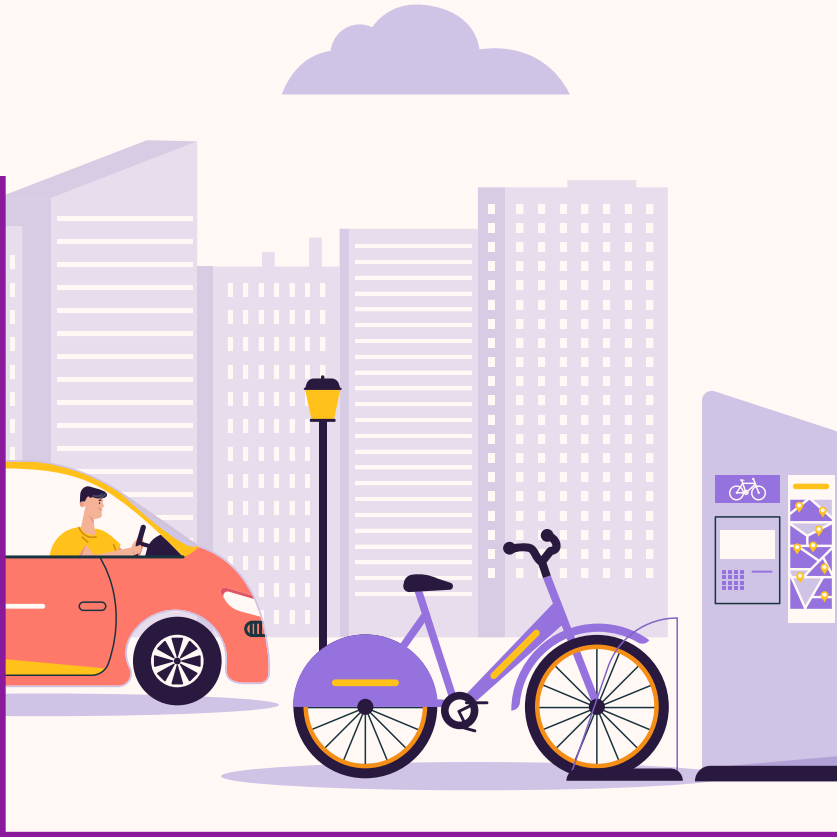
Innovate UK



UK Transport Vision 2050

Investing in the future of mobility

Second Edition

FEBRUARY 2024

Key messages

Transport Vision 2050

The quality and efficiency of the transport system are critical for the UK, its economy and the wellbeing of the population. Significant change over coming decades will drive and necessitate innovation. Innovate UK has identified three strategic imperatives to guide investments to minimise risks and maximise benefits.

The strategic imperatives are:

Net zero

scale-up manufacturing to deliver net zero products

Digitally enabled

greater efficiency and new products and services

Resilient and responsive

continuous safe and secure operation

UK transport is key to keeping the economy and society moving and to reaching net zero. Share your thoughts and get involved. Visit **our website**.

Foreword

Transport is vital for the success of the UK's economy and for that of our society more broadly.

So much is changing and needs to change, and our transport systems and providers have a great opportunity to innovate together to make that happen.

The need to decarbonise; the need for greater resilience and flexibility; and pervasive digital technologies all mean that this is and needs to be a time for real innovation.

As the UK's innovation agency, Innovate UK works to support the innovation and productivity journey for UK business, and transport innovation is a very important part of that work.

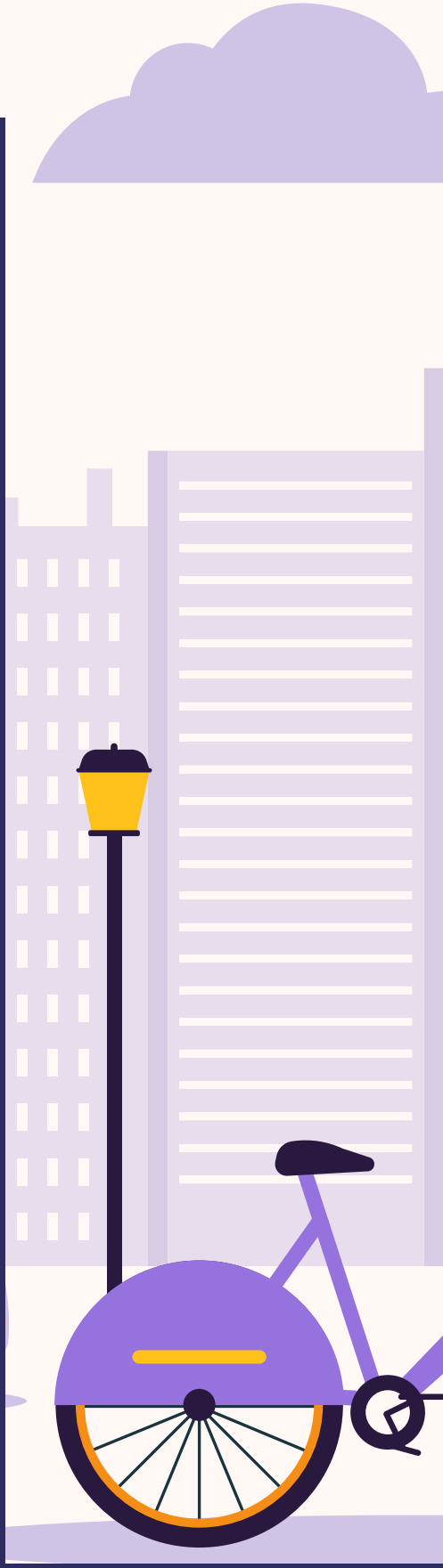
The Innovate UK team worked with over 200 partners in industry, academia, and government to develop Transport Vision 2050, first published in August 2021. This work reflected and stimulated many exciting ideas and discussions from electric HGVs to methanol for shipping.

Using many of the ideas and discussions, the Innovate UK team has updated Transport Vision 2050 and has created an enduring community for shared learning and working to build a prosperous future for the UK.

Welcome to the updated Innovate UK Transport Vision 2050.

Welcome to our active innovation community - let's reimagine transport now.

Indro Mukerjee
Chief Executive | Innovate UK



Executive summary

Transport is fundamental to the daily movement and communication of people and organisations, and trade of goods across the globe. The quality and efficiency of the transport system are critical factors for a place, its economy and wellbeing of the population.

Transportation and transport manufacturing generated more than £274 billion added value for the UK in 2022, 4% of the total UK output.

Transport remains one of the largest sources of greenhouse gas emissions in the UK, accounting for 25.5% in 2021 [5]. In parallel, technological advances improve safety, efficiency and offer new business models. These technologies and trends are also changing lifestyles and the need to travel.

The UK must respond to the challenges and opportunities represented by these significant changes. Innovate UK and our partners will invest £2 billion in transport innovation between April 2021 and March 2025. This investment will shape transport in the UK for many years.

This vision was first published in 2021. This second version has been updated to reflect increased understanding and changing circumstances. It has grown out of extensive research combined with consultation with our partners across industry, academia and government.

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 continue to update the vision to reflect the latest thinking.

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 safe, seamless, net zero, connected, cost effective, accessible and reliable means. It will be a world leader in 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

The transport system is driven by transport and traveller demand and needs. Our vision is informed by this and influenced by three strategic imperatives that are mutually supportive. The UK will increasingly meet transport and traveller needs with a transport system that embraces innovation to be:

- net zero by scaling-up manufacturing to deliver net zero products
- digitally enabled to deliver greater efficiency and new products and services
- resilient and responsive with continuous, safe and secure operation

By understanding and responding to traveller needs, and using the strategic imperatives to guide investments the transport system will support people's wellbeing and underpin the economy's productivity.

THE DRIVERS, ENABLERS AND PATHWAYS TO 2050

We have identified key drivers and enablers that shape the future transport system and five pathways where steps need to be taken to achieve the 2050 vision:

- driver: travel and transport demand
- enabler: digital
- connectivity
- energy vectors
- autonomy
- business models
- infrastructure

Travel and transport demand is driven by society and economic needs. The transport system must understand and respond to these requirements.

Digital, a key enabler, has been added to this second version of the transport vision. It impacts all pathways, so we have chosen to outline where those impacts are rather than have a separate pathway.

In each pathway we lay out a central assumption of the future and the steps and timescales on the road to achieving that future.

Fundamental, technical and applied research and innovation challenges need to be addressed in all 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

Advances in technology and changing lifestyles will accelerate changes in the way people travel and behave and drive improved transport services. We expect to see an increase in the use of most travel modes driven in part by increasing population and rising GDP.[6]

This is despite the changes that followed the COVID-19 pandemic, trends towards alternative forms of mobility and rises in the cost of living.

Growing demand for transport is a serious challenge to the UK's plan to reduce carbon-intensive activities by 2050. Reducing demand has a role to play alongside zero emission technology and modal shift away from more polluting transport modes. Policy changes and technology advances that aid behaviour change can reduce demand.

DIGITAL

Digitalisation is already changing transport services and we expect that impact to grow. Use of data and artificial intelligence to integrate and optimise services will allow millions of people to make journeys they would not have previously made. It will also enable travellers to make better informed journey decisions and mean greater driver and pilot assistance in vehicles, increasing levels of automation and better delivery services.

CONNECTIVITY

Improved communications and data connectivity will create opportunities for greater efficiency, new services for travellers, and new business products and amenities. We expect all vehicles and craft to be able to move cooperatively by 2050. Infrastructure maintenance, traffic planning, management and routing, refuelling systems and freight operations across all modes will all benefit significantly.

ENERGY VECTORS

The move to net zero by 2050 requires surface transport to make a complete shift from fossil fuels to sustainably produced electricity, hydrogen and other alternatives. For transport, we expect the main transition will come between 2030 and 2050. Electric propulsion will be dominant by 2050 and requires significant battery production and raw materials. We expect hydrogen to fuel 20% of heavy goods vehicles and coaches and 5% of aircraft by 2050. Aviation will still mainly use fossil fuels and will need to offset or remove carbon dioxide equivalent emissions.

AUTONOMY

Autonomy will make vehicles and craft smarter, provide accessible, fully autonomous transport and create new services such as medical deliveries by drone. Autonomy will be increasingly present and a significant part of the value offering, enabling new services and business models. We anticipate that road transport, air transport, rail freight and domestic ferries will be predominately autonomous by 2050.

BUSINESS MODELS

Evolving customer needs and advances in technology 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

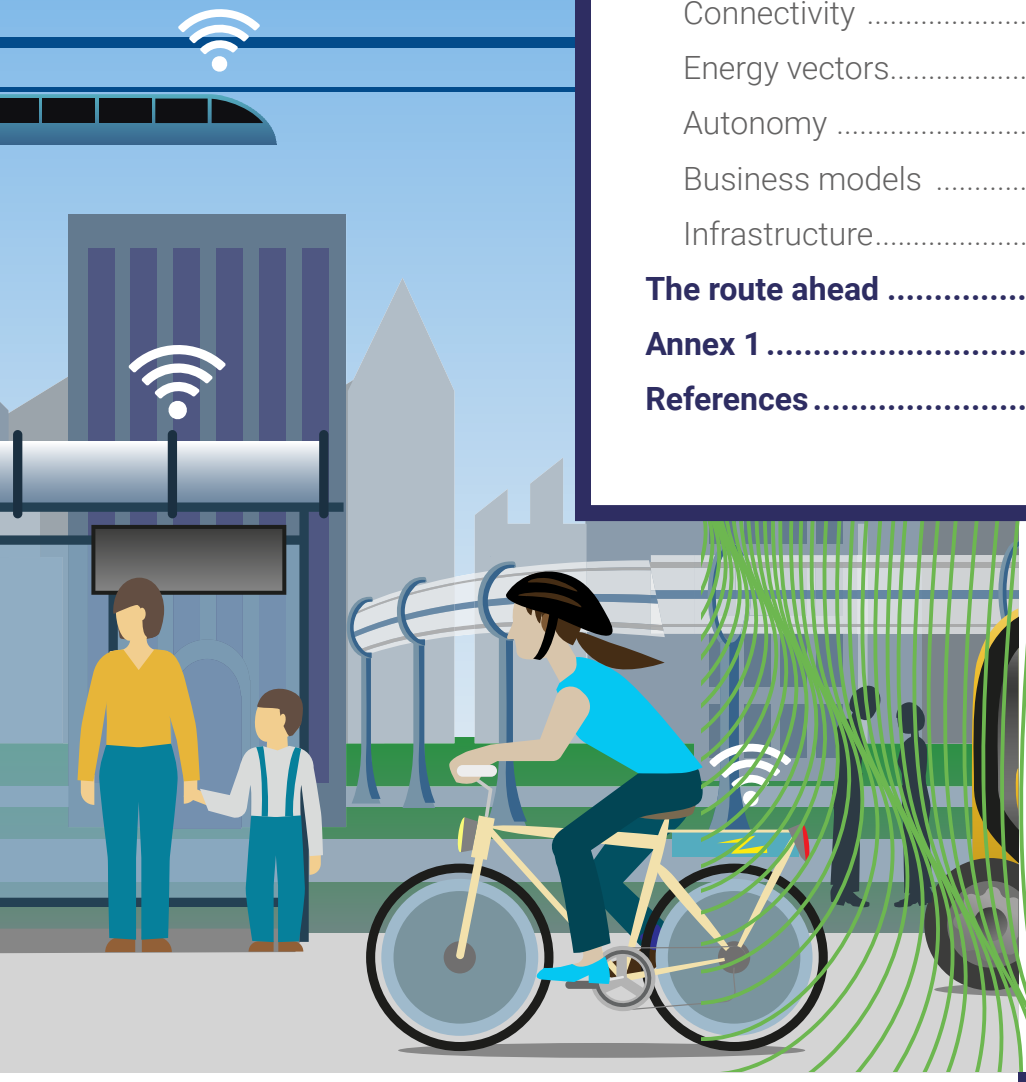
UK transport infrastructure will adapt to changing lifestyles and cleaner energy supplies. The need to meet net zero will create significant new business opportunities. Infrastructure development will include more green space and water environments. Transport charging networks will grow to serve the needs for both high and low power charging, and transport networks will become smarter and more reliable.

The route ahead

Changes to the transport system over the coming decades present significant challenges and great opportunities for the UK transport sector. By understanding and responding to traveller needs, and using the strategic imperatives to guide investments the UK can maximise societal benefits and economic growth.

We will use this vision and our assessment of the UK's relative strengths to determine where we invest our efforts and resources. We also want this vision to inform and guide our partners in the public sector and in industry when they are making their investment decisions. We look forward to working collaboratively to invest in the future of transport.

Contents



Introduction

Transport enables mobility, communication, trade and other forms of exchange between people.

The quality and efficiency of the transport system are critical factors for a place, its economy and its residents' well-being. Good transport helps people to get jobs, access services and enjoy social activities.

Transport connections also support businesses and trade, bringing industries closer together and reducing barriers. Transport industries directly contribute to the economy. Transportation and transport manufacturing generated more than £274 billion added value for the UK in 2022, 4% of the total UK output [1], and efficient transport impacts almost all other UK businesses [2][3][4].

Time for change

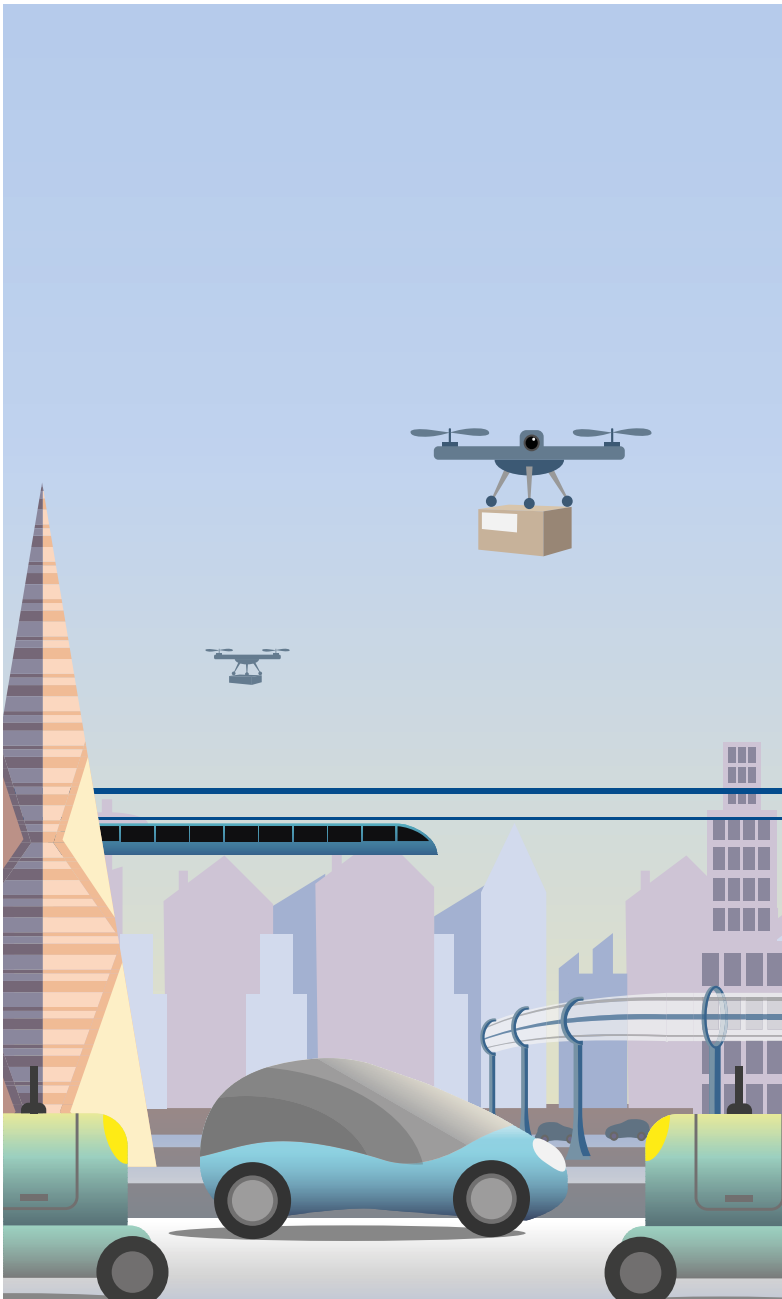
The way transport is delivered is changing. Transport remains one of the largest sources of greenhouse gas emissions in the UK, accounting for 25.5% in 2021 [5]. This is incompatible with the UK's legal commitment to reach net zero. Regulation and consumer demand are also driving change through the system.

In parallel, technological advances are creating tools that improve safety and efficiency and offer new business models. These technologies and trends are also changing lifestyles and the need to travel, reducing some demands and increasing others.

These changes create challenges and opportunities for those who deliver and use transport. 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 development and adoption of innovative products and services are increasingly important for UK competitiveness and to delivering value and providing accessibility to all.

The opportunity

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, increased productivity and greater 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 [7].



Putting forward a vision

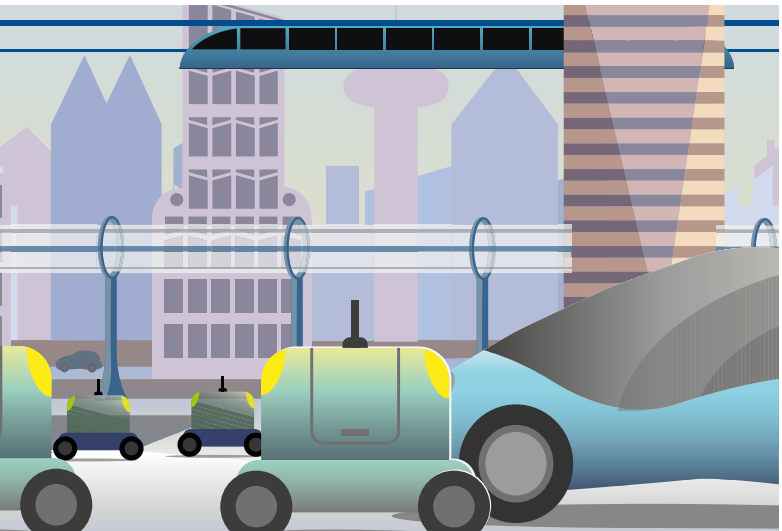
This is the Innovate UK vision of UK transport in 2050 and the steps along the way to achieving this. This is intended to be an aspirational but realistic view of the future transport system.

The vision is tailored to UK challenges and opportunities but is also a strong indicator of global trends. The UK transport system must interact with and work as part of a global system. The vision complements government policy documents, building on these and drawing on current evidence to provide specifics about the likely future.

The transport vision will do three things:

- inform our investments and activities. We'll use this vision of the future alongside other inputs, including **our international benchmarking work**, and our strategic priorities to guide our investments in the future of transport
- inform others investing in transport, including industry, UK government and arm's-length bodies. By having a common view of the future, investments can be aligned allowing the UK to gain the economic, environmental and societal benefits more quickly and at the appropriate value for money
- provide a platform for discussion and debate. 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

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 continue to update it regularly to reflect the pace of change in transport.



What do we mean by transport?

Transport vision 2050 encompasses the use of vehicles, fuels or 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 vision 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 or supporting infrastructure, or the production of fuels or energy vectors. This means we exclude off-highway vehicles as they facilitate transport rather than being transport themselves. We recognise the need to work with constructors, manufacturers and recyclers. This is addressed in the **Innovate UK Materials and Manufacturing vision**. Similarly, we do not include workforce skills and training. This is an area that requires broader consideration beyond transport alone.

Innovate UK is the UK's innovation agency.

We support business-led innovation in all sectors, technologies and UK regions. We help businesses grow through the development and commercialisation of new products, processes, and services. This access across sectors and organisations gives us a unique view.

Innovate UK and our partners will invest £2 billion in transport between April 2021 and March 2025. These investments are informed by our understanding of the future of transport.

This is the second iteration of our transport vision. We have had input from industry and academia and from our partners in UK Research and Innovation (UKRI) (including Engineering and Physical Sciences Research Council and Economic and Social Research Council), Innovate UK Business Connect, Connected Places Catapult, and the Department for Business and Trade, the Department for Transport and their arms length bodies.

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 **safe**, **seamless**, **net zero**, **connected**, **cost effective**, **accessible** and **reliable** means.

The UK transport system will be recognised as an asset for the UK, supporting people's well-being and underpinning the economy's productivity. It will be a world leader in design, innovation, manufacturing and deployment. The supporting industry will provide high-quality and skilled employment and continue to be a major contributor to UK GDP.

The purpose of a transport system is to connect people to other people and the things they need. The quality and efficiency of a transport system are a key part of how a place delivers for the people that live there. They are critical for the economy and people's well-being. Transport systems should therefore focus on the user, what they need now, and what they might need in the future.

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, safety 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. Inclusivity will be embedded as the transport system adjusts to suit the traveller, connecting people regardless of age, gender or ability. Travellers will be fully connected with work or leisure activities during the entire journey. They will continue to be productive and able to maximise the value of time spent travelling. Travellers will experience near 100% reliability and arrive on time.

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

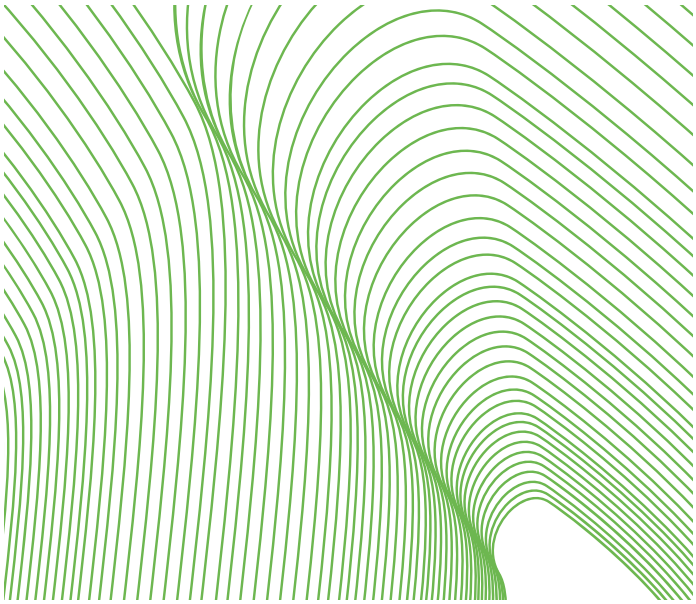
Our strategic imperatives

The transport system is essential for our vision for the UK, its economy and the wellbeing of the population. Our vision is influenced by three strategic imperatives that are mutually supportive. The UK will increasingly meet transport and traveller needs with a transport system that embraces innovation to be:

NET ZERO

Almost all transport will be zero emission at point of use in 2050, and the remainder offset. There will be a complete shift to sustainably produced electricity, hydrogen and other alternatives requiring new and revised infrastructure to produce and distribute energy vectors. Significant changes to vehicles and vessel design and production will radically alter production and supply chains. This carries risks and opportunities for manufacturing and supply chains, which will need to adapt and scale-up to secure market position and grow.

Emissions from the manufacture of transport solutions will be zero or offset with raw materials sustainably and ethically sourced. The Innovate UK **materials and manufacturing vision** focuses on how this will be achieved.



DIGITALLY ENABLED

Advances in robotics, autonomy and artificial intelligence along with increasing connectivity and data transmission and processing will create opportunities for greater efficiency, new services for travellers and new business models in multi-billion global markets and be critical to the operation of transport as a national infrastructure.

The 2050 UK transport system will be fully integrated, providing interconnected mobility that allows the seamless and sustainable transport of people and goods from one location to another. This includes both movements within the UK and those made on overseas legs of journeys to and from the UK.

RESILIENT AND RESPONSIVE

All travellers will feel safe to choose from all transport options, and confident in reaching their destination.

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 travellers, and provide real-time information to both incident-response teams and those travelling. Standards will 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 will be secure, resilient and meet the challenges of climate adaption, such as changes to weather and water levels.

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

Economic Contribution

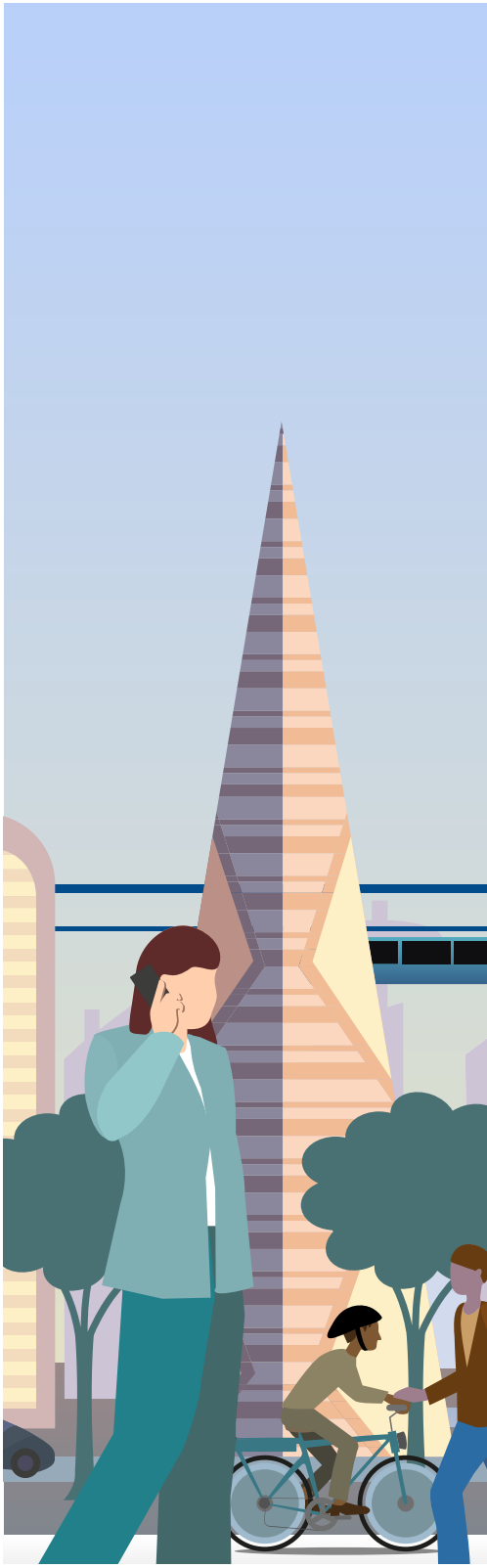
By using the strategic imperatives to guide investments in the transport system, the UK will meet transport and traveller needs. It will also deliver economic impact.

A high-quality, efficient and effective transport system in 2050 makes the UK a more productive place to do business and drives economic growth, exports, and jobs. It will be underpinned by the global leadership of UK companies and academia in research and development, manufacturing and delivery of transport systems, infrastructure, and resilient and secure supply chains.

The drivers, enablers and pathways to 2050

In this second version of the transport vision, we have identified **key drivers and enablers that shape the future transport system and five pathways** where steps need to be taken to achieve the 2050 vision. They are:

- **DRIVER: TRAVEL AND TRANSPORT DEMAND**
- **ENABLER: DIGITAL**
- **CONNNECTIVITY**
- **ENERGY VECTORS**
- **AUTONOMY**
- **BUSINESS MODELS**
- **INFRASTRUCTURE**



Travel and transport demand is driven by society and economic needs. The transport system must understand and respond to these requirements.

Digital, a key enabler, has been added to this second version of the transport vision. It impacts all pathways, so we have chosen to outline where those impacts are rather than have a separate pathway. Each pathway also reflects the expected impact of digital.

The five pathways set out our expectations in the timeframe between now and 2050. They draw on referenced sources and our 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 as needed in future versions.

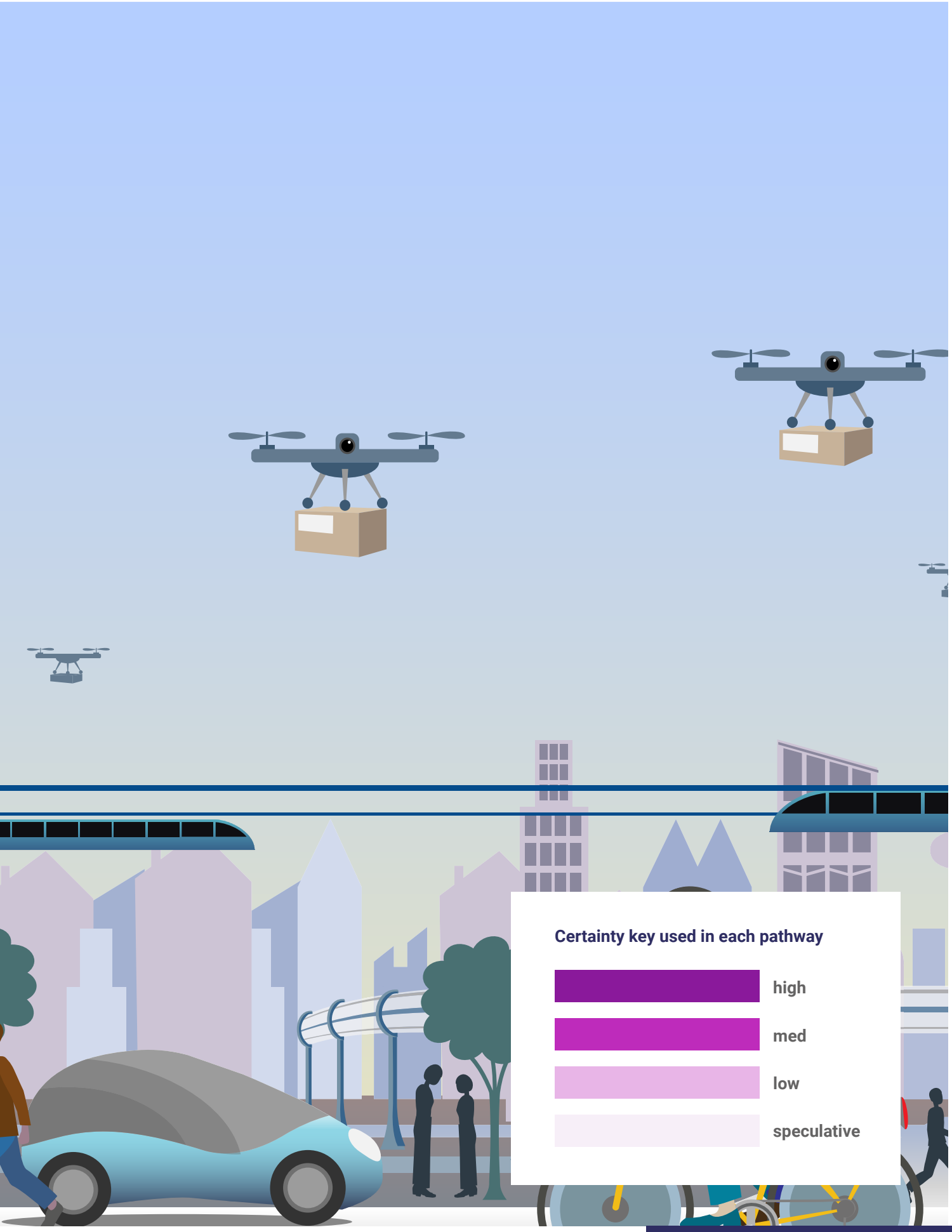
The pathways lay out a central assumption for the future and the routes to it. Our certainty and confidence in some routes and solutions is greater than others. Areas of higher confidence in a destination or route should provide greater certainty for investors in the system.

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.


Certainty key used in each pathway
high
med
low
speculative

Travel and transport demand

Advances in technology and changing lifestyles will accelerate changes in the way people travel and behave and drive improved transport services.

Predicting demand beyond 2030 with confidence is challenging. The sector's size and huge variables, including changing demographics, create a melting pot of possible scenarios. Using available references and informed opinion we have presented one possible scenario to encourage debate and draw our conclusions.

Population growth and rising GDP historically result in 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. An increasing focus on 'avoid' (or reduce non-essential travel), 'shift' (to more sustainable transport modes) and 'improve' (vehicle technology and efficiency) [60] is expected. The Scottish Government have set their reduce, switch and combine approach as part of a commitment to reducing car kilometres by 20 per cent by 2030 [41]. Cost of living, the increase in energy prices and industrial action have also impacted the way people travel. More than a third of British adults reported cutting back on non-essential journeys because of rising cost of living [59]. However, most sources predict an increase in most travel modes both in the UK and globally [32] [35] [40].

AVIATION

World passenger numbers in 2022 were estimated to be down by up to 1.281 billion (29%) compared to 2019. Passenger demand is expected to recover by the mid-2020s and then grow 1.4% a year to 2050. This assumes demand management measures are not implemented. 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 high cost compared 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 could be more than 900,000 operational drones by 2030 [5].

MICROMOBILITY AND ACTIVE TRAVEL

Active travel (walking and cycling) rose during the pandemic. The Department for Transport's Gear Change [21] strategy from 2020, has a challenging aim for 50% of all journeys in urban areas in England to be cycled or walked by 2030. Higher energy prices and cost of living have also impacted travel, and 35% of people have replaced some car journeys with walking or cycling [53]. However current statistics show levels of walking and cycling are relatively unchanged over the last 20 years [70]. Micromobility – use of electric and human-powered vehicles under 600kg and with speeds under 25kmph – will be prevalent in urban areas from 2025 and provide a transport option for all trips under 8km [23]. A balance between promoting active travel, with its health benefits, and use of micromobility will be necessary. Micromobility and active travel plans and policies for rural areas are less well developed.

MARITIME

Shipping accounts for 95% of international freight arriving in the UK [9]. 447.9 million tonnes of goods were handled between June 2021 and June 2022 (an increase of 4% on 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]. 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 destination by road or rail freight as required.

RAIL

Passenger journeys in January to March 2023 were 88% of the journeys in the same quarter four years ago (pre-pandemic, 2019) [67]. It is still relatively early to see the long-term impacts of COVID-19 on rail (and other forms of) transport. Passengers will continue to use rail, but changing home and office work patterns are impacting passenger numbers [45]. The volume of rail freight will grow to more than pre-COVID-19 levels, with the government setting a target for at least 75% growth in rail freight by 2050 [68]. This coincides with wider improvements, including in access and flexibility [31]. The introduction of some automation to parts of the network will also have significant impact. We expect improved rail links, with freight hubs bringing modal shift to track in some cases.

BUS

Local bus passenger journeys in England recovered to 3.09 billion in the year ending June 2022. Whilst numbers have

risen each quarter, they are still 27% below pre-COVID-19 levels [46]. Bus use nationally has been declining [69] and we forecast this to continue to 2040 due to modal shift and increases in shared services. This trend could, however, be reversed if projected reductions in operational costs are passed on to the customer and bus services grow in quality, frequency and coverage [47]. Recent bus subsidies and franchising in some regions could reverse projections.

ROAD LIGHT COMMERICAL VEHICLES (LCV)

LCV traffic increased 11.9% between 2020 and 2021 [18]. This is despite non-store (online) retail sales volumes falling since early 2021 as the wider economy re-opened after COVID-19. December 2022 to January 2023 saw non-store sales volumes rise by 2% [48]. Government data shows that LCV (and HGV) traffic is significantly above pre-pandemic levels, and that LCV traffic will grow in line with other traffic by between 8% and 54% between 2025 and 2060. The same National Road Traffic Projections 2022 predicts LCV mileage to grow from 57 billion in 2025 to 77 billion by 2060 [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 from 16 billion miles in 2025 to 18 billion by 2060, only a moderate increase when compared to LCVs [35]. However, truck movements will be focused on highways and the strategic road network. Noise and emission reductions associated with zero emission capability will improve operations.

ROAD CARS

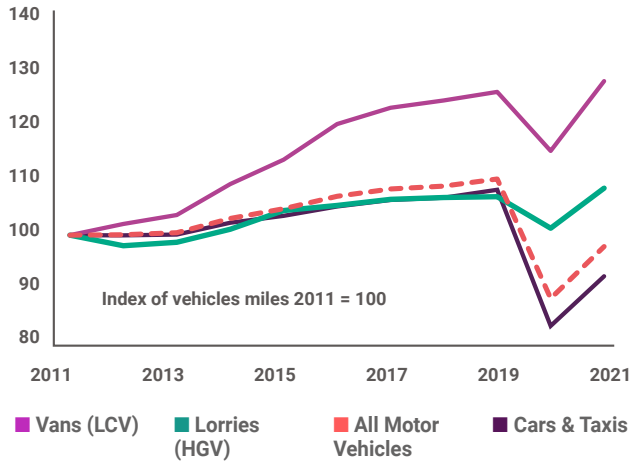
While car traffic remained lower than pre-pandemic levels in 2021 (down 15.8% compared to 2019), there was an increase of 12.2% from 2020 to 2021 [18]. However, changes in car use are notoriously difficult to predict given changes in technology, society and in transport systems [47]. While car traffic 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]. The challenge remains to ensure alternatives provide comparative accessibility, cost and convenience, as private car use remains the most attractive option for many reasons.

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. Policies that influence pricing and operating costs will in turn impact demand. 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].

Projected increased demand for transport is a serious challenge to the UK's plan to reduce carbon-intensive activities by 2050. Demand can be reduced, but zero emission technology and modal shift away from more polluting transport modes is equally important. Policy changes and technology advances that aid behaviour change can encourage 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 demand reduction and emissions benefits. Some reduced travel numbers do not tell the whole story however, with less commuting but more suburban car travel for example. 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 continue to influence both societal and business approaches to transport. These will aid the delivery of an optimised transport system.

Figure 1: Vehicle miles travelled by selected vehicle types in great Britain, 2011 - 2021



Source: Department for Transport Road Traffic Estimates Great Britain 2021, September 2022 [18]

Travel & transport demand pathway

Transport modes	Elements	2023 position	By 2025
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
	Passenger	Hydrogen and batteries to make greater inroads into the ferry and cruise sectors in 2023 [66]	Pax growth close to pre-pandemic levels [12] and increased demand for sustainable cruises [13]
	Freight	95% of goods moved by ships in 2020 [9]	Tonnage +3% dry bulks and containers
		In 2021 Tonnage traffic has continued to recover towards pre-pandemic levels [11]	Liquid bulk movements down due to less crude oil being shipped [14]
		Total tonnage +4% to 447.9m, June 2021-22 [11]	Freeports increase trade volume, more vessels in UK waters [15]
Micromobility and Active Travel	Market Drivers	C-19, cost of living and increase in fuel and energy prices have impacted the way we travel	Public scooter use & shared-vehicle schemes legalised
	Walking	2021 walking = 31% of all trips [55]	Walking displaces other modes post C19
	Cycling	2021 cycling = 2% of all trips [55]	Gear Change start showing results [21]
	Micromobility (all modes)	eScooter trials primed in circa 30 cities [56]	ebike sales nearly triple [22]
		+22.5m delivery app users in 2020 [19] [20]	Journeys <8km travelled by micromobility [23]
Rail	Market Drivers	Post-C19 travel remains lower than pre-C19. Rail usage impacted by industry strikes	Covid's impact still felt. Some freight increases as trade increases
	Passenger	359m journeys made in Jul - Sep 22, 80.3% of the same quarter of 2019 [26]	Pax demand still 10% below pre-lockdown levels
		In 2021 rail trips are 1% of all journeys [57] Almost half of rail journeys for commuting [57]	
	Freight	16.87bn net tonne kms rail freight / year [57]	2.9% annual growth after 2022 [30]
		Freight moved -6.4% in Jul – Sep 22 compared with 21 [28]	
Air Transport	Market Drivers	AAM Research, development and innovation, tech trials and piloted drones	Pax AAM available but piloted. Large growth in drone freight delivery. Air travel up
	Air Mobility Vehicles	Design and development ramping up	Rural routes certified for BVLOS
		Investor confidence and consumer interest high [0]	Early Adopters - Gov. and public services [5]
	Civil Aviation	Global pax reduction of c.1.3m (-29%) [1] Domestic 80% pre-C19 levels by 2022	International travel back to 2019 levels [3]
	International Freight	2020 UK airports handled 2m tonnes [39]	Air Freight - high value but very low volume
Road	Market Drivers	OEMs / gov. pledge to zero. TCO of ZEVs down. Freight up due to trade and consumer behaviour	Private car ownership continues upward. Last mile delivery options impact LCVs
	Car	2021 car traffic -12.1% from 2019 [18]	+5% increase in demand vs 2015 [35]
		Depression in mobility due to C-19 pandemic being short-lived	Less daily commute and public transport. Disincentivisation for private car use grows
	Bus & Coaches	Bus usage recovered to between 77% and 93% of pre-Covid use [53]	Demand decrease - less commuting and shift to micromobility
	Freight - Van / Light commercial	Traffic 11.9% from 2020 to 2021 to 54.4bvm [18]	
		LCVs 18% of total UK traffic [18]	Miles travelled may not reduce due to increased v
		Demand may exceed pre c19 levels [33]	Increase in other last mile mode options may limit
	Freight - HGV	Lorry traffic Increased by 7.9% from 2020 to 2021 to 17.5bvm [18]	Flat to gradual increase in demand of 2% compared to 2018
		Lorry traffic in 2021 was 1.6% higher than 2019 levels. [18]	

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By 2030	By 2040	By 2050
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
Pre C19 pax growth projections resume	Zero emission option for domestic ferry and leisure activities	Ports onward connections make them a multi-modal sustainable transport hub
Tonnage +8% compared to 20 level [14]	Tonnage +23% compared to 20 level [14]	Tonnage +41% compared to 20 level
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%
		Liquified gas +177% compared to 2020 [14]
Urban movements center around walking and cycling	Large-scale improvement in active travel & micromobility infrastructure	Active travel and micromobility embedded into transport system
50% of urban journeys cycled or walked by 2030 [21]	Health, wellbeing and accessibility benefits continue to result in high levels of active travel	
+5% user demand over 2025 levels [24]	Micromobility 10% pax mode share	Micromobility (incl. UAVs) serves majority of last-mile deliveries
Complementary to public transport [52]	Micromobility 30% of urban deliveries [25]	
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
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]
Demand +25% over 2022, mode share 10% [30]	Demand +65% over 2022, mode share 12% [30]	Demand +65% over 2022, mode share 14% [32]
Flexibility and road, air and sea tech advances could hamper demand	Modal competition drives down cost	
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
900k drones in UK airspace [5]	High demand - middle mile deliveries and into rural areas	50% of mode share for delivery
Commercially viable for metro air services - regs in place [6]		Common modal option for Pax
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]
Air freight 5.5% compound growth [7]	Air freight 4.5% compound growth rate [7]	
Reduced car travel encouraged. Consumers seek personalisation, cost and accessibility	Autonomy improves economics of HGVs. Personalised travel and sharing increase	Shift to personalised and on demand. 17% of car journeys replaced or removed [36]
+13% demand vs 2015 [35]	+25% in demand vs 2015 [35]	Cars up to 81% of traffic mileage [35]
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]
	9% of journeys replaced / removed [36]	Increases in effective road capacity
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
Long distance low cost services continue		Buses retained for commuting
'+7% demand compared to 2018 [35]		Growth of between 23% and 108% [35]
olume of goods		
LCV demand		
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]
	International RORO up due to improved economies [37]	Distance travelled reduced - influence of wider transport system

Digital

The digital revolution will transform transport by using data and artificial intelligence to integrate and optimise existing services and allow millions of people to make journeys that were previously inaccessible.

The increasing levels of connectivity and processing power mean increasing amounts of data can be collected, transmitted and processed. This is changing services, business models and traveller experiences by delivering information, recommendations and actions for individual travellers, transport providers and the transport system.

The digital revolution is already impacting daily journeys, including through digital tickets or dynamic planning of journeys that take account of changes in the transport system as they happen. Vehicles have increasing levels of automation. Assisted braking, lane keeping and parking now regularly feature in cars. And, behind the scenes, digital tools are used to make more cost-effective or efficient decisions such as on maintenance schedules.

We expect digitalisation to have an increasing impact in the future.

Cyber-physical systems such as digital twins – real-time digital counterparts of physical objects, systems and processes - will enable transport planners to efficiently model scenarios to understand impacts and optimise decision-making. Real-time information will provide live insights and the ability to proactively intervene and fix any emerging problems, increasing resilience and safety.

Travellers will be offered more journey-focused ticketing, with greater flexibility to make the right journey for the individual context and circumstances or in response to changes as they happen in the transport system.

Increasing levels of automation will mean vehicles and craft can operate without drivers or pilots, increasing safety and efficiency and reducing cost. Public transport and deliveries will be able to expand into under-served areas, and users will be able to access on-demand services to make both end-to-end journeys and to connect to further transport options. Both increase travel options and increase accessibility and inclusion.

The transport system must operate as a whole to truly unlock the value of digitalisation of transport, with secure but frictionless data access and decisions made automatically in a way that is fully trusted and safe. This requires a systems approach. International collaboration will be needed, and the UK will need to manage the risks and opportunities of international partnering and supply chain to deliver critical services. The way digitalisation is applied across the transport system will impact and be impacted by multiple different areas and stakeholders.

WIDER TRANSPORT NETWORK

Engagement across the transport sector is needed to realise the benefits of digitalisation. We have summarised below the key ways that digitalisation of transport over the coming decades interacts with and impacts on the main trends presented in the six pathways. Whilst digitalisation can enhance the progress set out in this vision, it is crucial that a wide range of stakeholders are engaged to maximise impacts and benefits. This includes communication with travellers to maximise understanding and adoption of new products and services.

TRAVEL AND TRANSPORT DEMAND

Predicting transport usage is extremely difficult and uncertainty is high even across the rest of this decade. Whilst one vision out to 2050 is presented, there remains significant scope to accommodate and influence shifting passenger flows and behaviours to deliver a more effective and user-centric transport network. Digitalisation will provide new and far greater insights into the transport network both in real time and in modelling future scenarios. This will enable decision-makers to balance supply and demand and plan effectively for the future.

CONNECTIVITY

Greater connectivity is a key to more efficient operations and to transport providers offering a wider range of services to make journeys more appealing. These services include traffic management in real time, traffic, service and infrastructure planning and user services whilst travelling. Connectivity needs to be combined with other digital tools to deliver this.

Key to this connectivity will be effective collaboration and dialogue between the wide range of stakeholders across the transport network and telecoms industry in areas such as availability, compatibility, accountability, and transparency in data exchange.

ENERGY VECTORS

Transport will transition to new renewable energy sources over the coming decades. The transition to net zero also requires vehicles and refuelling or charging infrastructure to be used in a more efficient way to reduce the total energy demand for transport. Digitalisation of the transport network will enable more efficient traffic flow, smoother driving operations and better connections to infrastructure.

AUTONOMY

Increasing autonomy will bring significant benefits, including safety, efficiency and inclusivity. Decision-making is at the heart of autonomy and needs to be trusted by the public, regulators, insurers and others.

That decision-making process must be interrogatable and understandable to enable learning and testing before it is approved for use, and it must be secure and robust when in use. AI must be developed and deployed responsibly. Multiple digital tools are needed, including efficient processing, security by design, robust data management and secure connectivity. These tools will also support developments outlined in other pathways.

INFRASTRUCTURE

Digital technologies will help us manage infrastructure more efficiently, supporting monitoring, more timely maintenance and better design and construction. Improvements to the supporting cyber-physical infrastructure are needed for digital technologies to deliver these benefits. This includes improvements to connectivity, data processing and storage, security and ability to evolve to meet future needs.

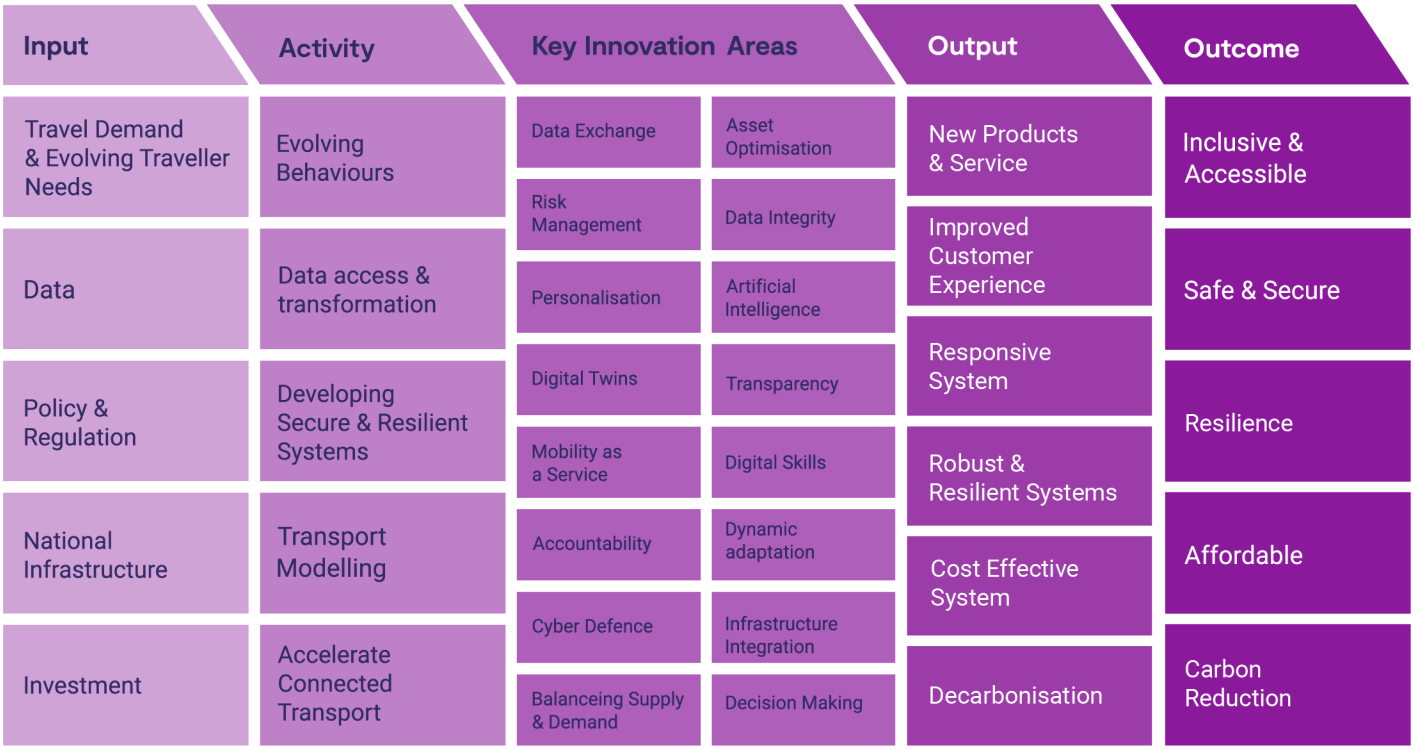
BUSINESS MODELS

Enabling appropriate, effective and secure data exchange across the range of stakeholders in the transport network is vital to improve the experience of transport users and bring other benefits. The specific business models for transport data exchange continue to evolve, so data models and service providers need to remain flexible and responsive. The value of data can be realised by the right business models and governance, unlocking data flows, innovation and growth.

Digital logic model

Digitalisation can enhance capabilities across the transport network, both within specific modes but also crucially in creating more effective cross-modal operations. Whilst the wider Transport Vision 2050 has been refreshed, the inclusion of a digital section marks the most significant addition to the vision. This section provides an overarching logic model for digitalisation using digital tools and inputs to achieve desired societal and economic benefits or outcomes. Key areas for innovation are included as critical to delivering these benefits.

Figure 2 - Digital logic model



Connectivity

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

Connecting transport systems and vehicles through cellular, satellite and other communication technologies will allow significant safety and efficiency gains and new services for both travellers and freight. Increasing data and digital connectivity will enable new business models and services, unlocking significant new economic and social value. Secure connectivity will be critical to the reliable operation of such businesses and services.

We expect this to be enabled by widespread 5G connectivity replacing 4G in populated areas by 2030 [17] and LEO satellite communications supporting areas of poor terrestrial coverage. 6G trials from 2028 [17] and rollout will be largely replaced with widespread 7G by 2050. These will increasingly connect all road vehicles with each other and enable a sophisticated central traffic management system. Road vehicles will offer users increasing levels of connected services, personalisation and experiences by 2030 [28] and seamless transfers across connectivity modes by 2050. Road vehicles will be capable of cooperating with other nearby vehicles to support traffic flow and safety by 2050.

Road vehicles and road users will be capable of fully cooperative operation and interaction 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, more real-time data will lead to improvements in traffic management on traditional roads and to efficiencies, cost savings and emissions reductions.

Improved connectivity and data will bring planning and payment services that allow people to choose alternatives to private cars, including moving away from personal vehicle ownership to usership models.

Connectivity will support the optimisation of freight movement at ports, depots and across borders and will help to maximise efficiencies in time, miles travelled and use of space.

The advanced train protection system, the European Train Control System (ETCS) level 2, will be rolled out on almost all UK passenger trains by 2040, and nearly all signalling will be digital by 2050.

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 [4].

People using active forms of travel, such as cycling and walking, will make more such trips [38] as they feel safer, experience better air quality and have more confidence in a connected and informed journey.

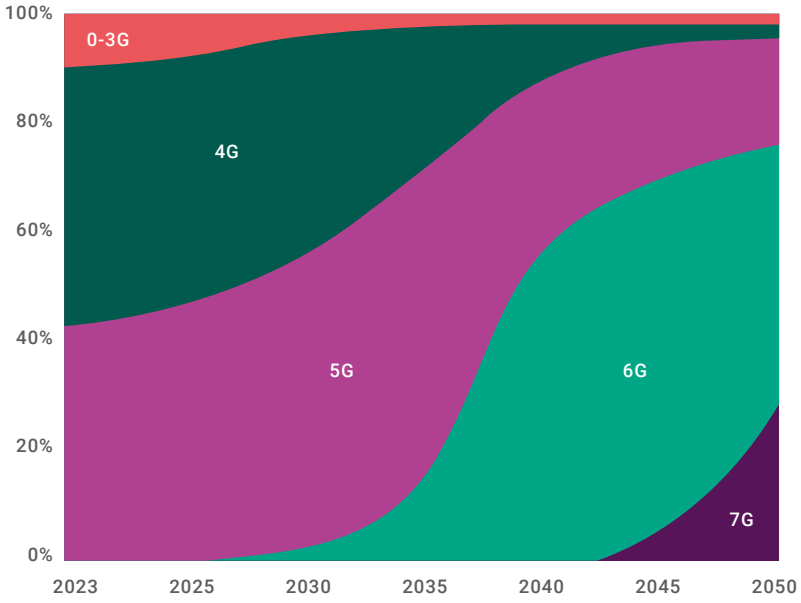
Connectivity and rich data gathering underpin the creation of cyber-physical systems such as digital twins. Better digital twins will facilitate improved travel planning and routing. AI and machine learning will enable improved simulations, leading to more transformational infrastructure usage.

All recharging and refuelling systems of vehicles and craft of all modes will be securely internet connected by 2030 to maximise energy management of electricity and all fuel types for users and energy networks.

Communications requiring precision timing will rely less on satellite systems and use more resilient terrestrial sources [39].

Figure 3 - Prediction of percentage of UK roads with consistent terrestrial cellular coverage by at least one mobile network operator.

Roads with 5G, 6G, 7G may also have lower generation technologies down to 4G. Levels up to 3G likely to be phased out after 2024, so '0-3G' after this time will likely reflect no cellular connectivity.



Connectivity pathway

Transport modes	Elements	2021 position	By 2025
All modes	Cellular connectivity		
	Satellite communications, positioning and timing		
Air transport	Traffic management	Upgrading air traffic infrastructure [1]	PBN using satellites
		ADS-B Trials [3]	Airspace systemised [4]
		OTS allows free routing [3]	Digital sharing ATC across airports [5]
	User connectivity	EAN allows connectivity [6]	Widespread satellite connectivity [7] [8] [9]
Maritime	Traffic management	Anonymous tracking trials	Shift to digital logistics via IoT
		5G unmanned CAV trials [10]	Increased use of IoT devices
	User connectivity	Reliance on land based comms	HAPS and Sat comms increased speed
		Expensive and unreliable sat comms [12]	
Rail	Traffic Management	GSM-R migrates to packet switching	FRMCS trials start
		ERTMS trials continue	FMRCS roll out
		Reduce ETCS deployment costs [13]	ETCS level 2 roll out [13]
	User connectivity	4G/5G provision location dependent	
		Ongoing discussion for national 5G	Some pass trains have wi-fi connectivity
Road	Traffic management	C-ITS enabling road safety, efficiency [15]	More C-V2V built in or added on [16]
		No. vehicles with C-V2X increases [18]	Data linked to insurance premiums [19]
		Vehicles broadcast emergency events [20]	Sensor enabling traffic management [21]
		Use of sensors to monitor traffic [22]	Geospatial info improving data [23]
		AI traffic management trials in UK [25]	
	User connectivity	4G across most of network [17] [26]	Many vehicles have connectivity [27]
		C3X on new vehicles: 80%: L1, 10%: L2 [28]	C3X on new vehicles: 40%: L2, 20%: L3 [28]
			ALN [31] and AURN data [32]
			AV monitoring established
			Users informed about route issues [34]
Active travel	Traffic management	Sensor tech to enable C-ITS	Improved connectivity [17] [34]
	User connectivity	Some info available on some routes [37]	Active travel increases [29] [30]

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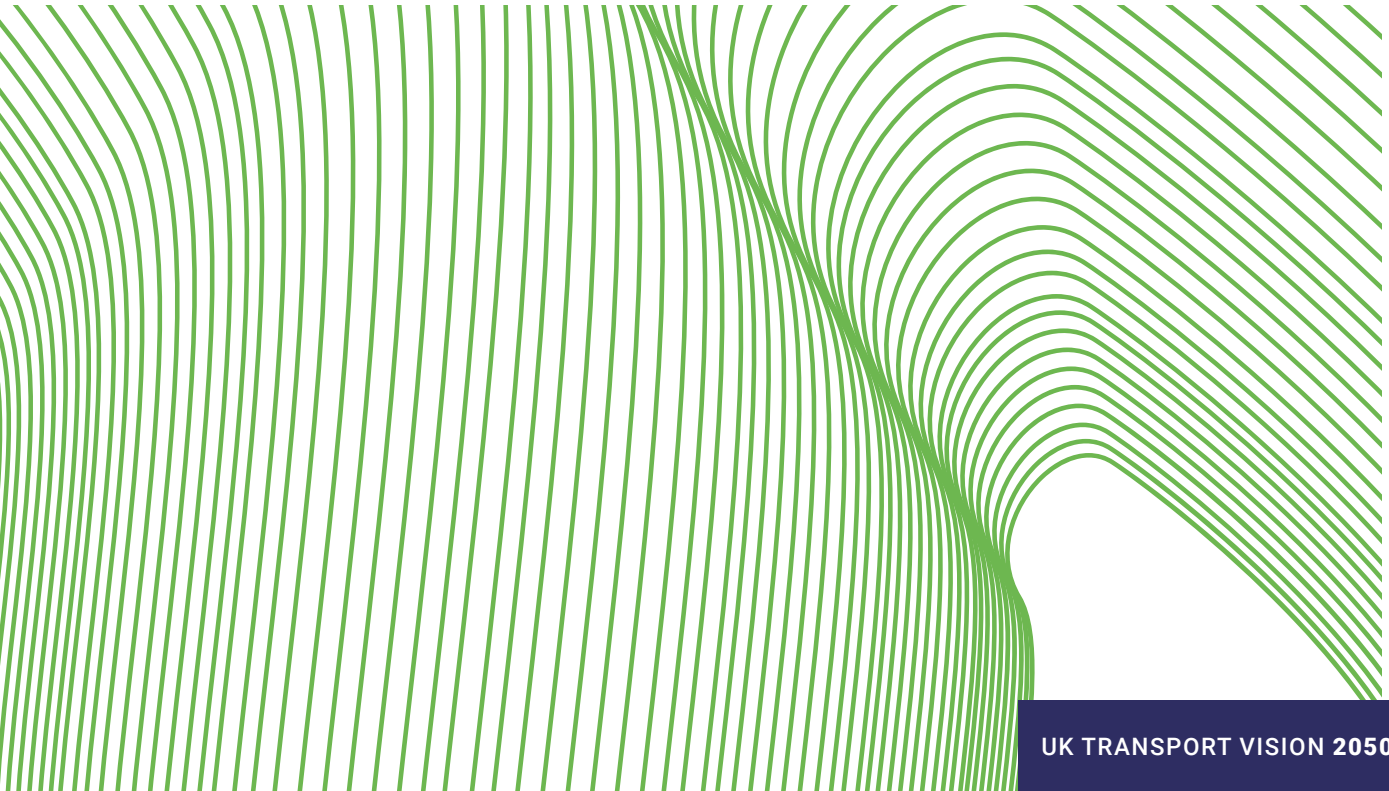
By 2030	By 2040	By 2050
Increasing connectivity		
Increasing connectivity		
Defragmentation of EU Skies [2]	Digital European Sky adopted	
UTM and ATM running together	UTM adopted	
Users routinely connected		
Increased use of AIS and LRIT for tracking	CAV capable vessels for berthing	Individual consignment tracking
Routes optimised for emissions [11]		Port side control for consignments
Centre for Smart Shipping established [10]		
~40% pass. trains fitted with ETCS L2	>99% pass. trains ETCS L2	>Most trains ETCS L2
~5% signalling will be digital	~40% signalling will be digital	~80% signalling will be digital
Trackside fibre available for pass comms [14]	Some mainlines have trackside coverage	Most mainlines have trackside coverage
Trains have wi-fi connectivity		
Traffic control systems influenced by AI	More traffic systems influenced by AI systems	Junctions controlled by AI [17]
New veh.s V2X / C-V2X, older ones retrofit		AV routes influenced by road authorities
Remote driving capability deployed		
Sensor tech for informed choice [24]		
New vehicles have 5G capability [27]	C3X on new vehicles: 70%: L3, 25%: L5 [28]	All new vehicles have 7G
In-vehicle infotainment run on 5G [27]	New vehicles report status to VOSA [30]	C3X on new vehicles: 25%: L4, 75%: L5 [28]
Trials on 6G commence 2028 [17] [29]	6G rollout by 2035 [33]	
Automatic switching between 4G/5G		
C3X on new vehicles: 60%: L3, 10%: L4 [28]		
Improved connectivity [17]	Cooperative road usage trials	Cooperative road usage common
Active travel suppored by real time data [35] [38]	Cycling and walking natural choice [35]	Improved connectivity [36]



Energy vectors

The move to net zero by 2050 requires surface transport to make a complete shift from fossil fuels to sustainably produced electricity, hydrogen and other alternatives. Aviation will still use some fossil fuels and will need to offset or remove carbon dioxide equivalent emissions.

Despite efforts to decarbonise using high-blend biofuels and electrification, 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 use fossil fuels in internal combustion engines (including hybrids), including at least two in three cars and vans, and about 80% of HGVs and buses. Nearly 90% of maritime crafts will be powered by liquid fuel. Around 15% of the rail fleet will be wholly diesel-powered. Most energy for air transport will be from fossil kerosene, although advanced air mobility (AAM) will predominately operate using renewable energy.

There will be a major transition to other energy vectors between 2030 and 2050. Digitalisation of the transport network will enable more efficient traffic flow, smoother driving operations and better connections to the infrastructure, contributing significantly to this aim. All domestic flights will be net zero by 2040 [3]. Goods and people may travel shorter journeys by air, using new electrified modes.

Decarbonising the maritime sector requires a range of energy sources, although there is limited consensus on the best approach. Methanol is now expected to play a more significant role in 2050 with a reduced role for ammonia in that timeframe. This update is in response to a growing order book for methanol-fuelled ships [37]. A plan for rail to achieve net zero is not yet approved but likely requires mass electrification. Battery electric with renewable energy will power more than 95% of cars and vans and the vast majority 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. Sustainable fuels and e-fuels will increase in production and uptake for air transport by 2030, and hydrogen will power 5% of flights by 2050.

Achieving net zero by 2050 means electrification will be the dominant energy vector. It will power at least nine in ten cars and vans, most buses, coaches and HGVs, most rail movements and all micromobility. These vehicles will also support a renewable electricity grid through bidirectional and smart charging.

Hydrogen will also be a significant energy vector by 2050, although below previous estimates. It will fuel around 20% of HGVs, buses and coaches, 5% of air transport and 3% of maritime directly. Ammonia and methanol will fuel 24% and 44% of maritime respectively, further adding to the hydrogen required. This hydrogen will need to be produced from renewable and low carbon sources. Autonomous aircraft, drones and regional air travel will mostly be electric/hybrid or hydrogen-fuelled. Gas (compressed or liquified methane) does not see significant share.

> **It is estimated 163TWh of electricity will be needed for transport by 2050**

The future transport system is expected to use significantly less energy despite rising demand. This is thanks to the efficiency gains of renewably powered transport solutions over the current fossil fuel approach. In 2050 we expect to use:

- 69 TWh of hydrogen for transport, including ammonia and methanol for maritime
- 163 TWh of electricity for transport

The impact of these changes is substantial. It will require significant battery production and the requisite raw materials. By 2040, nearly 200 GWh a year of battery supply will be needed in the UK to satisfy the demand for batteries in transport and grid storage [35]. This is a seismic change and carries a risk around supply chains and manufacturing scale-up. Furthermore, our vision could be altered by a range of unforeseen events, including increased electricity prices and the ability to cost effectively scale renewable hydrogen production and distribute it.

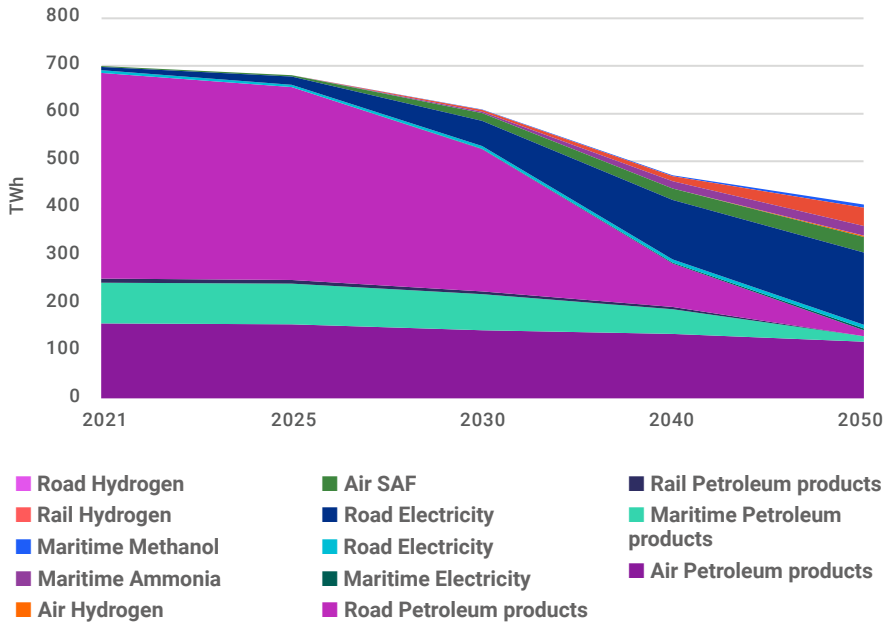
Ensuring renewable energy is the first choice for mass transit is key to a net zero future. Our vision suggests that further effort is required to ensure the UK achieves this.

Figure 4 – Tank to wheel/propellor energy vector changes over time

163 TWh of electricity and 69 TWh of hydrogen are among the energy vectors replacing nearly 50 million tonnes of fossil fuel a year by 2050.

We have extrapolated from our energy vector assumptions and assumed total traction energy needed for transport remains constant.

The reduction in overall energy consumed is enabled by greater efficiencies from electrified powertrains replacing less efficient combustion engines.



Energy vectors pathway

Transport modes	Elements	2023 position	By 2025
Air Transport [1 - 7]	Enablers	Early development of alternative energy vectors	UK SAF mandate implemented
			CORSIA mandatory for all UK int flights
			Power to Liquid (PtL) fuel Strategy 2023
	Advanced Air Mobility (AAM)		>99% Battery electric or Hydrogen
	Fuel mix [1-7] [36]	>99% Kerosene	98% Kerosene
		<1% Sustainable Aviation Fuel (SAF)	2% SAF
			Development of hydrogen fuelled aviation
	International and Domestic		A civilian flight using 100% SAF demonstrated before 2024
			At scale SAF plant by 2025
Maritime [8 - 15]	Trends [8-11]	All Marine Diesel & Heavy Fuel Oil (HFO)	BEV for short journeys only
			TRL3-7 Hydrogen & Ammonia projects
	Fuel mix [12-14] [33-34]	52% Marine diesel	52% Marine diesel
		48% Heavy & Low Sulphur Fuel Oil	47.9% Low sulphur and heavy fuel oil
			0.1% Battery electric and shore Power
Powered Light Vehicles [24]	Enablers	Encourage more active travel	Develop micro-consolidation hubs
		Provide infrastructure	
	Micromobility	E-scooter and e-cargo bike trials ongoing	>99% BEV and active travel modes
	Motorcycles (2023: 1.5m)	92% Fossil Fuel and renewable ICE [24]	84% Fossil fuel and renewable ICE
		3% BEV [24]	9% BEV
		5% Hybrid [24]	7% Hybrid
Rail [16 - 22]	Enablers	Develop hydrogen and battery solutions	Hydrogen and Battery electric trials
			Manufacture of non-hybrid diesel trains ends
	Fuel mix to power traction, light and heavy rail [17-18]	71% electric	75% electric
		29% diesel	25% diesel
Road [23 - 33]	Enablers	End of sale dates proposed for new non ZEVs	ZEV capability and affordability increased
	Cars (2022: 35.1m) [23-26] [33]	92% Fossil Fuel and renewable ICE [26]	84% Fossil Fuel and renewable ICE
		3% BEV [26]	9% BEV
		5% Hybrid [26]	7% Hybrid
	Light Commercial Vehicles (2022: 4.9m) [26] [33]	98.5% Fossil Fuel and renewable ICE [24] [27]	84% Fossil Fuel and renewable ICE
		1.3% BEV [24] [27]	9% BEV
		0.2% Hybrid [24] [27]	7% hybrid
		0% Hydrogen	0% Hydrogen
	Bus & Coaches (2022: 145k) [24] [26] [33]	97.6% Fossil fuel and biofuel ICE [24] [28]	95% Fossil fuel and high blend biofuel ICE
		0.4% Gas [24], increasingly renewable	0.6% Gas, largely renewable
		2% BEV [24]	4% BEV
		0.1% Hydrogen [24]	0.4% Hydrogen
	HGV (2022: 615k) [26] [33]	99% Fossil fuel and renewable ICE [24] [27] [28]	95.9% Fossil fuel and renewable ICE
		0.6% Gas [24]	3% Gas, increasingly renewable
		0.4% BEV [27]	1% BEV
		0% Hydrogen	0.1% Hydrogen

CERTAINTY high med low speculative

By 2030	By 2040	By 2050
All aircraft certified for 100% SAF	UK SAF industry established	
	Sufficient SAF for domestic flights	
90% Kerosene	85% Kerosene	75% Kerosene Offset [1-3] [40]
10% SAF	15% SAF	20% SAF (including some PtL)
		5% Hydrogen
Majority of UK airport ground operations are zero emission	All airport operations in England zero emission	
Zero-E flight demonstrator 2026	UK domestic aviation net zero by 2040	
SAF significant increase in production	Zero-E planes enter into service in 2035	
All new ships to be ZE capable	Large shift in take up of zero emission energy sources from 2030s	Domestic all zero emission
Wind, biofuel, electro-fuel and H2 demos		
41% Marine diesel, including renewable	28% Marine diesel, increasingly renewable	13% Marine diesel, largely renewable
47% Low sulphur and heavy fuel oil	33% Low sulphur and heavy fuel oil	0% Low sulphur and heavy fuel oil
4% Methanol	12% Methanol	44% Methanol (renewable)
3% Battery electric and shore power	7% Battery electric and shore power	14% Battery electric and shore power
4% Ammonia	18% Ammonia	24% Ammonia
1% Hydrogen	2% Hydrogen	3% Hydrogen
Large-scale urban freight consolidation		
Electric-powered last-mile delivery		
	100% BEV and active travel modes	
57% Fossil fuel and renewable ICE	8% Fossil Fuel and renewable ICE	
34% BEV	87% BEV	99% BEV
9% Hybrid	5% Hybrid	1% Hybrid
Increased electrification of network	Diesel trains removed by 2040	Wholesale integration with energy system
Manufacture of ZE trains only		Net zero rail network [16]
80% electric - direct and hybrid	85% direct electric	
15% fossils fuels and bio fuels	Electric diesel hybrids phased out	
2% hydrogen	5% hydrogen	
2% battery electric hybrids	5% battery electric hybrids	
1% battery	5% battery	
Emitting vehicles de-incentivised, economics generally support ZEVs	End of sale of new non ZE HGVs (smaller HGVs earlier) [16]	Circular economy for ZEVs, bidirectional charging normal
57% Fossil Fuel and renewable ICE	8% Fossil Fuel and renewable ICE	
34% BEV	80% BEV	95% BEV
9% hybrid	12% Hybrid	5% Hybrid
56.5% Fossil Fuel and renewable ICE	8% Fossil Fuel and renewable ICE	
34% BEV	86% BEV	94% BEV
9% Hybrid	5% Hybrid	3% Hybrid
0.5% Hydrogen	1% Hydrogen	3% Hydrogen
83.6% Fossil fuel and high blend biofuel ICE	49% Fossil fuel and high blend biofuel ICE	5% high blend biofuel or renewable ICE
1.4% Gas, largely renewable	1% Gas, largely renewable	0.5% Gas, largely renewable
12% BEV	42% BEV	74.5% BEV
3% Hydrogen	8% Hydrogen	20% Hydrogen
84% Fossil fuel and renewable ICE	46% Fossil fuel and renewable ICE	4% Renewable ICE (includes range extension)
6% Gas, increasingly renewable	8% Gas, increasingly renewable	2% Gas, majority renewable
8% BEV	40% BEV	77% BEV
2% Hydrogen	6% Hydrogen	17% Hydrogen

Autonomy

Automation will make vehicles and craft safer and smarter, provide various types of accessible, fully autonomous transport and create new services such as medical deliveries by drone.

Automation is being introduced in transport to improve overall efficiency and safety or to perform dull, dirty or dangerous human tasks. The balance between these objectives varies across different modes and applications, with some drivers and pilots expected to transition to remote support activities. 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 self-driving mode in limited areas – by 2035 [26]. They will allow those with mobility impairment to gain or maintain independence. Automated buses and minibuses will 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 other restricted areas such as airports and docks before more widespread usage. Agricultural and heavy plant automation will continue to grow [46].

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.

New passenger and freight carrying air vehicles will be developed with increasing levels of autonomy and able to operate with full autonomy by 2025 [3]. It is likely that these services will continue to have a pilot on board until public trust in the technology is suitably high. Increasing numbers of delivery, inspection, surveying and search and rescue services will be carried out by drones in 'beyond visual line of sight' and autonomous operations.

Autonomous trials of surface vessels in UK waters will expand. 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 the use of remotely operated vehicles.

Cyber security and trusted monitoring of the health of automated systems that have no human input will be key to public and commercial acceptance.

90% of motorway HGVs will be autonomous by 2050

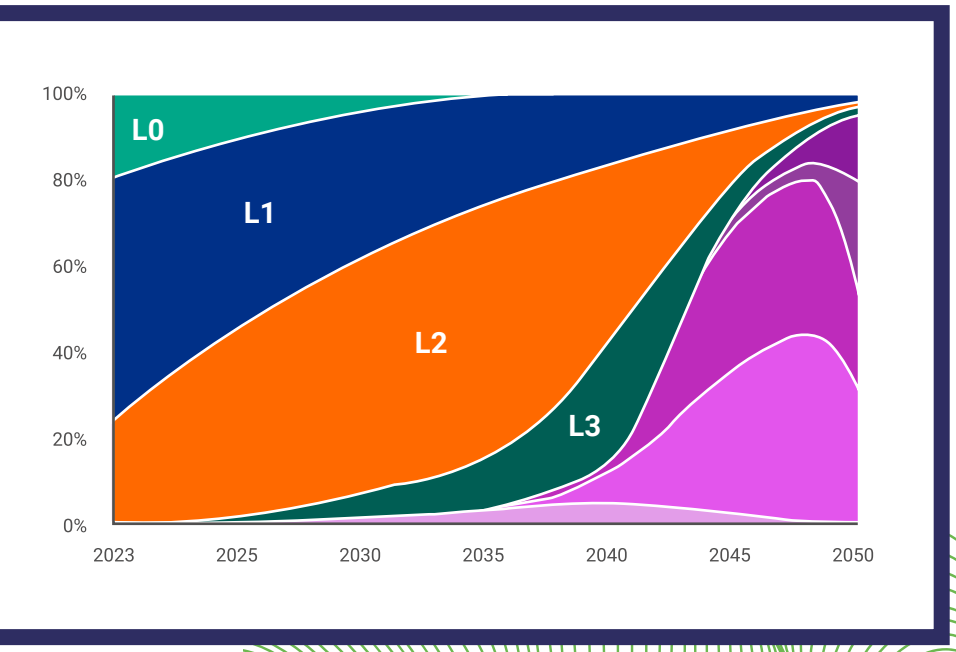
We anticipate that road transport, air transport, rail freight and domestic ferries will be predominantly autonomous by 2050. Some on-board staff will be retained to assist travellers and ensure accessibility. 90% of motorway HGVs will be autonomous by 2050. Last-mile deliveries in urban and rural areas will increasingly be completed by drone.

Figure 5 – Prediction of percentage of private and light commercial vehicles 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 **self-driving mode** in specific scenarios (level 3) by 2025, and operating in self-driving mode for all scenarios in limited areas (level 4) by 2030, with those areas expanding over time.

- **Almost all of UK roads**
- **Most rural roads**
- **Highway & suburban roads**
- **Urban roads**
- **Fixed routes**


100%
80%
60%
40%
20%
0%
L0
L1
L2
L3
2023
2025
2030
2035
2040
2045
2050

Autonomy pathway

Transport modes	Elements	2023 position	By 2025
Cross mode enablers	Perception & sensing		Technologies with increasing
	Autonomous control systems		Compute technologies with
	Connectivity & Cyber Security		Increasing connectivity c
Air transport	Airspace management	Upgrading air traffic infrastructure	Advanced network & operation services
			Cross border free routes [1]
			UTM system pilot
	Air vehicles	Initial UAM passenger ops by 2024 [3]	Expanded network of UAM pass. ops [3]
			BVLOS UAV delivery/inspection. ops routine
	Pilots to supervisors		Single pilot operations trial [4]
	Ground infrastr. & ops	Auton Taxi, Take-Off & Land trials [5]	
	Social acceptance of UAVs	Poor: Noise, privacy & environ impacts	Improving, with technology advances
Maritime	Vessel operation	Unmanned trials underway [6]	Unmanned vessels - deployment
		5G supports short sea autonomy [6]	Unmanned vessels - surveillance
		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]
			Remote pilotage trials
	Port side automation	Automated goods handling at ports [11]	Auton goods transport to / from ports
		Autonomous trucks at Felixstowe [12]	Auton passenger transport around ports
	Standards/Legislation	MASRWG 4th Code of Practice [13]	IMO MASS Code Published [14]
		MARLab report [15] & Maritime 2050 [16]	Updated Code of Practice Published
		Workboat Code Ed.3 Ann.2 ROUV [17]	
		National maritime security strategy [18]	
Rail	Trends	Automation options discussion [19]	Better connectivity -> more automation
		DLR has been driverless since 1987	
	Network		FMRCS trials start ~ 2023 [21]
	Design & operation	ATO/ETCS trials on UK mainlines [22]	ERTMS / ETCS L2 rollout commences [21]
	Maintenance	Network Rail autonomous inspection [24]	Inspecting railways with drones [24]
		Automat. roll. stock insp. concepts [25]	Outside automated inspection trials
Road	Trends	L4 Road Trials with safety driver [26]	Advanced road trials: no safety driver, segregated L4 comm deployments
	MaaS / pods / taxis	Autonomous vehicle trials [28] [29]	Pod road trials, no safety driver
	PSVs / Buses / Trackless Trams / ART / AVRT	Autonomous bus service trials [30] [31]	Bus depot automation [32]
			L4 buses & pods - lo complex. ODD [33] [34]
		ART / AVRT Feasibility studies [35]	
	Private vehicles	Initial vehicles with ALKS	Private vehicles with ALKS
		AVP concepts under consideration	Off-road AVP trials
		Main automation is ADAS	Improved safety intervention ADAS
	Freight / Plant	Freight depot automation trials [38]	Freight depot automation [39]
	Standards / legislation	ALKS adoption (2021) [41]	ALKS+ consultation (ECE)
		CCAV Policy Paper [42]	
		Code of Practice (trials) [43]	Advanced CAM trial approvals by 2023
		CAVPASS [44]	Low complexity ODD - GBTA
		Scenarios & weather standards in devt. [45]	Scenarios & weather standards in GBTA

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By 2030	By 2040	By 2050
capabilities & reliability (hardware and software) with cost reductions		
increasing capabilities (hardware and software) and cost reductions		
apabilities, evolving cyber threats and cyber security technologies		
ATM Data Services support CoD [1]	Digital European Sky [2]	
Virtual Centres support CoD [1]		
Change to trajectory based operations		
	UTM adopted UK: 2035, internat: 2040	
Autonomy Level 3/5	Autonomy Level 4/5	
Drones carrying loads <1 tonnes	Intercity passenger UAVs common [3]	
Assisted/autonomous systems certified	UAVs communicate autonomously with UTM	
	Single pilot ops, auton separation [1]	
Autonomous system + human supervisors	Auton. system, no human intervention	
Auton Taxi, Take-Off & Land ops [5]		
	Quantum sensors for poor weather [4]	
Generally widespread public acceptance		
Auton. shipping market £10.33bn [9]		
	6G supports surface vessel trials	
	Some automated vessel berthing in port	Automated arrival & berthing common
Software pilotage trials	Software pilotage common	
	1st MAFM through a UK port by 2035 [6]	Most ports smart & inter-connected
IMO MASS Code Mandated 2028		
Updated Code of Practice Published	Updated Code of Practice by 2036	
Centre for Smart Shipping estab [6]		Type approval framework for MASS
In-cab signalling commences	Smart trains adapt to situations [20]	Services adapt to meet demand [20]
New operational concepts	ATO (Freight) inc auton. handling [20]	Efficient pass. flow at stations [20]
FMRCS on priority routes from 2025	Digital signalling: 25% by 2035, 40% by 2040	Digital signalling: 60% by 2045, 80% by 2050
40% pass trains ETCS L2 fitted	>99% pass trains fitted for ETCS L2 [21]	
Autonomous trams / VLR trials [23]	Initial autonomous trams / VLR services	
More auton maint. reduces human risk		
Outsde & inside autom. inspect starts	Automated maint. of roll stock scales up	
Initial L4 road deployments	CAV industry worth £41.7billion [27]	Autonomous usage normal
	L4 Services common in urban areas	
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	
AVRT / ART / Trackless tram trials [36]	AVRT / ART / Trackless tram services	
L4 trials on series private vehicles	Self-driving mode on 40% new cars [27]	Self-driving mode on 95% new cars
Limited private vehicles with ALKS+ & AVP	Mid complexity / mid volumes [37]	High complexity / high volumes [26]
	High complexity / low volumes [37]	
Some L3 capabilities on freight vehicles [40]	L4 freight deployment (simple road ODD)	Widespread L4 freight deployments
ALKS+ adoption (ECE)	Full AD system approvals (ECE) by 2035	
Full AD system consultation (ECE)		
Medium complexity ODD – GBTA 2028	High complexity ODD - GBTA by 2032	
Complex scenarios agreed by ECE		

Business models

Evolving customer needs and advances in technology will transform business models and lead to a bundling of services, better use of resources and mass customisation.

Travel demands and needs are evolving with changing lifestyles. Expectations when travelling are also adapting, as is the way travellers buy products and services. Factors such as carbon footprint and accessibility for the estimated 16 million people in the UK with a disability [34] increasingly impact consumer choices. All of these changes offer significant business opportunities.

Increasing digitalisation of the transport sector offers many opportunities for those with the agility and confidence to innovate. Increased data flow will offer more avenues for data collection and therefore greater scope for use and exchange of data. Interoperability and openness through technical standards and ethical, legal and commercial frameworks are key to maximising societal and economic potential.

Cyber resilience will be critical to a trusted service and creation of a significant market opportunity. The global automotive cyber security market is predicted to grow to US$6 billion by 2028 [30]. The size of the market for data resulting from greater vehicle connectivity is estimated to be up to US$750 billion by 2030 [25].

Greater availability of data will allow deeper insights into the environmental and societal factors, including from the perspective of equality, inclusivity and accessibility. These should become increasingly influential in approaches to transport design.

Policy, legislation, green finance decisions, carbon accounting, tax and incentives will also significantly shape the future transport system. Businesses will find creative ways to minimise costs and maximise revenues, sharing these benefits with their customers to increase market share. However, they will also face increasing pressures to deliver green credentials. Creative approaches could all potentially shape future markets including:

- bundling services in a one-stop contract and increasing land-based shared mobility options
- maximising use of assets at times of low demand, such as using idle vehicles to transport goods or batteries for grid management
- mass customisation of transport products and offerings through data capture and personalisation

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.

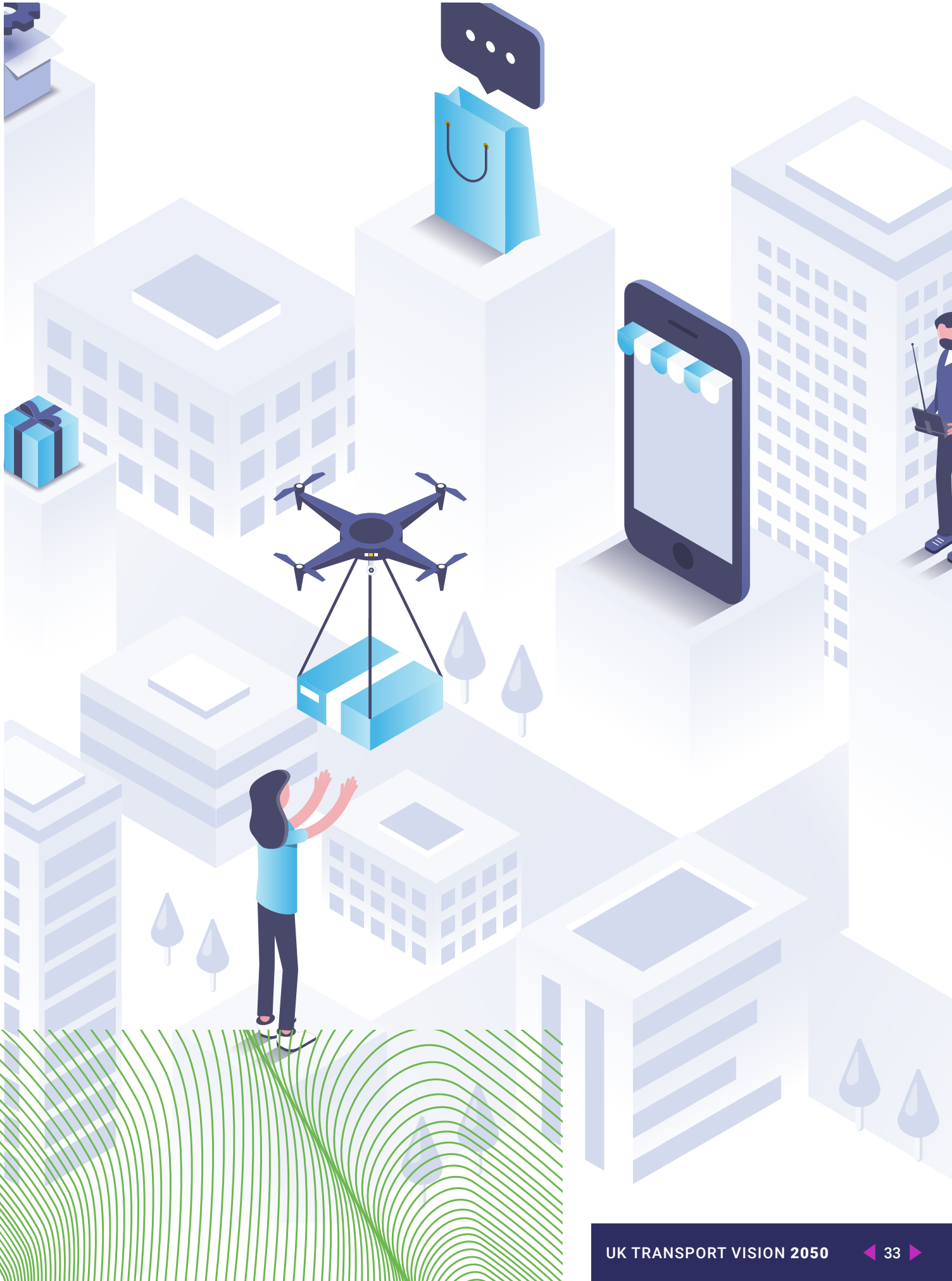
We expect online retail and associated home deliveries will increase from 26.5% in 2022 to over 60% by 2030 [6] [7]. About 40% of overall global logistics costs are associated with the last mile [13] [14]. Consumers are demanding faster and more reliable and convenient delivery services. This leads carriers to offer expensive timed, same-day and other traceable services [11] [12]. 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 [16] [17]. A push for cleaner, more sustainable urban mobility modes and the increased use of commercial drones will also impact the logistics industry [18] [31].

Insurance markets will be disrupted, with increasing levels of connectivity and data processing giving greater understanding of risk. Realtime data and calculations will offer deeper personalisation for individuals. Automated mobility will move the need for insurance away from the user and to the vehicle [1] [3].

> **We expect online retail and associated home deliveries will increase from 26.5% in 2022 to over 60% by 2030**

Greater connectivity of services and users will increase the use of apps to plan journeys, including replanning when travel is disrupted, and deliver on-demand personalised services. It will also expand the use of bundled services, including hailing of taxis, ordering of electric bikes and the purchasing of tickets for public transport [5, 8, 9, 10].

Planning and developments, both existing and new, will become more people and lifestyle-focused. Access to services and the need for transport will be key considerations. There will be an increasing focus on the environmental and human impacts, and how place and the transport network deliver for society.



Business models pathway

Business model areas		2023 position	By 2025
Retail	Delivery requirements	Consumer demand for faster, more reliable and convenient delivery services	
		Carriers to offer costly timed, same-day and other traceable services [11] [12]	
	Last mile delivery mode	98% van, <1% bike	
Insurance	User insurance	Insurance on static risk model	Pay how you drive [1] [4]
	Multimodal	Developing market for liabilities on system and service reliability	
	Vehicle insurance	Insurance adapting to ride sharing and gig	
Circular & resource efficient models	Air Transport [20]	End of use: 80-85% repurposed/recycled	95% repurposed/recycled [22]
	Rail [23]	Supply chain materials & waste mapped	Embed circular thinking in decision
	Road [19]	Low levels of circularity	More circularity & efficient asset use
Point of sale	Public, private and shared	Increasing use of apps (with predictive analytics) to plan journey and delivering on demand personali	
		Increasing levels of bundled services including hailing taxis, ordered electric bikes, as tickets for buse	
		Reducing car ownership / ability to drive -> increasing fleet operators, with companies repositioning t	
Data flow and security	Data flow	Cars 25GB data per hour [26]	AVs 3,600GB data per hour [26]
	Cyber security	Global auto market $5.56bn [28], aviation $6.5bn [29]	
Batteries	Automotive	Limited trials of battery swapping/BaaS	
	Micromobility	Trials of battery swapping offerings	
Enablers		Public policy changes. Advancing technologies and expanding opportunities for data exchange. More journey options with enhanced services. More cost effective system. Improved accessbility and inclusivity leading to more flexible personal mobility.	
Air Transport [24]		'Hub and spoke' operating model	Consistent operating / revenue model
		Traffic returned to pre pandemic level	
Advanced air mobility		Concept	Trials
Maritime (ferry)		Fixed route & schedule, discrete ticket	Fixed route & schedule, increasing integration of tr
Maritime (private hire)		On demand door-to-door service, private hire, priced by arrangement	
Maritime (freight)		Fixed routes & schedule, commercial pricing	
Maritime (ports and harbours)		Smart ports and harbours trials	
Micromobility		Initial private hire e-scooter & bike	Wide deployment hire e-scooter & bike
		Private payment, not integrated	Private payment, not integrated
Rail		Fixed route & schedule, discrete ticket	Fixed route & schedule, increasing integration of tr
		Product based value chain	Pilot revenue & operating model changes
		Some service and utilisation contracts	Block chain enables micro-investment
Road (private vehicle)		>90% of cars bought on finance	Peer car share & car club growth
		Revenue from vehicle sale & servicing	Growth in fully serviced vehicles
Road (bus)		Fixed route & schedule, discrete ticket	Intelligent routes & schedule, increasing integratio
Road (taxi)		On demand door-to-door, private and shared, priced per mile / time	
		Increasing market for on demand vehicle support - maintenance, cleaning, servicing etc. - brand diffe	
		Increasing utilisation of private hire fleet during non peak passenger times, generating value streams	
Kerbside		Digitalised kerbside mapping and kerbside strategies created	

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By 2030	By 2040	By 2050
Increasing use of consolidation models and data-driven non-traditional logistic methods		
20% robot / drone, 78% van, 2% bike and powered light vehicles (PLVs)	35% robot / drone, 43% van, 22% bike and powered light vehicles (PLVs)	80% robot/drone, 18% van, 2% bike [31]
AV insurance (cheaper vs human) [1]	Real-time risk insurance [1]	
Increasing market for liabilities on system and service reliability		
Major shift to insuring vehicles [2]	Real-time risk insurance [1]	Real time risk insurance [1]
100% repurposed/recycled [21]	End of life aircraft material become cheaper than primary materials	
100% reuse/recycle non-hazardous infra	100% circular processes across network	
Circularity widely in business models	Full circular value chain & net +ve	
sed service. Data capture then used to tailor and influence travel options.		
s and trains [5] [8] [9] [10]		
o sell multi modal mobility service rather than products		
Digital twin enable services [27]	Real time digital twins enable new business models	
Cyber in vehicle approval [27]	Continued 10-20% CAGR expected. Critical to national asset	
	Selective OEMs to offer battery swapping/BaaS as part of their services	
Widespread battery swapping for shared services		
Consistent operating / revenue model	Increased regional hubs & p2p travel	Int travel at few large airports
Pilot distributed aviation	Distributed aviation fully realised	Increased on demand services
Trials	Pilot UAM private hire	Early deployment UAM private hire
avel pricing	Fixed route & schedule, full integration of pricing – purchasing mobility	
		Widespead use of smart ports and harbours [32]
Increasing market for personal scooters (lightweight, high density battery). Impacts fleet scooter market		
Greater integration of mobility pricing		
avel pricing	Fixed route & schedule, full integration of pricing – purchasing mobility	
Services through private partnerships	Service based value chain	
Block chain secures digital data - individual tailored travel plan & track asset utilisation & maintenance		
	Lower utilisation of private vehicles	
	On demand shared vehicles more affordable and more reliable	
n of travel pricing	Intelligent routes & schedule, full integration of mobility pricing	
Increasing micro transit services	Increasing competition in on demand private vehicles	
rentiator and significant revenue source		
from goods services or V2G allowing cost savings to be shared with passengers		
Dynamic kerbside managerment widespread in urban centres with flexible bookable, reservable and paid-for kerbsides. Residential kerbside sees greater priority given to sustainable travel modes [33]		

Infrastructure

Transport infrastructure will respond to changing lifestyles, cleaner forms of energy and climate pressures, creating significant new business opportunities.

The development of secure and resilient-by-design infrastructure for energy supply, cross-modal mobility hubs and smart transport tools will accelerate. New business models will emerge to support the UK's need to meet net zero commitments.

This section focuses on the infrastructure required to deliver a transport system meeting both domestic and commercial users' travel needs whilst also protecting the natural environment.

The use of natural features in infrastructure development will increase to reduce environmental impacts and improve climate resilience. This green and blue infrastructure will improve air quality, biodiversity, woodland cover and drainage systems and mitigate air, light, noise and visual impacts. Infrastructure will deliver social, environmental, economic and cultural regeneration using modern methods of construction (MMC) [55].

The road network will be safer, more reliable, integrated and smart to maximise the use of space, reduce congestion and improve user experience [6]

The public smart charging network will grow with the right type of charge points in the right places. This will facilitate short duration charging for long-distance users, high power charging for heavy-payload vehicles and lower power charging to meet the needs of long duration residential users who cannot charge at home. Smart charging facilities in depots will be essential to manage complex operational pressures for logistics organisations. Static wireless charging will be deployed for some fleet uses, but the business case for dynamic inductive or conductive charging is still uncertain. Battery-swap will be more-widely used for micromobility solutions and will also be explored for some heavy-freight uses.

Electric vehicles will help energy systems cope with extra demand by acting as distributed energy storage resources (V2X).For long-distance, heavy vehicles where hydrogen may be a more effective zero carbon fuel, significant advancements in clean hydrogen production and distribution systems will create an effective infrastructure.

Electric vehicles will help energy systems cope with extra demand

Network Rail will produce 25% of its feed-in electricity needs from renewable sources by 2030 through connection of solar and wind generation to buildings and infrastructure, becoming zero carbon by 2050. Trials of bi-mode, hydrogen and battery trains are already underway, and all diesel-only trains will be removed from the network by 2040. Increasing track electrification will be seen out to 2050, with comparatively limited use of hydrogen and battery options.

Decarbonisation is more complicated, protracted and uncertain in maritime and air because of the wide variety of infrastructure needs. Ground support and on-shore equipment will be largely electrified but a range of alternate fuels will be needed for the wide range of aircraft and vessels.

Urban fringes, ports and airports will be ideally suited for the development of multi-modal transport hubs for both personal and commercial travel needs.

Digitalisation will enable more resilient and adaptable management of transport infrastructure by gathering real-time insights, accurately diagnosing issues, and proposing responses quickly. This will lead to lower down time, enhanced maintenance capabilities and a reduced number of failures. These enhanced capabilities will support the adaptation and resilience of transport systems to better withstand the impacts of climate change.

The increasing prevalence of a virtual world when thinking about transport infrastructure will enable more sophisticated testing and design to ensure solutions are as safe and effective as possible before real-world deployment.

Through effective use of data, decision-making for infrastructure will also be improved, for example in planning the deployment of new EV charging infrastructure or in the deployment of new micromobility solutions.

Understanding consumers' likely adoption of transport infrastructure innovations is key to enable markets and investors to align, share costs and help to shape the desired transitions in technology and behaviour. This requires an understanding of existing behaviour as well as culture, habits, knowledge and acceptance to minimise infrastructure adoption risks.

Infrastructure pathway

Transport modes	Elements	2023 position	By 2025
All mode enablers	Data	National Digital Twin Programme [19] Promoting open data sources for infrastructure.	Transport Location Data tools [19] CAM federated data architecture framework [46]
	Transport energy system - electricity	Developing V2X flexibility solutions [24]	Standard approach for DNO flex procurement & energy network access reforms [24]
	Transport energy system - hydrogen	Small-scale electrolytic production co-located with early users [3]	Large-scale CCUS-enabled Hydrogen production in at least one location [3]
Air transport	Air Traffic Management	Small scale demonstrations on infrastructure	Improved traffic control for drones
		Upgrade for future demand [11]	Autonomous traffic control pilots
	Electric Infrastructure		Low & high voltage chargers implemented [27]
			Battery charging at lead airports [2]
	Hydrogen Infrastructure		Hydrogen available at lead airports [2]
	SAF Infrastructure		>5 UK SAF plants under construction [2]
			SAF at lead airports & SAF Mandate introduced [2]
	Ground support		5% zero emission
	UAM / AAM		Pilot (100s) loading and charging pads
	Other infrastructure		Pilot EV/V2G systems at airports [2]
Maritime	Alternative fuel bunkering (including storage)		Improved solutions for fuel flexibility and multi-fuel use [18]
	Alternative fuel production and logistics	Limited logistics for alternative fuels [35]	Pilot alternative fuel for demonstration
	Connected infrastructure and smart shipping	Increased use of IoT to improve flow	Electrification of port equipment [37]
		Pilot connected infrastructure	Pilot smart shipping concept [8]
	Offshore charging	Pilot shore-to-ship connections [34]	Shore-side power c60GWh / year [38]
	Port & Marina developments	Increasing "blue tourism" [8] Development of marina V2G [47]	Automated e-boat charging system developments [49]
Active travel	Cycling and Walking	12,800 miles in the National Cycle Network [28]	Improving cycling & walking infrastructure [12]
		Shared cycle hire in most cities [39]	
	C-ITS	C-ITS for active travel pilot [40] [41]	Pilot C-ITS to protect travellers [33]
Micromobility (MM)		Enabling policies for MM infrastructure [30]	
		Trials to support infra decision-making [30]	Pilot multimode e-Mobility hubs [39]
Rail	Vehicle Fleet	Trials of bi-mode, hydrogen, and battery trains begin [15]	
	Traffic Management	Conventional signalling [22]	ERTMS / ETCS level 2 roll-out [22]
	Track	38% (12000 STK) track electrified [14]	40% (12600 STK) track electrified [52]
			Restoration and reopening of a number of old stat
	Hydrogen Infrastructure		
	Battery infrastructure		
Road	Highways	Little use of Green & Blue Infrastructure (GBI) in local area planning & deployment [51].	Improvements to freight corridors & connectivity [6] Education and support for GBI [51]
	Home & workplace charge points (CP)	>277k home + 22k workplace chargers [20] New private CP must be smart [20]	Smart charging becomes the norm [24] Reduced upfront connection costs [20]
	Public EV charge points (CP) (cars & vans)	42,500+ Public CP installed [9] Trials of wireless charging for fleets	Voluntary consumer service code of conduct [24]. SRN blueprint for charging [6]
		7,920+ rapid CP in UK [9] Never >25 miles from rapid charger on SRN [20]	Every motorway service area has 6+ high power CP (>100kW) [20]
	Heavy freight Chargin (CP) infrastructure	Zero Emission HGV Demonstrations announced inc electric & hydrogen infrastructure [13]	350kW chargers & 1st MW - hubs & major routes. 22-100kW - depots [32] HGV charging Investment plan 2028 [6]
	Hydrogen refuelling stations	9 H2 fuelling stations in UK [53]	15 H2 fuelling stations in UK
		Few examples of public infrastructure, others under development [50] [43] [13]	Revenue support (RTFO) in place [3]

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By 2030	By 2040	By 2050
National Underground Asset register [19] CAM Vehicle-to-infrastructure (V2I) connectivity [46]	Predictive pipeline tool to assess Infrastructure needs and constraints [19]	
2035 Net-zero power system [42] Most EVs provide energy flex services [3]		
Integration with gas network [3]	Distribution & storage integrated with CCUS, gas & electricity networks [3]	
Airspace modernisation [2]	Autonomous traffic control in service	
Re-design of lower airspace [2]		
Aircraft battery swapping available [27]		
Airports substantially electrified		Battery charging at all airports
Liquid Hydrant Systems available [27]	Hydrant refuelling systems replacing Bowser tanks at medium and large airports [17] Medium and large airports deploying on-site liquefaction of Hydrogen [17]	
Sufficient SAF for domestic flight [2]	2037 - Up to 14 SAF production facilities [16]	
SAF Mandate requiring at least 10% SAF	UK SAF industry established by 2038 [2]	
20% zero emission	60% zero emission	100% zero emission
1,000s loading and charging pads	10,000s loading and charging pads	
Pilot charging and maintenance infra	Airport ops in England zero emission [2]	Urban airports/ helipads implemented
Safe high volume storage capability for ammonia and hydrogen [18]	By 2035, low or zero emission fuel bunkering options readily available [10]	
Local H2 generation at ports [36]	Berthing infrastructure updated	
		Ports as multi-mode hubs [8]
		Digital port with central control [8]
Increasing use of BESS systems at marinas & V2G by moored leisure craft [49]		
Increasing combo travel [7]	World class cycling and walking network in England [1]	6 billion active travel stages [1]
Aim: half of urban journeys cycled or walked [1]	Active travel for short journeys and combo travel for long journeys are the natural choices [1]	
25% EV chargers cover mixed vehicles [39]	100% of shared MM pair with infrastructure [39]	50% EV chargers cover mixed vehicles [39]
Increased use of battery swap (BaaS)	50% of private MM pair with infra [39]	1% of urban roads have MM lane [39]
Network Rail 25% renewable electricity [15]	All diesel-only trains removed [1] [5] [15]	Network Rail zero carbon [15]
50% covered by ERTMS / ETCS L2 [22]	70% covered by ERTMS / ETCS L2 [22]	95% covered by ERTMS / ETCS L2 [22]
50% (15800 STK) track electrified [52]	70% (22100 STK) track electrified [52]	91% (25000 STK) track electrified [4]
ions and lines [31]		
Pilot H2 fuelling deployed		5% track H2 (1300 STK) [4]
Pilot battery charging points		3% track battery (800 STK) [4]
Improve public transport hubs, micromobility & walking routes on SRN [6] National GBI standards for highways [51]	Increase connectivity on SRN [6] Net gain in biodiversity [6] "Zero Harm" goal nearing zero [25]	SRN & MRN connect all areas well [25] By 2050, SRN user emissions to be net zero [6]
Bi-directional charging (V2X) becomes the norm, EVs storing & exporting energy [24]		
300,000 public CP installed [20] Long duration public charging mostly smart [24]	Some use of battery swap stations (BaaS) - dependent upon EV OEMs	520,000 public chargepoints [48] Public CP growth (types and locations) will be driven by need and business models
>2,500 high-powered chargers in England [20]	6,000 high power CP on SRN in England by 2035 [20]	
>500kW - 1MW chargers - hubs & major routes <100 kW - depots [32] [43] 1,500 kW every 100 miles on SRN [45].		
40 H2 fuelling stations in UK	250 H2 fuelling stations in UK [54]	300 H2 fuelling stations in UK
700-bar dispenser every 200km [45] 1 hydrogen station per 60 trucks [32]		

The route ahead

The vision and pathways highlight major new opportunities for economic growth and societal benefit and convey 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 strategic imperatives and drivers we identify are listed below:

Net Zero

The transition to alternative energy vectors brings substantial changes to transport production and supply chains. It will require significant battery production and the requisite raw materials. This carries risks and opportunities for manufacturing scale-up and supply chains, which will need to adapt and evolve to secure market position and grow.

Innovate UK will work with government and industry to maximise UK content and the role of UK companies in future supply chains to secure economic benefit including jobs.

Digital enabled

Advances in robotics, autonomy and artificial intelligence along with increasing connectivity, data transmission and processing will create opportunities for greater efficiency, new services for travellers and new business models in multi-billion pound 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.

Resilient and responsive

Traveller safety and confidence is essential for society whilst the continuous operation of the transport system underpins business and societal activity. It must be resilient to environmental impacts, production and supply challenges, and geopolitical events. Digital solutions must be implemented in a safe and secure way.

Innovate UK will work with government and industry to identify and manage threats and to embrace emerging and digital technologies, develop skills and embed safety and resilience.

Responding to evolving traveller needs

The transport system is driven by transport and traveller demand and needs. The more these demands and needs are understood, the better the transport system. Technology advances to improve transport services, reduce costs and revolutionise business models will accelerate the changes already apparent in the way people travel. This includes increasing understanding and accommodation of travellers' needs. Smart polices are needed to cater for these changes and ensure a sustainable and more inclusive transport system.

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

Delivering for the economy

A high-quality, efficient and effective transport system in 2050 makes the UK makes the UK a better connected and more productive place to do business.

By understanding and responding to traveller needs, and using the strategic imperatives to guide investments the UK can maximise economic growth, UK content, exports, and jobs.

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 the UK 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 and on the welcome contributions of many organisations and stakeholders. New information and future change will need to be reflected in future versions. We will ensure there are ways to provide feedback to us and we will update this vision as often as we need to. We look forward to working with you to invest in the future of transport.

Annex 1

Abbreviations used in pathway summaries

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
PSV	Passenger Service Vehicle
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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