogen, ammonia and sustainable fuel for transport is forecast to grow exponentially and create new opportunities for generation, production, and distribution.

> **Innovate UK will help to bring together and optimise transport and energy systems.**

Digital revolution – Advances in robotics and increasing connectivity will create opportunities for greater efficiency, new services for travellers, new business products and amenities in multi-billion global markets, and be critical to the operation of transport as a national infrastructure.

> **Innovate UK will work with the transport and digital industries to gain maximum advantage for the UK from the digital revolution and work with government to understand and mitigate risks.**

Responsibility for managing demand – The way people travel and behave is changing, and this will be accelerated by advances in technology that will improve transport services, reduce costs, and revolutionise business models. These changes could result in an unsustainable transport system without smart policies and interventions.

> **Innovate UK will work with others to understand the impact of innovation and help inform policy to deliver an optimised transport system.**

Investing collaboratively

We must invest collaboratively across the UK's transport system to maximise societal and economic benefit. UK transport is part of a global system and we must work with international partners to develop global solutions. We will take a systems-wide approach needed to ensure that changes to the way people and goods move are well considered and benefit everyone. We will use this Vision 2050 document alongside our international benchmarking and other inputs to inform our decisions, including on where to invest.

The future is yet to be written. We have based our conclusions on information available today. New information and future change will need to be reflected in the document. We will ensure there are ways to provide feedback to us and we will update this document as often as we need to. We look forward to working with you to invest in the future of transport.

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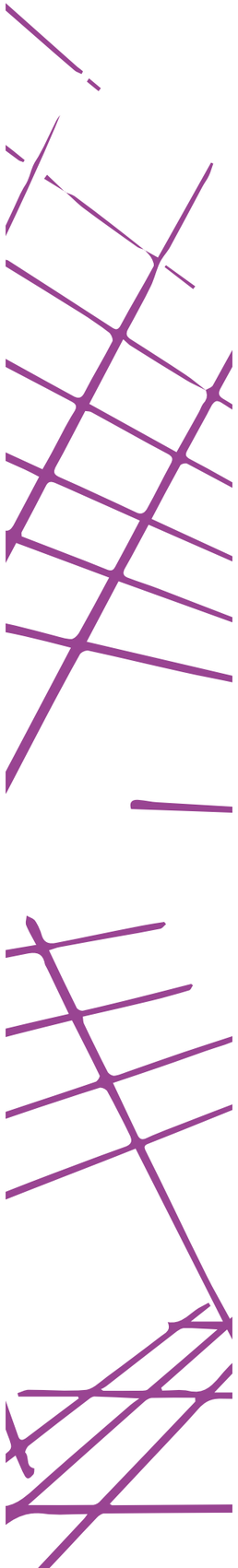

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Annex 1

Pathway graphic abbreviations

4G	fourth generation of broadband cellular network technology
5G	fifth generation of broadband cellular network technology
6G	sixth generation of broadband cellular network technology
7G	seventh generation of broadband cellular network technology
AAM	advanced air mobility
AD	automated (or autonomous) driving
ADAS	advanced driver assistance system
ADS-B	automatic dependence surveillance broadcast
AI	artificial intelligence
AIS	automatic identification system
ALKS	automated lane keeping system
ALN	Automatic London Network
Alt.	alternative
AMV	air mobility vehicle
app	mobile app
AURN	automatic urban and rural network
ATM	air traffic management
ATO	automatic train operation
AV	autonomous vehicle
AVP	autonomous valet parking
BEV	battery electric vehicle
BVLOS	beyond visual line of sight
C3X L1 etc	connected car customer experience
CAM	connected autonomous mobility
CARG	Compound Annual Growth Rate
CAV	connected autonomous vehicle
CAVPASS	connected and autonomous vehicle process for assuring safety and security
C-ITS	cooperative intelligent transport systems
CoD	capacity on demand
CORSIA	carbon offsetting and reduction scheme for international aviation
CP	control period
C-V2X	cellular vehicle to everything
DLR	Docklands Light Railway
EAN	European Aviation Network
ECE	United Nations Economic Commission for Europe (also UNECE)

e-mobility	electric mobility
ERTMS / ETCS	European Rail Traffic Management System / European Train Control System
EV	electric vehicle
FRMCS	future railway mobile communication system
GBTA	Great Britain Type Approval
GDP	gross domestic product
GSM-R	global system for mobile communications - railway
H2	hydrogen
HARPS	Highly Automated Road Passenger Services
HGV	heavy goods vehicle
ICE	internal combustion engine
IMO	International Maritime Organisation
IoT	internet of things
LCV / LGV	light commercial vehicle / light goods vehicle
LEO	low earth orbit
LRIT	long range identification and tracking
MaaS	mobility as a service
MAFM	multimodal autonomous freight movement
MARLab	Maritime Autonomy Regulation Lab
MASRWG	Maritime Autonomous Systems and Regulatory Working Group
MASS	maritime autonomous surface ships
Micromobility	electric and human-powered vehicles under 200kg and with speeds restricted to under 25mph
no	number
ODD	operational design domain
OTS	organised track structure
P2P	peer to peer
pax	passengers
PAYG	pay as you go
PBN	performance based navigation
PtL	power to liquid
R&D&I	Research, Development and Innovation
RORO	roll on roll off
SAE	Society of Automotive Engineers
SAF	sustainable aviation fuel
SD	safety driver
STK	single track kilometre
SRN	Strategic Road Network
TCO	total cost of ownership
TPNT	terrestrial positioning, navigation and timing
TRL	technology readiness level
UAM	urban air mobility
UAV	unmanned aerial vehicle
UTM	unmanned air traffic management
V2X	vehicle to x
VOSA	Vehicle and Operator Services Agency
VTOL	vertical take-off and landing
Zero-E	Zero Emission

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