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, innovate 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 emerging trends 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.
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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. Transportation and transport manufacturing generated over £109 billion added value for the UK in 2019, 5.5% of the total UK output, 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. 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 and in the government commitment to raise investment in research and development, including through its UK Research and Development Roadmap.

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 armoits 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.

UK TRANSPORT VISION 2050
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 traveler 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

[Shadings indicating high, med, low, and speculative 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. 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[1], a greater push for reducing travel[2] 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[3, 4, 5] 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[6]. 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$10 billion by 2040[7] and there will be 76,000 operational drones by 2030[8]. 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[9, 10], 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 active travel, with the figure rising to 30% for walking, both figures up on pre-pandemic levels[10]. These changing attitudes are recognised in the Department for Transport’s Gear Change[11] 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[12]. Micromobility will also complement public transport by offering a viable option for the first and last mile of the journey[13]. 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[14] – 419.1 million tonnes of goods were handled in 2020–21 (a fall of 11% from the previous year)[15]. Freight is expected to grow in the short to medium term with the advent of new freighters[16] and the associated improvements in efficiency and cost of operations at UK ports[18]. Coastal ports and their interaction with large hubs will unlock the potential of short shipping for freight movement between 2025 and 2040[18]. This shift may impact road and rail freight mileage. However, coastal ports will require investment to handle increased freight volumes efficiently[15], 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[19]. 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[18]. Passengers will continue to use rail, but changing home and office work patterns will impact passenger numbers[20]. 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[21]. 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[22]. 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[23].

Road light commercial vehicles (LCV) – LCV traffic fell by 9% between 2019 and 2020[24], but a rise in online sales to 27% 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[24]. Government forecasts suggest LCV traffic will grow between 23% and 108% by 2050[25]. 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%)[22] given the improved economies. 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[25], but use has quickly rebounded. Total road traffic is forecast to grow by between 17% and 51% between 2015 and 2050[26] 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[27]. Autonomy, an increase in shared services and incentives to decongest roads will deliver a "modest"[21] 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[28]. Private car ownership remains attractive for households, but it is a comparatively inefficient means of travel[29].

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[30].

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[31]. 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
<table>
<thead>
<tr>
<th>Transport Modes</th>
<th>Elements</th>
<th>2021 Position</th>
<th>By 2025</th>
<th>By 2030</th>
<th>By 2040</th>
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</thead>
<tbody>
<tr>
<td><strong>Air Transport</strong></td>
<td>Market Drivers</td>
<td>Pax travel at historic low. Freight movements hampered by C19 and EU exit.</td>
<td>EU Exit offers new way to trade incl. rise of Freeports. Pax travel up</td>
<td>Cargo air demand increased in 2021</td>
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<td></td>
<td>Air Mobility Vehicles</td>
<td>Demand decrease - less commuting and shift to health, wellbeing and accessibility benefits continue to result in high levels of active travel</td>
<td>Rural routes certified for BVLOS</td>
<td>Business travel C19 impact possible</td>
<td>Business travel C19 impact possible</td>
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<td></td>
<td>Civil Aviation</td>
<td>Common modal option for Pax</td>
<td>Early Adopters - Gov and public services</td>
<td>Passenger numbers approx. 13% higher in 2030 than in 2019</td>
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<td></td>
<td>International Freight</td>
<td>2020 UK airports handled 2.7m tonnes, ~50% less than 2019</td>
<td>Air Freight - high value but very low volume</td>
<td>Estimates put air freight at a 4.5% compound growth rate</td>
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<td><strong>Maritime</strong></td>
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<td>Passenger</td>
<td>Short sea ferry pass down 0.3% in 2020</td>
<td>Pax growth close to pre-pandemic levels</td>
<td>Demand for sustainable cruises</td>
<td>Demand for sustainable cruises</td>
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<td></td>
<td>Freight</td>
<td>95% of goods moved by ships in 2020</td>
<td>Tonnage +3% dry bulks and containers</td>
<td>Tonnage +8% compared to 20</td>
<td>Tonnage +8% compared to 20</td>
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<td>Movements down by 5-10% in 2020 but beginning to recover</td>
<td>Liquid bulk movements down due to less crude oil being shipped</td>
<td>Increase in coastal shipping sees modal shift away from road</td>
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<td>Micromobility (all modes)</td>
<td>Micromobility 30% of urban deliveries</td>
<td>Freeports increase trade volume, more vessels in UK waters</td>
<td>Air cargo demand increased in 2021</td>
<td>Air cargo demand increased in 2021</td>
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<td><strong>Micromobility and Active Travel</strong></td>
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<td>Urban movements center around walking and cycling</td>
<td>Cargo demand increases in 2021</td>
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<td>Walking</td>
<td>2019 walking +26% of all trips</td>
<td>50% of journeys in towns and cities cycled or walked by 2030</td>
<td>Freeports increase trade volume, more vessels in UK waters</td>
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<td>Cycling</td>
<td>Cycling 45% above 19 levels</td>
<td>44% user demand over 2025 levels</td>
<td>Urban movements center around walking and cycling</td>
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<td>Micromobility (walking)</td>
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<td>Complementary to public transport</td>
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<td><strong>Rail</strong></td>
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<td>Freight</td>
<td>Mode share 9% for freight</td>
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<td>Cargo demand increases in 2021</td>
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<td><strong>Road</strong></td>
<td>Market Drivers</td>
<td>85% of journeys made in 2019</td>
<td>Pax AAM available but piloted. Large growth in drone freight delivery/air travel up</td>
<td>Cargo air demand increased in 2021</td>
<td>Cargo air demand increased in 2021</td>
<td>Cargo air demand increased in 2021</td>
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<td>Car</td>
<td>2020 car traffic -24.7% from 2019</td>
<td>Pax AAM available but piloted. Large growth in drone freight delivery/air travel up</td>
<td>Cargo air demand increased in 2021</td>
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<td>Bus &amp; Coaches</td>
<td>Shift away from public transit (bus)</td>
<td>Pax AAM available but piloted. Large growth in drone freight delivery/air travel up</td>
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<td>Freight - Van / Light Commercial</td>
<td>Traffic -9.1% from 2019 to 50.5 bvm</td>
<td>Pax AAM available but piloted. Large growth in drone freight delivery/air travel up</td>
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<td></td>
<td>Freight - HGV</td>
<td>Traffic -9.1% from 2019 to 50.5 bvm</td>
<td>Pax AAM available but piloted. Large growth in drone freight delivery/air travel up</td>
<td>Cargo air demand increased in 2021</td>
<td>Cargo air demand increased in 2021</td>
<td>Cargo air demand increased in 2021</td>
</tr>
</tbody>
</table>

**Note:** The table above represents the UK TRANSPORT VISION 2050 report data, detailing the market drivers, passenger and freight transport trends, and future projections. The CERTAINTY column indicates the level of certainty for each projection. The report includes scenarios and data on travel and transport demand, focusing on modal changes, technology adoption, and policy impacts. The table provides a snapshot of the forecasted changes across various transport modes, highlighting the impact of COVID-19, technical advancements, and policy interventions.
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 [15]. 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 Experience level 3) by 2030, and 75% having intelligent decision making by 2050 [34]. 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.

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 (C3X)

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.

- L1. Basic vehicle monitoring
- L2. Link to driver’s digital ecosystem
- L3. Personalisation for all occupants
- L4. Multisensory interactions for all occupants
- L5. Intelligent decision making & seamless link to environment
<table>
<thead>
<tr>
<th>Transport modes</th>
<th>Elements</th>
<th>2021 position</th>
<th>By 2025</th>
<th>By 2030</th>
<th>By 2040</th>
<th>By 2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>All modes</td>
<td></td>
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<tr>
<td>Cellular connectivity</td>
<td></td>
<td>Upgrading air traffic infrastructure</td>
<td>BSN using satellites</td>
<td>Defragmentation of EU Skies</td>
<td>Digital European Sky adopted</td>
<td></td>
</tr>
<tr>
<td>Satellite, positioning and timing</td>
<td></td>
<td>ADS-B Trials</td>
<td>Airspace systemised</td>
<td>UTM and ATM running together</td>
<td>UTM adopted</td>
<td></td>
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<tr>
<td>Traffic management</td>
<td></td>
<td>OTS allows free routing</td>
<td>Digital sharing ATC across airports</td>
<td>Widespread satellite connectivity</td>
<td>Users routinely connected</td>
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<tr>
<td>User connectivity</td>
<td></td>
<td>EAN allows connectivity</td>
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<tr>
<td>Maritime</td>
<td></td>
<td>Anonymous tracking trials</td>
<td>Shift to digital logistics via IoT</td>
<td>Increased use of AIS and LRIT for tracking</td>
<td>CAV capable vessels for berthing</td>
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<tr>
<td>Traffic management</td>
<td></td>
<td>5G unmanned CAV trials</td>
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<tr>
<td>User connectivity</td>
<td></td>
<td>Reliance on land based comms</td>
<td></td>
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<tr>
<td>Rail</td>
<td></td>
<td>GSM-R migrates to packet switching</td>
<td>NORMS trials start</td>
<td>75% trains fitted with ERTMS/ETCS L2</td>
<td>100% trains ERTMS/ETCS L2</td>
<td>85% network ERTMS/ETCS (2044)</td>
</tr>
<tr>
<td>Traffic management</td>
<td></td>
<td>LRITMS trials continue</td>
<td>NORMS roll out</td>
<td>Trackside infrastructure for comms</td>
<td>50% network ERTMS/ETCS L2</td>
<td>95% network ERTMS/ETCS (2049)</td>
</tr>
<tr>
<td>User connectivity</td>
<td></td>
<td>Reduce ETCS deployment cost</td>
<td>NORMS / ETCS level 2 roll out</td>
<td>Trains have wi-fi connectivity</td>
<td>70% network ERTMS/ETCS L2</td>
<td>100% network ERTMS/ETCS (2059)</td>
</tr>
<tr>
<td>Road</td>
<td></td>
<td>C-ITS enabling road safety, efficiency</td>
<td>More C-V2V built in or added on</td>
<td>New cars have V2X / C-V2X capability</td>
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<tr>
<td>Traffic management</td>
<td></td>
<td>No vehicles with C-V2X increases</td>
<td>Data linked to insurance premiums</td>
<td>Retrofit older models with V2X/C-V2X</td>
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<tr>
<td>User connectivity</td>
<td></td>
<td>Vehicles broadcast emergency events</td>
<td>Sensor enabling traffic management</td>
<td>Remote driving capability deployed</td>
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<tr>
<td>Maritime</td>
<td></td>
<td>Use of sensors to monitor traffic</td>
<td>Geospatial info improving data</td>
<td>Sensor tech for informed choice</td>
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<td>Traffic management</td>
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<td>AI traffic management trials in UK</td>
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<tr>
<td>User connectivity</td>
<td></td>
<td>4G ubiquitous across network</td>
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<tr>
<td>Road</td>
<td></td>
<td>80% new vehicles meet C3X L1</td>
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<tr>
<td>Traffic management</td>
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<td>90% new vehicles meet C3X L2</td>
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<tr>
<td>User connectivity</td>
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<td>10% new vehicles meet C3X L1</td>
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<tr>
<td>Active travel</td>
<td></td>
<td>Sensor tech to enable C-ITS</td>
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<tr>
<td>Traffic management</td>
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<td>Some info available on some routes</td>
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<tr>
<td>User connectivity</td>
<td></td>
<td>Active travel increases</td>
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<tr>
<td>Maritime</td>
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<td>Trials begin</td>
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<tr>
<td>User connectivity</td>
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</table>

**CERTAINTY**
- **high**
- **med**
- **low**
- **speculative**
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).

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. 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.

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

<table>
<thead>
<tr>
<th>Transport modes</th>
<th>Elements</th>
<th>2021 position</th>
<th>By 2025</th>
<th>By 2030</th>
<th>By 2040</th>
<th>By 2050</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Air transport</strong></td>
<td>Policy enablers</td>
<td>Early dev of alt. energy vectors</td>
<td>UK SAF mandate implemented</td>
<td>All aircraft certfied for 100% SAF</td>
<td>UK SAF industry established</td>
<td>CERTAINTY: high</td>
</tr>
<tr>
<td></td>
<td>Advanced Air Mobility (AAM)</td>
<td>&gt;99% battery electric or hydrogen</td>
<td>Development of hydrogen powered aviation</td>
<td>ZE flight demonstrator 2026</td>
<td>70% kerosene</td>
<td>43% kerosene offset</td>
</tr>
<tr>
<td></td>
<td>Fuel mix [36-41]</td>
<td>99% kerosene</td>
<td>Transatlantic flight 100% SAF demonstrator by 2025</td>
<td>All aircraft certified for 100% SAF by 2030</td>
<td>20% SAF</td>
<td>32% SAF (including some PtL)</td>
</tr>
<tr>
<td></td>
<td>International and domestic</td>
<td>&gt;99% battery electric or hydrogen</td>
<td>Domestic flight 100% SAF demonstrator by 2023</td>
<td>SAF significant increase in production</td>
<td>25% hydrogen for commuter to short-range</td>
<td></td>
</tr>
<tr>
<td><strong>Maritime</strong></td>
<td>International</td>
<td>Marine diesel &amp; heavy fuel oil (HFO)</td>
<td>BEV for short journeys only</td>
<td>All new ships to be ZE capable</td>
<td>Large shift in take up of ZE energy sources from 2030s</td>
<td>CERTAINTY: high</td>
</tr>
<tr>
<td></td>
<td>Domestic</td>
<td>3% shore power</td>
<td>Wind, biofuel, fuel cell and H2 demonstrators</td>
<td></td>
<td>1% marine diesel</td>
<td>1% marine diesel</td>
</tr>
<tr>
<td></td>
<td>Fuel mix [16]</td>
<td>3% shore power</td>
<td>90% marine diesel</td>
<td></td>
<td>8% low sulphur and heavy fuel oil</td>
<td>1% SAF</td>
</tr>
<tr>
<td><strong>Micromobility</strong></td>
<td>Policy enablers</td>
<td>Encourage more active travel</td>
<td></td>
<td></td>
<td></td>
<td>CERTAINTY: high</td>
</tr>
<tr>
<td></td>
<td>All modes</td>
<td>Provide infrastructure</td>
<td>Develop micro-consolidation hubs</td>
<td></td>
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<tr>
<td><strong>Rail</strong> [22d,24b,29]</td>
<td>Policy enablers</td>
<td>Develop hydrogen and battery solutions</td>
<td></td>
<td></td>
<td></td>
<td>CERTAINTY: high</td>
</tr>
<tr>
<td></td>
<td>All modes</td>
<td>Hydrogen and battery electric trials</td>
<td></td>
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<tr>
<td></td>
<td>Fuel mix</td>
<td>71% electric</td>
<td>Manufacture of diesel trains ends</td>
<td></td>
<td></td>
<td>CERTAINTY: high</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25% diesel</td>
<td></td>
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<tr>
<td><strong>Road</strong> [22a,b,34,35]</td>
<td>Policy enablers</td>
<td>ICE sales end 2030, hybrids 2035</td>
<td></td>
<td></td>
<td></td>
<td>CERTAINTY: high</td>
</tr>
<tr>
<td></td>
<td>Cars (2020: 32.9m) [22b,e,25]</td>
<td>97.6% ICE</td>
<td></td>
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<td></td>
<td>8% ICE</td>
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<tr>
<td></td>
<td>Vans (LCVs) (2020: 4.3m) [22c,22e]</td>
<td>98.6% ICE</td>
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<tr>
<td></td>
<td>Motorcycles (2020: 1.4m) [22d,24a]</td>
<td>99.6% ICE</td>
<td></td>
<td></td>
<td></td>
<td>5% ICE</td>
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<tr>
<td></td>
<td>Bus &amp; coaches (2020: 144k) [22f]</td>
<td>99.9% ICE</td>
<td></td>
<td></td>
<td></td>
<td>5% battery electric hybrids</td>
</tr>
<tr>
<td></td>
<td>HGV (2020: 508k) [22d,24a,29]</td>
<td>99.9% ICE</td>
<td></td>
<td></td>
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<td>100% BEV</td>
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</tbody>
</table>

### Key notes:
- **ICE sales end 2030, hybrids 2035**
- **100% BEV and active travel modes**
- **UK SAF industry established**
- **Wholesale integration with energy system**
- **ZEV capability and affordability increased**
- **Shift to ZEV for HGVs**
- **Circular economy for ZEV established**
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.
## Autonomy pathway

### Transport modes

<table>
<thead>
<tr>
<th>Elements</th>
<th>2021 position</th>
<th>By 2025</th>
<th>By 2030</th>
<th>By 2040</th>
<th>By 2050</th>
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</thead>
<tbody>
<tr>
<td><strong>All modes</strong></td>
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<tr>
<td>Perception &amp; sensing</td>
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<tr>
<td>Autonomous control systems</td>
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<tr>
<td>Connectivity &amp; Cyber Security</td>
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<tr>
<td><strong>Air transport</strong></td>
<td>Upgrading air traffic infrastructure</td>
<td>Advanced network &amp; operation services</td>
<td>ATM data services support CoD</td>
<td>Digital European Sky</td>
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<td></td>
<td>Cross border free routes</td>
<td>Virtual centres support CoD</td>
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<td></td>
<td>UTM system pilot</td>
<td>Change to trajectory based operations</td>
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<tr>
<td></td>
<td>BVLOS passenger UAVs in operation</td>
<td>Drones carrying loads &lt;1 tonnes</td>
<td>UTM adopted UK, 2035; internat: 2040</td>
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<tr>
<td></td>
<td>City air transport services start</td>
<td>Interally passenger UAVs common</td>
<td>Autonomy level 4/5</td>
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<tr>
<td></td>
<td>Single pilot operations trial</td>
<td>UAVs communicate autonomously with UTM</td>
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<td>Single pilot ops, auton separation</td>
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<td>Auton. system, no human intervention</td>
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<td><strong>Vessel operation</strong></td>
<td>Unmanned trawl deployment</td>
<td>Unmanned vessels - surveillance</td>
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<td>Unmanned vessels - marine observation</td>
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<td>Autonomous vessel trials</td>
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<td><strong>Vessel automation in ports</strong></td>
<td>Vessel automatic - UK ports</td>
<td>Software pilotage trials</td>
<td>Some automated vessel berthing in port</td>
<td>Automated arrival &amp; berthing common</td>
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<td>Remote pilotage trials</td>
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<td><strong>Port side automation</strong></td>
<td>Automated goods handling at ports</td>
<td>Auton goods transport to / from ports</td>
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<td>Auton passenger transport around ports</td>
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<td><strong>Standards/Legislation</strong></td>
<td>MASRWG 4th Code of Practice</td>
<td>Updated Code of Practice published</td>
<td>Centre for Smart Shipping estab.</td>
<td>Type approval framework for MASS</td>
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<td>MAS, LR report</td>
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<td>New MASS approved case-by-case</td>
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<tr>
<td><strong>Trends</strong></td>
<td>Automation options discussion</td>
<td>Better connectivity -&gt; more automation</td>
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<td></td>
<td>DLR has been driverless since 1987</td>
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<tr>
<td><strong>Network</strong></td>
<td>ATO/ETCS trials on UK mainlines</td>
<td>Inspecting railways with drones</td>
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<td><strong>Design &amp; operation</strong></td>
<td>Network Rail autonomous inspection</td>
<td>Network Rail autonomous inspection</td>
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<td><strong>Maintenance</strong></td>
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<td><strong>Road</strong></td>
<td>L4 road trials with safety driver</td>
<td>Advanced road trials: no safety driver</td>
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<td></td>
<td>Autonomous vehicle trials</td>
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<td>Autonomous bus service trials</td>
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<tr>
<td><strong>Private vehicles</strong></td>
<td>Initial vehicles with AKS</td>
<td>Private vehicles with ALKS</td>
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<td></td>
<td>AVP trials (off road)</td>
<td>Private vehicles with off-road AVP</td>
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<tr>
<td></td>
<td>Main automation is ADAS</td>
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<td><strong>Freight</strong></td>
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<tr>
<td><strong>Equipment &amp; systems</strong></td>
<td>Code of Practice (trials)</td>
<td>Advanced CAM trial approvals by 2023</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>CAVPASS (speculative)</td>
<td>Low complexity ODD - all A</td>
<td></td>
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<tr>
<td></td>
<td>Scenarios &amp; weather standards in dev</td>
<td>Scenarios &amp; weather standards in GBTA</td>
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<tr>
<td><strong>Standards / legislation</strong></td>
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</tr>
</tbody>
</table>

### Technologies with increasing capabilities & reliability (hardware and software) with cost reductions

1. **Increasing connectivity capabilities, evolving cyber threats and cyber security technologies**

   - **By 2025**
     - Self-driving mode on 95% new cars
     - Software pilotage common
     - Inspecting railways with drones
     - L4 road trials with safety driver
   - **By 2030**
     - Multi-technology ODD - all A
     - Medium complexity ODD - all A
   - **By 2040**
     - High complexity ODD - all A
   - **By 2050**
     - Medium complexity ODD - all A

### Compute technologies with increasing capabilities (hardware and software) and cost reductions

- **By 2025**
  - 95% network ERTMS/ETCS L2 by 2035
  - Autonomous system, no human intervention
  - New MASS approved case-by-case
  - L4 passenger transport around ports
  - Efficient pass. flow at stations

- **By 2030**
  - All trains fitted for ETMS / ETCS L2
  - 50% network ERTMS/ETCS L2 by 2035
  - 70% network ERTMS/ETCS L2 by 2040
  - 95% network ERTMS/ETCS L2 by 2050

- **By 2040**
  - 1st MAFM through a UK port
  - BVLOS passenger UAVs in operation
  - BVLOS passenger UAVs in operation

- **By 2050**
  - Autonomous usage normal
  - CAV industry worth £41.7 billion
  - High complexity ODD - all A
  - High complexity ODD - all A
  - Widespread L4 freight deployments
  - Most ports smart & inter-connected
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 [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, 8, 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

<table>
<thead>
<tr>
<th>Business model area</th>
<th>2021 position</th>
<th>By 2025</th>
<th>By 2030</th>
<th>By 2040</th>
<th>By 2050</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Retail</strong></td>
<td>2019: 20% of market share[1]</td>
<td>60% market share<a href="3">2</a></td>
<td>85% market share<a href="5">4</a></td>
<td>80% market share</td>
<td>85% market share</td>
</tr>
<tr>
<td><strong>Insurance</strong></td>
<td></td>
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<tr>
<td><strong>Multimodal</strong></td>
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<tr>
<td><strong>Road</strong></td>
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</tr>
<tr>
<td>**Circular &amp; resource efficient</td>
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<tr>
<td><strong>Point of sale</strong></td>
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<tr>
<td><strong>Data flow and security</strong></td>
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<td><strong>Cyber security</strong></td>
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<td><strong>Enablers</strong></td>
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<tr>
<td><strong>Air Transport</strong></td>
<td>Hub and spoke operating model</td>
<td>Consistent operating / revenue model</td>
<td>Consistent operating / revenue model</td>
<td>Increased regional hubs &amp; p2p travel</td>
<td>Int travel at few large airports</td>
</tr>
<tr>
<td><strong>Urban mobility</strong></td>
<td>COVID-19 reduced traffic</td>
<td>Traffic returns to pre pandemic level</td>
<td>Pilot distributed aviation</td>
<td>Distributed aviation fully realised</td>
<td>Increased on demand services</td>
</tr>
<tr>
<td><strong>Maritime (ferry)</strong></td>
<td>Fixed route &amp; schedule, discrete ticket</td>
<td>Fixed route &amp; schedule, increasing integration of travel pricing</td>
<td>Fixed route &amp; schedule, full integration of pricing – purchasing mobility</td>
<td>Fixed route &amp; schedule, full integration of pricing – purchasing mobility</td>
<td></td>
</tr>
<tr>
<td><strong>Maritime (private hire)</strong></td>
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<tr>
<td><strong>Maritime (freight)</strong></td>
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<tr>
<td><strong>Micromobility</strong></td>
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<tr>
<td><strong>Rail</strong></td>
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<tr>
<td><strong>Road (private vehicle)</strong></td>
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<td><strong>Road (bus)</strong></td>
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<tr>
<td><strong>Road (taxi)</strong></td>
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<tr>
<td><strong>Revenue and operating model</strong></td>
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</tr>
</tbody>
</table>

### Key Points
- **Consumer demand for faster, more reliable and convenient delivery services**
- **Low levels of circularity**
- **95% repurposed/recycled**
- **Initial private hire e-scooter & bike trials**
- **Cyber in vehicle approval**
- **Supply chain materials & waste mapped**
- **Real time digital twins enable new business models**
- **80% rob/drone, 18% van, 2% bike**
- **Major shift to insuring vehicles**
- **Global auto market $5.56bn**
- **Increased on demand services**
- **Cars 25GB data per hour**
- **Block chain secures digital data - individual tailored travel plan & track asset utilisation & maintenance**
- **By 2040**
- **By 2050**
- **85% market share**
- **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, 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 and the chargepoints needed for the 800km of railway running on battery trains in 2050. 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.
## Infrastructure Pathway

<table>
<thead>
<tr>
<th>Transport modes</th>
<th>Elements</th>
<th>2021 position</th>
<th>By 2025</th>
<th>By 2030</th>
<th>By 2040</th>
<th>By 2050</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All mode enablers</strong></td>
<td>Cellular connectivity</td>
<td>Improved traffic control for drones</td>
<td>Airspace modernisation</td>
<td>Autonomous traffic control in service</td>
<td>65.8m tonnes petroleum products</td>
<td>65.8m tonnes petroleum products</td>
</tr>
<tr>
<td></td>
<td>Satellite / TPNT</td>
<td>Autonomous traffic control pilots</td>
<td>Re-design of lower airspace</td>
<td>UK SAF industry established by 2038</td>
<td>65.8m tonnes petroleum products</td>
<td>65.8m tonnes petroleum products</td>
</tr>
<tr>
<td></td>
<td>Air traffic management</td>
<td>Upgrade for future demand</td>
<td></td>
<td>65.8m tonnes petroleum products</td>
<td>65.8m tonnes petroleum products</td>
<td>65.8m tonnes petroleum products</td>
</tr>
<tr>
<td></td>
<td>Energy / fuel</td>
<td>13.7m tonnes petroleum</td>
<td>61.9m tonnes petroleum products</td>
<td>61.9m tonnes petroleum products</td>
<td>61.9m tonnes petroleum products</td>
<td>61.9m tonnes petroleum products</td>
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<tr>
<td></td>
<td></td>
<td>Fossil fuel based kerosene</td>
<td>SAF available at lead airports</td>
<td>First UK SAF scaled manufacturing</td>
<td>Airports substantially electrified</td>
<td>65.8m tonnes petroleum products</td>
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<tr>
<td></td>
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<td>10% of fuel is SAF = 1.4m tonnes</td>
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<td>65.8m tonnes petroleum products</td>
<td>65.8m tonnes petroleum products</td>
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<td></td>
<td>Ground support equipment</td>
<td>Pilot (100%) loading and charging pads</td>
<td></td>
<td>60,000s loading and charging pads</td>
<td></td>
<td>65.8m tonnes petroleum products</td>
</tr>
<tr>
<td></td>
<td>UAM / AAM</td>
<td>Pilot EV/VTG systems at airports</td>
<td>Pilot charging and maintenance infra</td>
<td>Urban airports / helipads implemented</td>
<td>65.8m tonnes petroleum products</td>
<td>65.8m tonnes petroleum products</td>
</tr>
<tr>
<td></td>
<td>Other infrastructure</td>
<td>27.7m tonnes of petroleum products</td>
<td>68.1m tonnes of petroleum products</td>
<td>68.1m tonnes of petroleum products</td>
<td>68.1m tonnes of petroleum products</td>
<td>68.1m tonnes of petroleum products</td>
</tr>
<tr>
<td><strong>Maritime</strong></td>
<td>Energy / fuel</td>
<td>Marine diesel 160PJ (52%)</td>
<td>Marine diesel 128PJ (48%)</td>
<td>Marine diesel 128PJ (48%)</td>
<td>Marine diesel 128PJ (48%)</td>
<td>Marine diesel 128PJ (48%)</td>
</tr>
<tr>
<td></td>
<td>Energy / fuel</td>
<td>Heavy &amp; Low sulphur fuel oil of 148 PJ (48%)</td>
<td>Heavy &amp; Low sulphur fuel oil of 148 PJ (48%)</td>
<td>Heavy &amp; Low sulphur fuel oil of 148 PJ (48%)</td>
<td>Heavy &amp; Low sulphur fuel oil of 148 PJ (48%)</td>
<td>Heavy &amp; Low sulphur fuel oil of 148 PJ (48%)</td>
</tr>
<tr>
<td></td>
<td>Energy / fuel</td>
<td>Pilot shore-to-ships connections</td>
<td>Shore-side power 0.6GWh / year</td>
<td>Pilot C-ITS to protect travellers</td>
<td>Pilot sensors to monitor traffic</td>
<td>Pilot direct vehicle - satellite communications</td>
</tr>
<tr>
<td></td>
<td>Other infrastructure</td>
<td>Limited logistics for all fuels</td>
<td>Pilot alt fuel for demonstration</td>
<td>Aspiration: 50% of trips active</td>
<td>Increasing combinat</td>
<td>Pilot multimode e-Mobility hubs</td>
</tr>
<tr>
<td></td>
<td>Other infrastructure</td>
<td>Increased use of IoT to improve flow</td>
<td>Electricit of port equipment</td>
<td>Increasing combinator</td>
<td>No specific user connectivity infra</td>
<td>No specific user connectivity infra</td>
</tr>
<tr>
<td><strong>Active travel</strong></td>
<td>Energy / fuel</td>
<td>64,000km urban cycle routes in UK</td>
<td>68,000km urban cycle routes in UK</td>
<td>68,000km urban cycle routes in UK</td>
<td>68,000km urban cycle routes in UK</td>
<td>68,000km urban cycle routes in UK</td>
</tr>
<tr>
<td></td>
<td>Energy / fuel</td>
<td>4,500 GWh / year</td>
<td>3,700 GWh electricity consumed</td>
<td>200% of MM lanes electrified</td>
<td>1% of urban roads have MM lane</td>
<td>1% of urban roads have MM lane</td>
</tr>
<tr>
<td></td>
<td>Energy / fuel</td>
<td>Pilot O-CTS to protect travellers</td>
<td>Pilot D-ITS to protect travellers</td>
<td>Pilot transport system on roads</td>
<td>Pilot smart shipping concept</td>
<td>No specific user connectivity infra</td>
</tr>
<tr>
<td></td>
<td>Energy / fuel</td>
<td>Improved cycling &amp; walking infra</td>
<td>Battery exchange in 50% schemes</td>
<td>100% of shared MM pair with infra</td>
<td>50% of private MM pair with infra</td>
<td>50% of private MM pair with infra</td>
</tr>
<tr>
<td></td>
<td>Energy / fuel</td>
<td>Battery exchange in 50% schemes</td>
<td>Pilot multimode e-Mobility hubs</td>
<td>Pilot smart shipping concept</td>
<td>Pilot D-ITS to protect travellers</td>
<td>Pilot D-ITS to protect travellers</td>
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<tr>
<td></td>
<td>Energy / fuel</td>
<td>Limited logistics for all fuels</td>
<td>Pilot alt fuel for demonstration</td>
<td>Limited logistics for all fuels</td>
<td>Limited logistics for all fuels</td>
<td>Limited logistics for all fuels</td>
</tr>
<tr>
<td><strong>Micromobility</strong></td>
<td>Energy / fuel</td>
<td>Pilot shore-to-ships connections</td>
<td>Pilot alt fuel for demonstration</td>
<td>Limited logistics for all fuels</td>
<td>Limited logistics for all fuels</td>
<td>Limited logistics for all fuels</td>
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<tr>
<td></td>
<td>Energy / fuel</td>
<td>Limited logistics for all fuels</td>
<td>Pilot alt fuel for demonstration</td>
<td>Limited logistics for all fuels</td>
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<td>Energy / fuel</td>
<td>Limited logistics for all fuels</td>
<td>Pilot alt fuel for demonstration</td>
<td>Limited logistics for all fuels</td>
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<td>Limited logistics for all fuels</td>
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<tr>
<td></td>
<td>Energy / fuel</td>
<td>Limited logistics for all fuels</td>
<td>Pilot alt fuel for demonstration</td>
<td>Limited logistics for all fuels</td>
<td>Limited logistics for all fuels</td>
<td>Limited logistics for all fuels</td>
</tr>
<tr>
<td><strong>Rail</strong></td>
<td>Energy / fuel</td>
<td>48,000 tonnes of petroleum</td>
<td>55,000 tonnes of petroleum</td>
<td>62,000 tonnes of petroleum</td>
<td>67,000 tonnes of petroleum</td>
<td>72,000 tonnes of petroleum</td>
</tr>
<tr>
<td></td>
<td>Energy / fuel</td>
<td>24% (6,082 STK) track electrified</td>
<td>42% (7,924 STK) track electrified</td>
<td>62% (10300 STK) track electrified</td>
<td>98% (14,260 STK) track electrified</td>
<td>98% (14,260 STK) track electrified</td>
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<tr>
<td></td>
<td>Energy / fuel</td>
<td>5% 100 GWh electricity consumed</td>
<td>25,650 GWh electricity consumed</td>
<td>20,700 GWh electricity consumed</td>
<td>38,700 GWh electricity consumed</td>
<td>38,700 GWh electricity consumed</td>
</tr>
<tr>
<td></td>
<td>Energy / fuel</td>
<td>Negligible levels of hydrogen consumed</td>
<td>Negligible levels of hydrogen consumed</td>
<td>Negligible levels of hydrogen consumed</td>
<td>Negligible levels of hydrogen consumed</td>
<td>Negligible levels of hydrogen consumed</td>
</tr>
<tr>
<td><strong>Road</strong></td>
<td>Energy / fuel</td>
<td>3.3m tonnes of petroleum</td>
<td>4.1m tonnes of petroleum</td>
<td>6.0m tonnes of petroleum</td>
<td>9.0m tonnes of petroleum</td>
<td>12.0m tonnes of petroleum</td>
</tr>
<tr>
<td></td>
<td>Energy / fuel</td>
<td>Accounts for 9% road transport</td>
<td>Accounts for 9% road transport</td>
<td>Accounts for 9% road transport</td>
<td>Accounts for 9% road transport</td>
<td>Accounts for 9% road transport</td>
</tr>
<tr>
<td></td>
<td>Energy / fuel</td>
<td>48,000 GWh / year for charging</td>
<td>62,000 GWh / year for charging</td>
<td>92,000 GWh / year for charging</td>
<td>155,000 GWh / year for charging</td>
<td>155,000 GWh / year for charging</td>
</tr>
<tr>
<td></td>
<td>Energy / fuel</td>
<td>16,000 public charge points</td>
<td>8,500 public charge points</td>
<td>40,000 public charge points</td>
<td>200,000 public charge points</td>
<td>200,000 public charge points</td>
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<tr>
<td></td>
<td>Energy / fuel</td>
<td>33% high power (100kW+)</td>
<td>33% high power (100kW+)</td>
<td>66% high power (100kW+)</td>
<td>50% high power (100kW+)</td>
<td>50% high power (100kW+)</td>
</tr>
<tr>
<td></td>
<td>Energy / fuel</td>
<td>3,000 GWh hydrogen per year</td>
<td>3,000 GWh hydrogen per year</td>
<td>6,000 GWh hydrogen per year</td>
<td>12,000 GWh hydrogen per year</td>
<td>12,000 GWh hydrogen per year</td>
</tr>
<tr>
<td></td>
<td>Energy / fuel</td>
<td>12,000 hydrogen fuel stations in UK</td>
<td>12,000 hydrogen fuel stations in UK</td>
<td>15,000 hydrogen fuel stations in UK</td>
<td>18,000 hydrogen fuel stations in UK</td>
<td>18,000 hydrogen fuel stations in UK</td>
</tr>
<tr>
<td></td>
<td>Energy / fuel</td>
<td>3,200 public charge points in city</td>
<td>3,200 public charge points in city</td>
<td>4,000 public charge points in city</td>
<td>6,000 public charge points in city</td>
<td>6,000 public charge points in city</td>
</tr>
<tr>
<td></td>
<td>Energy / fuel</td>
<td>No road catenary infrastructure in UK</td>
<td>No road catenary infrastructure in UK</td>
<td>No road catenary infrastructure in UK</td>
<td>No road catenary infrastructure in UK</td>
<td>No road catenary infrastructure in UK</td>
</tr>
</tbody>
</table>

### Traffic management

- **User connectivity**
  - No specific user connectivity infra
  - Pilot line side connectivity
  - 84,000 tonnes of petroleum
  - 55,000 GWh electricity consumed
  - Negligible levels of hydrogen consumed

- **Traffic management**
  - Some localised traffic control
  - Widespread satellite comm using LEO
  - Widespread hand-over cellular and satellite
  - Cellular V2X capabilities expanded
  - LED satellite comm modules
  - Widespread Vivo

- **User / other connectivity**
  - No specific user connectivity infra
  - Widespread 4G, some 5G

- **Autonomy**
  - No changes expected to enable autonomous driving - some enables such as digitisation of road rules

### Energy / fuel

- **Energy / fuel**
  - 5,100 GWh electricity consumed
  - Negligible levels of hydrogen consumed
  - Negligible levels of hydrogen consumed

### Rail

- **User connectivity**
  - No specific user connectivity infra
  - Pilot line side connectivity
  - 84,000 tonnes of petroleum
  - 55,000 GWh electricity consumed
  - Negligible levels of hydrogen consumed

- **Traffic management**
  - Some localised traffic control
  - Widespread satellite comm using LEO
  - Widespread hand-over cellular and satellite
  - Cellular V2X capabilities expanded
  - LED satellite comm modules
  - Widespread Vivo

- **User / other connectivity**
  - No specific user connectivity infra
  - Widespread 4G, some 5G

- **Autonomy**
  - No changes expected to enable autonomous driving - some enables such as digitisation of road rules
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.
Connectivity


[5] Clean Maritime Plan Scenario analysis: take-up of emissions reduction options and their impacts on emissions and costs, July 2019


Energy vectors


[3] UK TRANSPORT VISION 2050
Business models


[6] ONS - Internet sales as a percentage of total retail sales (%, June), https://www.ons.gov.uk/businessindustryandtrade/retailindustry/timeseries/47mc0/dsi


[19] TRACTION DECARBONISATION NETWORK STRATEGY - Intermediate Programme Business Case, 31 July 2020, Pg 10:


[23] RAPID RECOVERY AND REVITALISATION - Interim Programme Business Case 31 July 2020, Pg 6:


Infrastructure


[3] TRACTION DECARBONISATION NETWORK STRATEGY - Intermediate Programme Business Case, 31 July 2020, Pg 10:

[4] Clean Maritime Plan, July 2019, Pg 36:


the higher infrastructure costs compared to the hydrogen scenario in the time frame considered (up to 2050). Fuel costs and overall energy demand are lowest for the electric scenario; however, this does not offset the hydrogen-fuelled HGV industry in the UK leading to the lowest overall infrastructure costs."

[50] Extrapolation from [34] and [36], assuming energy used directly proportional to track power type.


[52] Extrapolation from [34] and [36], assuming energy used directly proportional to track power type.


[54] Innovate UK conclusion after analysing ref [5] and consultation including with Maritime and Coastguard Agency

**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:** automatic advanced driver assistance system
- **ADS-B:** automatic dependent 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:** app
- **AURN:** autonomous urban and rural network
- **ATM:** air traffic management
- **ATO:** automatic train operation
- **AV:** autonomous vehicle
- **AVP:** autonomous vehicle park
- **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
- **CAY:** connected autonomous vehicle
- **CAPPASS:** connected and autonomous vehicle process for assuring safety and security
- **C-ITS:** cooperative intelligent transport systems
- **CoD:** capacity on demand
- **CORSSIA:** carbon offsetting and reduction scheme for international aviation
- **CP:** control period
- **C-VZX:** cellular vehicle to everything
- **DLR:** Docklands Light Railway
- **EAN:** European Aviation Network
- **ECE:** United Nations Economic Commission for Europe (also UN/ECE)
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