Government Office for Science

A time of unprecedented change in the transport system

January 2019

The Future of Mobility

Foresight

Preface

Transport is critical for the economy. It creates opportunities for growth, generates jobs, and facilitates trade and realises economies of scale. It enhances UK competitiveness by improving connectivity across local, regional and national areas.

Mobility is central to the whole of society. It allows people to connect with places, and shapes how we live our lives. Social changes in the last twenty years have greatly altered how and why we use the transport system; shifts over the next twenty years will likely be even more significant.

Changes such as the growing, ageing population will meet technological advances in electric power, digitalisation and automation. These technologies will bring opportunities, offering fresh innovation to existing needs, as well as radical new approaches. They will also bring challenges, however.

Realising the full potential of technology requires us to consider how users' travel behaviour will respond to it, and how all of society and our economy can benefit. To be truly transformational, we need to view transport as a system: to consider it as a whole. The future of transport needs to balance a wide range of considerations. Capacity has a role to play, but it must be linked to making travel more sustainable overall, be this through lower emissions, less travel or better linking our journeys to housing and work.

A focus on people is central to the future of mobility. Understanding how citizens and businesses make decisions and interact with technology provides an opportunity to place the user at the heart of an integrated system. It holds the key to understanding and optimising the acceptance, adoption and impact of new technologies. Behavioural and social science can help us better design our built environment and its transport system around users, and allow technology to improve the lives of individuals and society.

This report on the Future of Mobility brings together evidence to inform the UK's response to a range of challenges and opportunities. To be successful, industry, science and policy-makers will need to work together, along with citizens. The UK has leading expertise and knowledge that places us at the cutting edge of transport innovation. Through the Industrial Strategy and more broadly, we should grasp the commercial opportunities to fully exploit our potential, creating a transport system that is ready for the future.

During this project, we considered evidence from a wide range of sources, through commissioning working papers to organising roundtables that brought together experts to develop and test new ideas. We also developed a number of case studies which highlight specific opportunities for the future of mobility. We considered four scenarios: one in which progress continues incrementally; one where technology is allowed to dominate; one where environmental and social issues take precedence; and a fourth where less data sharing predominates. None of these scenarios is absolute, but choices will need to be made to secure the right mix.

We are grateful to the academics and industrialists from across the country who provided the invaluable knowledge and expertise which underpins this report.

Sir Patrick Vallance
Government Chief
Scientific Adviser

Ministerial foreword

Over the next two decades, transport technology will change faster than at any time since the Victorian era. In place of cars powered by fossil fuels and internal combustion engines, we will have electric and autonomous vehicles. High speed rail will transform journeys between our major cities, and hugely enhance freight capacity. Drones will deliver goods to people's houses. And people will continue to produce and use more data than ever before, with profound implications for transport.

The advent of new technologies is already revolutionising the ways in which we think about travel. We are starting to see the emergence of "mobility as a service", bringing together functions such as customer information and payments across different transport modes. In time that should mean a vast expansion of services, more choice for consumers, more reliability and accountability, greener journeys and lower cost. For government, it means a once-in-a-generation opportunity to develop a genuinely integrated 21st Century transport system underpinned by digital connectivity and data.

The future scenarios developed in this project will be a useful tool to help the Department for Transport to anticipate and shape future trends as new technologies are brought to market. These scenarios should help us ensure that they deliver positive outcomes for transport users.

This work is also an important part of the evidence base we are building for the Future of Mobility Grand Challenge, which feeds into the wider UK Industrial Strategy. This means transport will be considered alongside other key areas of planning – such as housing, environment and land use – and will help define cross-Government solutions to our future mobility needs.

It is a truism that transport is never just about transport. Given the impact of new technologies, more than ever today transport is about creating green, safe, healthy, connected and inclusive communities, and about enhancing economic growth and productivity.

Ministerial foreword

We are very fortunate in this country to have innovative and world-leading transport companies and technology developers. As the market for cleaner, safer and more efficient technology grows, there will be unprecedented opportunities for the government to harness this expertise. This report will help us to grasp those opportunities, with potentially transformational benefits for the travelling public and for the UK economy.

Jesse Norman MP
Minister of State for the
Department for Transport

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This document is not a statement of government policy


Central Cambridge B
Stagecoach
AE09 GYC

Executive summary

The pace at which transport users now experience change is rapid, increasingly so. There is a window of opportunity to move towards a better transport future; learning lessons from the past, shaping the future – and now is the time to act.

We live in a time of unprecedented change in the transport system. Changes in the nature of working and shopping, new technologies and behaviours – such as automation, vehicle electrification and the sharing economy – are already having an impact on how the system functions, while the intersection of the physical and digital realms is changing how transport is planned and used. These developments bring exciting possibilities which, if grasped, will bring significant social benefits. Government has an excellent opportunity to capitalise on these, particularly through the Future of Mobility Industrial Strategy Grand Challenge.

Some of the coming changes to the transport system could have unintended negative consequences, though, if not properly anticipated. There is also much uncertainty: how demand for mobility will change between now and 2040; how the public and businesses will react to technological shifts; and exactly what our future transport system will look like. Government will need to consider these and plan accordingly.

This report reflects on the history that has shaped transport and mobility in the UK, examines the current trends in the system, and considers different scenarios that will help policy-makers to identify the choices and trade-offs to come – and to grasp the exciting opportunities that exist.

Our transport system

Transport is more than just travel. It connects people; it provides access to jobs, communities and goods; it delivers vital social services. Historically, individual transport modes have evolved at different rates and times, from the decline of horse-drawn carriages to the rise of the car, or the drop in canal freight to the expansion of the railways. This has led to a complex, fragmented approach to transport governance, one in which different modes and regions are considered in isolation.

During the 20th century, our culture became heavily reliant on the automobile. This situation persists today: in rural areas, 87% of personal trips are made by car or van, and 78% in urban areas. Linked to the rise of automobility, there has been a decline in walking and cycling over time. Our reliance on automobiles extends to the freight sector; by tonne-km, 76% of freight goes by road, compared with 15% by water and 9% by rail.

Current trends

Understanding the social and individual factors affecting people's lives, and hence how people make the lifestyle choices they do – including their travel choices – is key to understanding future transport demand. It is also essential if government wants to realise the beneficial changes, for example by managing demand or encouraging modal shifts in the transport system. This report illustrates some of these changes, using case studies.

Overall, we are currently travelling less at an individual level, although population growth means the total distance travelled is increasing. The reasons behind this decline in individual travel are complex, but broader social factors, such as the changing nature of work, having families later and attending university, have all had an impact. For individuals, affordability, accessibility, safety, reliability and habit are all important factors. Travel behaviours, particularly those of young people, are shifting. Initial data indicates that car use and ownership is less prevalent among young cohorts than it was in the past. This is mirrored by their greater openness to the sharing economy, which new technology will increasingly facilitate.

The economic burden of transport to individuals is magnified in places with poorer access to, and higher costs of, public transport. These are both influenced by where people live. For example, it is traditionally challenging to provide good transport services to low-density suburban areas, but these are where the poorest people are increasingly likely to live. Their lifestyle choice – where they live – therefore influences their travel behaviour.

Travel behaviour also varies considerably by location. This report reflects on some solutions that might usefully be considered in urban, suburban and rural locations, drawing on the potential offered by new technologies and business models. Both hard and soft measures are likely to be necessary to achieve real change and stimulate shifts in habitual travel behaviour.

Wider social changes, such as a growing and ageing population in the UK, overlay and interact with mobility, leading to further complexity. For example, active travel (walking and cycling) tends to decrease with age, while car use increases. This combines with the challenge of keeping the older population healthy and living independently for longer. Car reliance is compounded by the fact that the population is ageing more rapidly in rural areas, where access to services, including public transport, is limited. This restriction on travel choices has implications for well-being and social capital.

The reasons *why* people use the transport system are also changing, with implications for the transport system. Currently, shopping is the most common reason for personal travel, with commuting coming second. Yet social changes are influential here too, and again the links to the transport system come into play. The rise of e-commerce has seen a decline in the high street, as more people shop and order meals online. This has led to an increase in home deliveries. This, combined with growth in service vehicles, may help to explain the significant rise in van use. These vehicles offer greater flexibility than heavy-goods vehicles, which are more heavily regulated. However, the rise in van use brings with it environmental impacts, in terms of emissions and congestion.

Freight is an essential part of the transport system, but often overlooked in land-use planning. Decisions tend to be shaped by cost and accessibility, with a premium placed on flexibility – hence the reliance on road freight, which is the most flexible, in terms of route and timing. There are fewer opportunities for government intervention in this sector, which is largely privately owned, compared with passenger transport (which is under greater public control). However, government does still have a considerable impact on freight, with environmental legislation, pricing and taxation of road and rail strongly influencing its use and relative popularity.

Looking to the future

Meeting today's transport challenges, for example reducing congestion and air pollution, while providing the seamless, user-centric services that people and businesses want and expect, will depend on making the right policy choices. Increasing data use and connectivity will also have a greater role to play in the future. There is an opportunity to rethink how we plan and operate infrastructure using data. Away from infrastructure, the volume of privately-owned data is growing – users are already making use of this, but wider social benefits may not be felt if local authorities do not have access to this.

This time of social change and new technologies, from autonomous vehicles to e-scooters, offers extensive opportunities. As described in our scenarios, government plays an important role in grasping these and shaping the roll-out of new technology, as well as its location and impact. Whether new technologies can be rolled out for all remains an open question.

Who will benefit from the new data that will be generated? Public attitudes will be important, such as resistance to change or scepticism about new developments. Furthermore, the impacts of technological change – which can be rapid and are often disruptive – are highly uncertain, which makes it difficult to assess them using conventional planning tools.

By contrast, scenario planning can help decision-makers to explore how policy choices will play out in different futures; it also helps to make policy decisions more resilient.

To explore the most important areas of uncertainty this study developed four scenarios.

- **Trends Unmodified** illustrates a world where only incremental, mostly reactive, change occurs; this scenario highlights the risks of inaction.
- By contrast, **Technology Unleashed** considers a future where technology is developed and delivered in a highly permissive environment.
- **Individual Freedoms** outlines a future in which this environment is tightly constrained due to increasing public concerns over companies' handling of their private data.
- Lastly, **Greener Communities** suggests a future where change is geared towards beneficial social and environmental outcomes.

Each scenario combines government choices and external factors to create plausible futures. They illustrate the impact of policy choices and allow policy-makers to check if their plans are robust under a variety of circumstances. Scenarios can also be used to set out a vision for a particular location, and then consider the role of vehicles in enabling that vision. This approach is already being used in cities across Europe, while in the UK, it was adopted in the Greater Manchester 2040 strategy and the London Mayoral Transport Strategy.

Based on the analysis of past and current trends, and the likely impacts of new developments under different scenarios, this report identifies ten priority areas for the UK government to consider. Chapter 8 explains these in more detail. Across all these areas, data and the appropriate sharing of data will be critical to realise the opportunities.

1. **Consider transport as a system, rather than loosely connected modes.** This will maximise the delivery of government goals and wider benefits, such as employment, health and access to services. Aligning the policy levers for intervention can improve outcomes, deliver value for money and minimise the burden of a complex governance landscape. There are tools available to facilitate such an approach.
2. **Consider the wider objectives that the transport system can help to achieve.** Government should consider what it wants transport to provide. Health and well-being, social inclusion, job opportunities, trade, access to services, sustainable places and other objectives can all be supported through the careful design and planning of the transport system. Trade-offs will need to be addressed, though, and this requires broad collaboration across government. It also requires value judgements as to which outcomes are more desirable and, accordingly, receive greater weight.
3. **Outline a clear, long-term national vision and set goals that are mindful of varying local priorities.** This will allow coming trends and modes to be shaped rather than responded to. Infrastructure decisions taken now have long-lasting effects and there are choices and trade-offs, but there should be a focus on making best use of the whole system. Government could take the opportunity of responding to the first National Infrastructure Assessment to set out such a vision.
4. **Understand that geography is key to ensuring outcomes are practical at local and regional levels**. Different places exhibit vastly different travel behaviour, even when similarly sized. There is a need for a tailored approach to ensure these unique challenges are adequately addressed. Decentralised decision-making should enable the opportunities that exist across our towns, cities and rural areas to be taken, provided that the relevant funding, operational and strategic layers are fully integrated.
5. **Examine the specific challenges facing rural areas.** Given the low population density (and hence low profitability) of rural areas, it is a challenge for the market to provide efficient, sustainable transport solutions. The increasing age of rural populations poses further challenges, while

the lack of transport infrastructure means there are fewer opportunities for rural people to switch transport modes. New technologies such as autonomous vehicles can improve accessibility and mobility, including for elderly rural people. This also raises the wider question: how can government respond to transport challenges equitably?

6. **Integrate passenger transport with freight, alongside housing priorities, when making planning decisions.** Government can minimise future uncertainty by designing policies that meet multiple objectives and reconfiguring the way in which space is used, for example planning transport developments alongside housing development, while also integrating with existing town and city infrastructure. Government should also work in partnership with the privately-operated freight sector to ensure that developments cater for passenger and freight transport, where possible.
7. **Use a scenarios approach to explore different futures, identify opportunities and help mitigate the unintended consequences of new transport modes, technologies and/or trends.** This can make policies more resilient and help to facilitate decisions about long-term transport infrastructure, for example by avoiding stranded assets (investments that become obsolete). Solutions must increasingly be flexible, and policies may be tested against several alternative future scenarios.
8. **Use both hard and soft measures to achieve the scale of change needed.** As most travel behaviour is habitual, it is critical to understand what users want and how they make decisions when faced with incentives. Further research and regional data collection to understand travel behaviour at local scales should be used to inform local policies.
9. **Consider the impact of future technologies on revenues and costs.** This is important, given the likely scale and pace of change. With current policies, the shift to electric vehicles decreases revenue from fuel duty, and automation may decrease parking charges. Policy choices such as road pricing may need to be considered among other demand-side interventions. Technology can also significantly reduce operational and infrastructure costs.
10. **Consider prioritising walking and cycling when allocating land use for transport to promote wider social benefits.** Such an approach can change transport behaviour, improve people's health, reduce levels of physical inactivity and sedentary behaviour, and reduce air pollution and congestion. Effective ways to increase walking and cycling are well known internationally; for example, Copenhagen has markedly increased cycling over the last 20 years. Overall, this entails a mixture of investment in hard infrastructure (e.g. dedicated separate cycle networks) and softer measures.

Scope of this report

The Government Office for Science developed the Future of Mobility project in consultation with colleagues from across government. Its purposes are to inform a national long-term approach to mobility, to provide evidence of current trends, and to guide strategic thinking for the future.

This report looks in detail at the movement of people and goods by all means, across the whole domestic UK transport system. It covers the history of the system and key external trends, and looks in depth at users, freight, logistics and governance. It concludes by summarising insights from the analyses and highlighting priority issues looking towards 2040. Overall, it synthesises the evidence we gathered, which includes our commissioned evidence reviews (listed after references), roundtables with experts, and insights obtained from industry and academia.

Introduction

Mobility – the movement of people and goods – is generally not an end in itself. Its value lies in the accessibility it provides and how this contributes to the functioning and quality of people's lives, as individuals and as a society. Similarly, the transport system is far more than just our pavements, roads, railways, ports and airports, and the various vehicles using them. Rather, this system enables organisations and companies to do business, and influences how people live their lives.

Mobility is vital to the efficient movement of people and goods that underpins our economy. During the 20th century, mobility levels increased and transformed access to jobs, opening up new markets and driving the changing nature of land use. All of this brought long-term benefits for regional economic growth. Indeed, consumer demand for goods and services was a major shaper of mobility in the 20th century in terms of traffic, employment and emigration.

Mobility is essential for social cohesion, widening people's opportunities and improving their health and well-being. It has transformed society, the structure and locations of towns and services, and has also been an important contributor to individual choice; the car added to women's emancipation, for example.

Nevertheless, inequalities remain in people's mobility. The lack of mobility for some, and the burden it places on others (e.g. those who have to spend a high proportion of their income on transport), are persistent issues. These reduce opportunities such as access to employment and essential services. Young people, older people and those living in rural areas are currently underserved by the transport system in many regions.

Transport – the means by which we are mobile – comes in various modes. These include walking, cycling, cars, railways, ships and aeroplanes. These are all deeply interrelated: the increasing use of one often leads to a reduction in another. The advent of the railway in the 1830s, for example, replaced canals as the main mode for transporting freight. And from the 1950s onwards, private cars and road haulage have successively undermined the tram freight, rail and bus systems. Cycling and walking were similarly sidelined by the spread of private cars and the road infrastructure built to cater for them.

In other cases, the relationship has been complementary. Rail freight stimulated road transport, for example to and from railheads. Synergies in the technological development of internal combustion engines and aviation during World War II helped drive transport-related industries in the post-war period. Multi-modal travel has been a persistent feature of mobility and, even today, many journeys to work combine a number of different modes, often including walking.

Transport today

As its history shows, the transport system is dynamic, constantly changing as new developments and drivers force it to adapt. This is no different today. We are currently in a period of considerable technological change, and more data about transport is being generated and collected than ever before. It is likely that the next 20 years will be a time of exciting progress.

Automation, electrification and greater connectivity will bring new opportunities, including improved road safety, health benefits, increased accessibility and environmental gains. These developments will intersect with social trends, such as increasing urbanisation and a shift towards a more sharing-based economy, further altering the ways in which we travel.

Yet these trends could potentially be disruptive as well, with some sections of society left out of the benefits. Other social trends, including the demographic changes of a growing and ageing population that particularly affect rural areas, will place further demands on the transport system. Dealing with the inherent uncertainties about what will happen adds to the complexity.

By analysing these trends and highlighting the trade-offs, the Future of Mobility project developed a range of future scenarios to help evaluate what mobility in the UK could look like in 2040. Our main finding is that transport needs to be considered as a holistic system, not as sequential or separate elements. The 'predict and provide' principle that guided transport planning between the 1950s and 1990s tended to treat modes separately, but this will no longer suffice.

New technologies create a window of opportunity to move towards a more integrated, UK-wide transport policy. For users of our transport system, multi-modal travel is likely to grow in importance as new options become embedded, such as autonomous and shared transport. Users want seamless end-to-end journeys, and an integrated approach helps to plan for this. There are also economic opportunities. Today, 2.54 million people – 8% of the UK's total workforce – work in transport logistics, with the annual turnover for the UK logistics sector being £1,000 billion (Freight Transport Association, 2017). This can be supported by giving greater consideration to the freight sector in transport policy and land-use planning, which will help to address future challenges and ensure a fully integrated transport system.

Structure of this report

Given the importance of thinking about the transport network as a whole, and about its role in society, this report takes a systems approach. **Chapter 1** summarises the history of our transport system, then **Chapter 2** examines its governance. **Chapter 3** looks at current trends, particularly user and freight demand, while **Chapter 4** focuses on users: what they want and how this might change with the coming technological revolution. **Chapter 5** looks at future trends and emerging technologies, and **Chapter 6** presents four possible future scenarios up to 2040, including the consequences of different actions –

and of inaction. **Chapter 7** explores the issues raised by different geographies. The conclusions summarise the main challenges and opportunities, and highlight priority areas for government to consider.


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A brief history of the UK transport system

Key findings

- **The UK was a pioneer in automobility and rail transport.** Innovations in these modes transformed the transport sector, helping to make it a critical enabler of economic growth and social benefits (Sections 1.1.2, 1.1.4).
- **The transport system has become increasingly complex and its modes are interrelated.** During the last century, the rise of air travel and automobility contributed to declines in buses, trains, trams, walking and cycling (Section 1.2).
- **The UK experienced several transport challenges during the 20th century.** These included fixed and old infrastructure; unchanging working practices; legacy systems; fragmented private and public ownership; transport poverty; congestion; and the environmental and safety impacts of transport Section 1.1).
- **Modal and regional siloes evolved within the transport system.** This led to incentives and policies specific to each part of this complex system, rather than these being structured in a way that maximised the overall social, environmental and economic benefits (Section 1.1).

1 hour

typical time an average person travels per day (historical data)

1 in 5

of all commutes taken by bicycle in late 1940s, second only to buses

20-33%

of people in smaller cities and towns walked to work, up to 1970s

rising car ownership has transformed land use

1.1 Changes in modes of transport

1.1.1 Human-powered transport: walking and cycling

Looking at the 20th century, walking was the commonest way of getting to work until the 1930s and remained an important part of multi-modal journeys during the interwar years. The impact of mass public transport and private automobility made walking less publicly visible, though, and its decline began in earnest as private and public automobility increased after World War I, alongside a rise in cycling. This shift was not immediately seen across the whole country, though: as late as the 1970s, walking was the main way of commuting for 20-33% of the population in smaller cities and towns (Pooley and Turnbull, 1999). Even today, walking remains critical, both on its own and as a key enabler and stage in other modes (e.g. walking to a station or bus stop).

Cycling first developed in the late 19th century, primarily as a leisure pursuit for wealthier people. It was soon taken up by better-off segments of the working class, owing to its usefulness, and grew further in the first half of the 20th century (Joyce, 1980). In the 1930s, 34% of all trips in Manchester were made by bicycle (Bruhèze and Veraart, 1999) and it is likely that other UK cities had similar proportions of cycle use around that time. The increased availability of affordable cycles expanded users' access to potential job opportunities and their range of social activities.

By the late 1940s, the number of cycles in the UK peaked and cycling was second only to the bus as a means of commuting, accounting for one-fifth of all such journeys (Pooley and Turnbull, 1999). From around 1950, though, cycles declined as a mode of transport in the face of competition from motorbikes and private cars. The rise of automobility brought significant growth in the associated infrastructure without an equivalent increase in dedicated cycling infrastructure. As a result, cycling declined until the mid-1970s, at which point its use levelled off. It has fluctuated since (Parsons and Vigar, 2018) and cycling currently accounts for around 2% of all trips (Department for Transport, 2018, NTS0303). Cycling rates vary with geography; London and Bristol, which have increased their dedicated cycling infrastructure, have seen an overall growth in trips and distances over the last 10-15 years (Transport for London, 2017a; Sustrans, 2017a; Ballinger, 2017).

Up to the 1970s, 20-33% of the population in smaller cities and towns walked to work.

1.1.2 Private road transport

Long before the automobile, horse-drawn vehicles ruled our roads. Their use grew sharply throughout the 19th century as roads improved and disposable income grew. For many years, horse-drawn vehicles were the main form of private road transport (The National Archives, 2004). The use of horse-drawn buses peaked around 1900 in London (Transport for London, 2013a) and slightly later elsewhere. The swift rise in automobility led to a dramatic fall in the use of horses for both vehicular travel and agriculture, though (Crossman, 2010).

Britain was a motoring pioneer. The mass production of cars began in 1896, and manufacturers such as Austin, Rover and Sunbeam all launched

Box 1.1

From rail to road: the shift in freight

One of the most striking post-war shifts was the growth of road freight, much of which came at the expense of the railways. Almost all categories of rail freight declined between the wars, while the number of goods vehicles on the roads increased fivefold to 488,000 (Gunn, 2018b). Then, the majority were owned by small independent operators. Today, the road freight sector remains similarly split: 90% of haulage companies are small businesses with fewer than 10 employees (Office for National Statistics, 2017a). Chapters 3 and 5 look at the freight sector in more detail.

models before World War I. Automobility continued to grow in importance between the wars, as Britain established a motoring culture. Road freight also increased during this period (see Box 1.1). A national road network, with classified A and B roads, was established in 1922; trunk roads were designated as a separate category from 1937 onwards.

By 1939, there were around 2 million motor vehicles in the UK. From the 1950s onwards, mass motorisation expanded further as the cost of motor vehicles fell and disposable incomes rose. But the rise of the motor car brought challenges. Congestion and traffic collisions causing injury were noted as problematic as early as 1929. The Pedestrians' Association was founded in 1929 to push for improvements such as Belisha beacons and speed limits for motor traffic.

Compared to North America and other European countries, Britain was late to invest in its motorways, but investment increased sharply from the early 1960s. Two influential reports were commissioned by the UK government during that decade. Buchanan (1963) highlighted the growing negative impacts of cars in urban areas and the intersecting effects of traffic and urban planning, while Smeed (1964) introduced the technical and economic possibilities of road pricing.

From the late 1960s, government became increasingly aware that road deaths and injuries were rising with mass motorisation, and of the growing public concern about the impacts of automobility on the environment and personal safety. It sought to regulate driving behaviour more strongly, through measures that included Ministry for Transport policies to make drink-driving an offence and legislation to introduce seat belts into cars.

Public concern over the health impacts of transport are long-standing. From the 1970s, there have been concerns about lead emissions from petrol and their harmful effects on children (Gunn, 2018a). Other negative health effects from transport pollution include lung disease, cancer, asthma, heart disease, obesity and dementia (Royal College of Physicians, 2016). Partly because of this, the UK led much of the early work on sustainable transport. This included a major enquiry into the effects of freight vehicles on the environment in the 1970s, and the subsequent establishment of an independent committee to advise on this issue (McKinnon, 2018). By 1970, private cars accounted for 77% of all passenger miles in the UK (Aldcroft, 1975) and this proportion has increased ever since (Department for Transport, 2017, TSGB0101).

Broadly, from the 1960s to the 1990s, transport policy was based on the 'predict and provide' principle. This meant estimating future traffic demand and trying to build enough capacity to accommodate it. This approach generally dealt with modes individually and worked against integrated transport planning.

Box 1.2

The rise and fall of the tram

The use of electric trams in the UK peaked in the late 1920s but declined dramatically afterwards, as they were replaced by motor buses and trolley-buses. This was broadly due to the tram's perceived lack of flexibility – while trams travel on fixed tracks, buses can travel on almost all roads – and the high cost of infrastructure investments (Collins, 1995). Through the late 1940s and early 1950s, trams continued to decline, with more lines being scrapped; most were gone by the late 1950s (Collins, 1995; Wolmar, 2016). Since the 90s, limited tram routes have been reappearing across the UK, for example in cities like Edinburgh, Sheffield and Manchester.

1.1.3 Public road transport

Once public motorised buses had started to replace horse-drawn buses and trams (see Box 1.2), their use increased exponentially. By 1932, 100 local authorities ran municipal bus services, alongside a host of private companies (Barker and Savage, 1974). Motorised bus transport peaked in the early 1950s, with passenger kilometres in 1951/52 accounting for around 42% of all kilometres travelled (London Transport Museum, 2008).

Since then, though, bus use has steadily declined (Department for Transport, 2017, TSGB0101), reflecting a general decline in public transport. The number of bus passenger journeys almost halved between 1950 and 1970, mainly due to the growth in car ownership, lower urban densities and the rising real costs of providing bus services. These factors led to revenue losses, which operators tried to offset by reducing service levels and increasing real fares.

In the last 30 years operating costs per bus-km have decreased sharply following deregulation (outside London) and competitive contracting for services (within London). Despite this, and excepting London, which has displayed strong ridership growth since the mid-1980s (see Chapter 3), passenger kilometres have broadly declined in Great Britain, with buses now accounting for just 4% of the total distance travelled each year (Department for Transport, 2017, TSGB0101). This trend has been exacerbated recently as costs have risen, due to the need to increase staff wages and improve working conditions, while costs associated with growing traffic congestion have also increased (White, 2018).

1.1.4 Railways

The major expansion of the UK's railway system occurred between the 1840s and the 1890s, and was privately led. Before this, most inland freight was moved on canals, but as the railways grew, canal freight started a decline that continued until World War I.

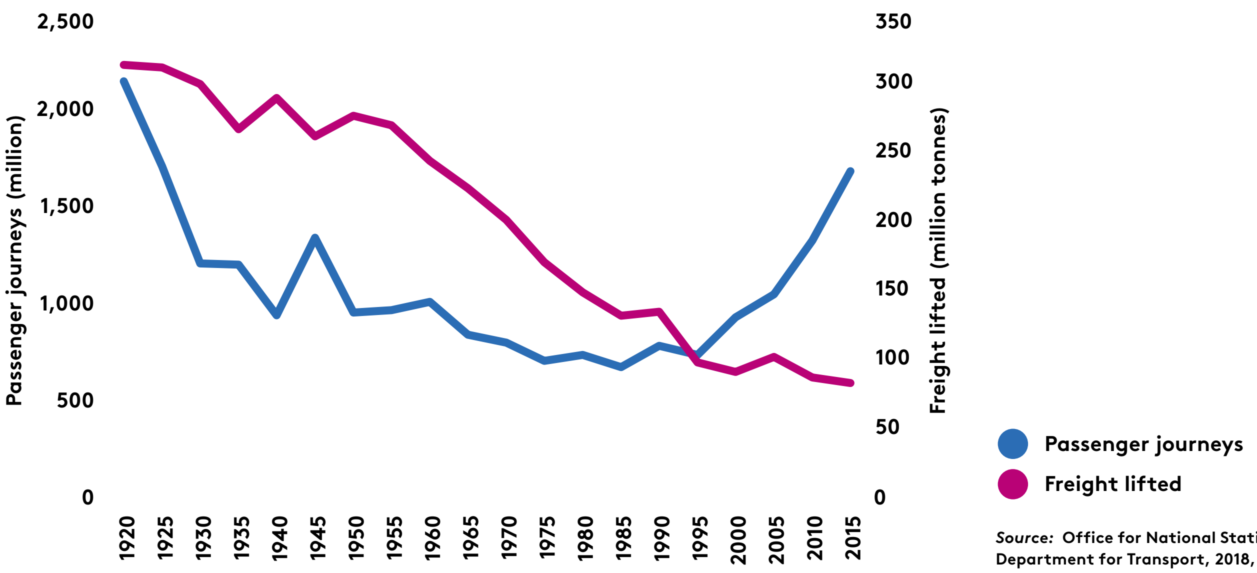
The use of railways peaked around World War I, and rail freight peaked in 1913 (Edwards, 2015). But from the 1920s, the railways endured a long period of decline that continued until the 1980s (see Figure 1.1). Both passenger numbers and the amounts of freight contracted sharply, especially in the depression years between the wars. Rail freight has never recovered to its 1913 peak, being replaced by road freight that grew steadily through a large number of small private companies.

In 1947, the government took the railways into national ownership, under the control of the British Transport Commission (Barker and Savage, 1974). This failed to arrest the decline in rail freight or passenger services, though. Government policy in the mid-1950s attempted to make the railways more commercially competitive, with successive governments instigating modernisation programmes. Diesel and electric engines replaced steam in the 1960s, but their immediate effect on the sector's viability was limited. The railways recorded deficits in every year from 1956 onwards, with a loss of £104 million in 1962 alone (Gourvish, 1986).

The need to restore the railway's economic viability led to the commissioning of the 1963 Beeching report. This recommended closing uneconomic lines and stations, developing intercity routes and overhauling freight with a combined road–rail container service (Loft, 2006). The effects of the report were drastic, especially for suburban services, many of which were stopped. Altogether, some 7,000 route-miles were cut by 1970, almost two-thirds of stations closed, and the rail workforce almost halved (Gunn, 2018b).

Unsurprisingly, these cuts were unpopular with the travelling public, and Beeching became a symbol of narrowly focused bureaucracy and economics being favoured over the importance of public services and the wider values of transport to society. Nor did this report achieve its aims: from 1968, the spiral of decline in passengers and freight continued, with annual deficits escalating to £677 million by 1980 (Gourvish, 1986; Loft, 2006).

Figure 1.1 **Railway passenger journeys and freight lifted, 1920-2015**



Source: Office for National Statistics, 1970; Department for Transport, 2018, RAI0402

Railway privatisation in 1993 established a complex structure that separated companies providing track services from those providing railway services. Privatisation was controversial at the time, and remains so (Gourvish, 2008). But since the mid-1990s, the rail market has exhibited strong growth (Association of Train Operating Companies, 2013; Rail Delivery Group, 2016). Passenger demand has risen sharply: rail passenger kilometres have increased by 108% and train kilometres by 46% since privatisation, although the factors behind this rise are complex (Department for Transport, 2017a). These include changing travel behaviour among younger generations; increasing road congestion; increased commuting distances (particularly in London and the South East); the shift from manufacturing to city employment; and economic rebalancing in the North of England. The impact of these varies by geography, but overall they reflect the historical importance of rail in contributing to the UK's economic growth.

The period of privatisation has also seen growth in the rail freight market: measured in net tonne kilometres, this grew by 67% between 1995/96 and 2014/15 (Office of Rail and Road, 2018a). It shrunk by nearly a quarter in the two years to 2016/17, though, principally due to the continued contraction of heavy industry (e.g. coal, metals) (Preston, 2018).

1.1.5 Shipping

The UK entered the 20th century as the world's leading maritime power. But over the course of the century, there was a relative decline in the amount of cargo carried by ships, and an absolute decline in passenger traffic. The number of UK-registered ships dropped sharply following World War II, and the UK's share of the world tonnage fell from 26% in 1938 to 11% in 1970 (Aldcroft, 1975).

The reasons for this decline were multiple, including growing competition from foreign fleets and the spread of flags of convenience.[1] There was also a slowness to enter lucrative new forms of trade, and antiquated infrastructure meant that ports were unable to adapt to new types of trade. Passenger numbers also fell during this post-war period (1945-1970). In 1960, the number of air passengers overtook those going by sea for long-distance journeys, and for all international travel by 1965 (Office for National Statistics, 1970). The fragmented nature of the shipping sector was another factor behind its decline. While parts of the coastal shipping and dock network were nationalised under the 1947 Transport Act, much of the shipping industry remained in private hands, and six different authorities were responsible for Britain's ports in the 1960s (Oram, 1971).

Government did less to address the decline of shipping than that of the railways. However, the Rochdale Committee of Inquiry, reporting in 1970, indicated official anxiety about the state of the sector. It recommended investment in the country's docks to accommodate tankers and containers. Government also intervened by setting up Freightliner, a rail freight and logistics company, in 1965 to integrate the growing sea-container business with rail freight (Gourvish, 2015). None of these measures managed to halt the

1. This is a business practice in which ships are registered in a country other than the owner's country. Historically, this has sometimes been used to minimise business costs and decrease the regulatory burden.

Box 1.3

Shifting patterns of freight in the UK

Patterns of freight traffic have always been driven by consumer and business demand for goods and services, or by secondary demand (e.g. for electricity). This remains the case today. The history of ports shows the challenges they faced from fragmentation and the need for expensive investment in new technologies and infrastructure, alongside global changes in the nature of trade. This history also highlights the importance of onward connectivity from ports, via roads, rail and inland shipping.

decline in the size of Britain's merchant fleet, though.

Shipping remains an important sector, although its patterns across the UK have altered (see Box 1.3). Felixstowe and Southampton have emerged as the most important sites for new container ships, and Immingham for bulk goods such as coal; these have eclipsed the old ports of London and Liverpool (Levinson, 2016). The growth in world trade and the rise of containerisation have also contributed to renewed growth in cargo since 1990. As capacities of key European ports (such as Rotterdam and Antwerp) grew, larger ships were used. Over the past century, the orientation of the UK's shipping has also changed, moving away from Atlantic trade and towards Europe. This change is reflected in the expansion of the ports at Folkestone and Dover for cross-channel traffic, both passengers and road haulage, from the late 1950s onwards.

1.1.6 Aviation

Civil (i.e. non-military) aviation grew dramatically during the 20th century, both for freight and passengers. War catalysed much of this development, with companies established for military production moving into civil aviation. The first UK airline, Imperial Airways, was established with government subsidies in 1924, and nationalised in 1939. In 1946 it was split into two government-owned companies, British Overseas Airways Corporation and British European Airways. These merged to become British Airways in 1974, which was privatised in 1986.

The advent of passenger jets in the 1950s transformed air travel and increased passenger numbers six-fold, from just over 1 million in 1950 to 6 million in 1960. As a result, the major London airports, Heathrow (1946) and Gatwick (1958), were further developed. Manchester and Glasgow (Prestwick) followed in 1958 and 1964, respectively.

Deregulation of airlines in the European Union (EU) from the early 1990s encouraged the spread of low-cost airlines, including easyJet and Ryanair. This helped feed a growing demand for international air travel that continues to the present. Overall, the UK has been a major international player in aviation since the 1930s in terms of aerospace manufacturing, passenger traffic and airport hubs, and it remains so today.

1.2 A summary of transport trends

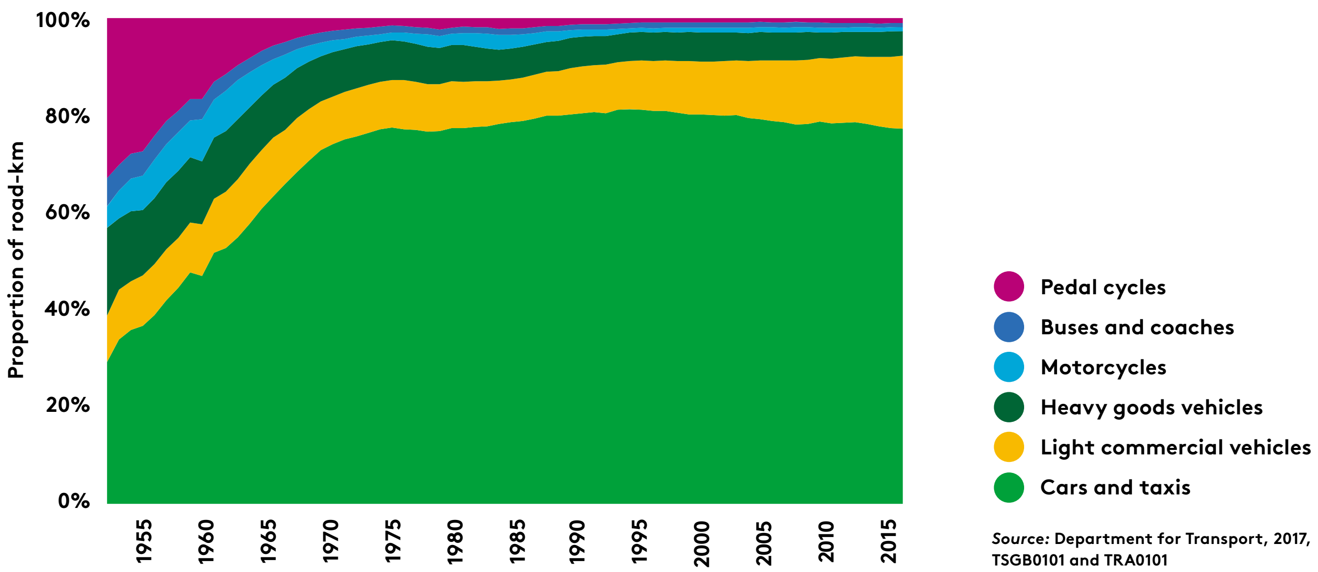
The various transport modes described in Section 1.1 followed very different trends in use during the 20th century. The 'winners' were automobility and air travel, both of which experienced growth rates that outstripped contemporary predictions. Almost all other transport modes saw steady declines, suffering from competition with these two modes. Some declining modes saw a recovery in the late 20th century onwards, however, notably passenger rail (Figure 1.1) and international sea freight (Department for Transport, 2018, PORT0102).

Figure 1.2 shows the proportion of road kilometres driven in the second half of the 1900s. This clearly identifies the decline of buses and coaches, cycles and motorbikes – all of which have lost out to cars, taxis (including private-hire vehicles) and vans. Figure 1.3 shows the trends of the share of total distance travelled by different modes of passenger transport.

While some modes have been negatively affected by the rise of others, in certain cases the relationship has been complementary. Rail freight has been stimulated by increasing road transport to and from railheads, for example. And while these figures suggest distinct categories of journey type, multi-modal travel is a persistent feature of mobility. For example, most journeys to work combine different modes, and usually include walking. Others have seen complementarity in technical developments. During World War II, breakthroughs in aviation and motoring industries synergised and, coupled with investment in these sectors, drove both these industries forward in the post-war years.

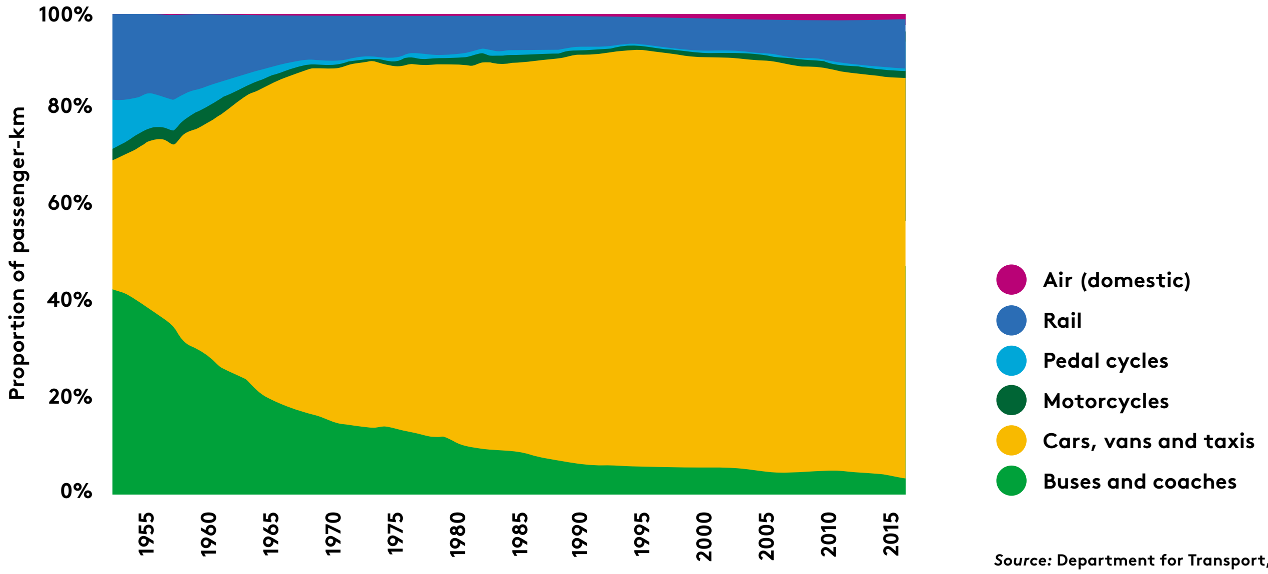
Arguably, over the last 1,000 years and certainly over the last 50, people have travelled for around one hour each day (Metz, 2016) but newer, faster modes of transport have allowed for greater distances to be travelled. From the mid-20th century onwards, towns and cities have been shaped by rising car ownership and the growing road network. Increasing access to cars means faster travel times, converted into longer distances (but the same time spent

Figure 1.2 **Proportion of road-km driven by mode, Great Britain, 1952-2016**



Source: Department for Transport, 2017, TSGB0101 and TRA0101

Figure 1.3 **Proportion of passenger-km travelled by transport mode, Great Britain, 1952-2016**



Source: Department for Transport, 2017, TSGB0101

travelling) and commutes. This in turn has increased people's access to cheaper land and housing away from centres of employment services and leisure.

Urban sprawl and the growth of suburbs, often considerable distances away from towns and cities, naturally favour car ownership. At the same time, they have made town centres hard to access for those walking or cycling (Royal Town Planning Institute, 2018) and exacerbated the challenge of providing public transport that is frequent, accessible, comprehensive and affordable. A car-centric culture was partially responsible for the lack of integrated transport planning (Plowden, 1971).

The poorest sections of community were largely left out of the 'mobility revolution' in the 20th century, notably the rise of cars and subsequent decline in public transport. This probably affected women, children and the elderly the most, as they were more reliant on public transport. As a result of inadequate or costly transport facilities, a significant proportion of these groups have suffered from diminished access to employment and services (Pooley, 2016). Lack of mobility is also a social problem, and one of many factors behind the multifaceted deprivation identified by numerous social policy studies. Spatial inequalities have also risen: between London and the rest of the UK, between north and south, and between urban and rural areas. These are felt especially where they overlap with other drivers of social inequality.

Policy implications

- **Transport will continue to evolve and will remain a critical enabler for the economy and society.** Health and well-being, social inclusion, job opportunities, trade, access to services, and sustainable places can all be harnessed and achieved through careful design and planning of the transport system.
- **Modal and regional siloes are a significant barrier to achieving integrated outcomes for the transport system.** By taking a 'whole system' approach – one not bound by different types of transport mode – government goals and wider benefits can be achieved.

Governance of the transport system

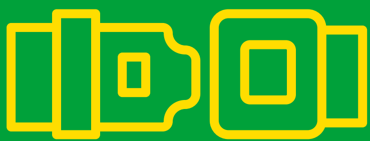
Key findings

- **There are diverse institutional arrangements in place across the UK transport system.** For historical reasons, there is no single approach that applies across the whole system. This complicates cross-system governance (Section 2.1).
- **Reforms of sub-national governance processes have added further layers of complexity to decision-making.** This makes the integration of policy, strategy and funding across different institutions and transport modes even more challenging (Section 2.2).
- **A clear vision, agreed goals, a network of stakeholders and long-term funding make it easier to deliver complex transport projects.** Governance is key to understanding the different incentives within the system. The incentives faced by users and providers are critical, as they shape the economic, social and environmental outcomes (Section 2.2.1).

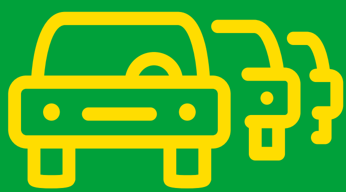
governance arrangements shape the incentives of different transport providers, and consequently the experience of all transport users

98%

of road network in England under local authority control; local authorities have about 300 statutory transport responsibilities



the UK has one of the best road safety records in Europe



Stockholm's congestion charging scheme was designed to allow cheap adoption by other cities

2.1 Transport governance, past and present

The private sector has initiated many significant changes in the UK's transport system, for example the roll-out of the railways and the rise of the car. However, in time these usually came to be shaped – often heavily – by government. During the 20th century, the role of successive governments in the transport system has taken the form of investment, regulation and ownership.

The most significant government interventions were nationalisation, and subsequently privatisation. Under the 1947 Transport Act, government brought large swathes of the railways, road haulage, canals and ports under the direction of the British Transport Commission. With 900,000 workers, this Commission became the largest employer of labour in the country (Barker and Savage, 1974). During the following 45 years, however, successive governments steadily returned parts of the transport system to the private sector. Road haulage was partially returned as early as 1953, completing in the 1980s. While the 1980s and early 1990s saw the largest tranche of privatisation, with British Aerospace, British Airways and British Rail all put up for sale (Parker, 2009, 2012).

Both nationalisation and privatisation were controversial at the time, and their effects continue to be debated (Gourvish, 2008). Nationalisation in particular suffered because the industries involved, such as the railways, were ailing at the time of acquisition and required large-scale infrastructural investment from taxpayers.

Other government interventions during the 20th century took the form of regulation. During both world wars, for example, government took control of the transport system to support the war effort; for instance, in 1916 all ships were requisitioned. These interventions continued into the post-war years in each case. The 1921 Railways Act, for example, set the framework for continued private operation by enforced consolidation and standardisation (Aldcroft, 1975). For motoring, government established the 1920 Road Fund to provide a source of revenue; it also set speed limits, and subjected buses and haulage to a licensing system (Plowden, 1971). Obligatory practical driving tests were introduced in 1935 (Driver and Vehicle Standards Agency, 2018).

Investment decisions also form part of government's overall governance of the transport sector. For example, through taxation it funded the motorways programme that began in the late 1950s, while also promoting transport research in areas such as road safety and civil aviation.

Investment can also fund innovation, but during the last century, government efforts have often been hampered by path dependency – old infrastructure, fixed capital and inherited working practices – which made tackling problems harder (Divall et al., 2016). Additional governance challenges included the negative health and environmental impacts of transport; congestion; road collisions; transport poverty; fragmented service provision; and the different social and spatial provision of transport across the UK. Further, there were trends outside any government's full control – the rise of containerisation, the decline of Atlantic trade, the global increase in automobility – that have markedly changed the UK's transport landscape.

Overall, governance measures have been reactive rather than proactive. Historically, Britain has not subscribed to the French or German *dirigiste* model, where a government intervenes heavily to shape the market. There were examples, though, such as through the 1921 Railways Act and the creation of the London Passenger Transport Board in 1933, where government created smaller, more manageable bodies whose incentives were better aligned with improved service delivery.

Generally, however, governance today of the UK transport system is highly complex, reflecting the organic evolution of different transport modes over various timescales. Legislation and regulation were targeted at each mode or industry (road, rail, air, maritime) at specific points in time, and each form of infrastructure and service provision has evolved its own unique institutional structure, with various levels of state involvement.

As a result of these modal silos, governance approaches have also tended to be modal. For example, the 'predict and provide' approach to transport planning applied between the 1950s and 1990s treated each mode separately, which hindered the development of an integrated UK transport policy.

Powers of devolved administrations in the UK

Devolution is based on a formal division of power between Parliament in Westminster and the administrations in Northern Ireland, Scotland and Wales. There is legislation in place that lists certain matters or powers that are held by, or reserved to, Westminster.

- **Roads policy** is substantially devolved, although with important reservations that include vehicle safety standards and road traffic law.
- **Railways policy** is generally reserved to Westminster. The Scottish Parliament now has powers to specify the franchise for passenger rail services beginning and ending in Scotland, and the funding of rail infrastructure. Similar arrangements will apply to Wales for future franchises. Powers over the structure, safety and economic regulation of the rail industry remain reserved to Westminster.
- **Maritime policy** is generally reserved to Westminster.
- **Aviation policy** is generally reserved, although the Scottish and Welsh Parliaments can influence certain aspects of policy, especially regarding airports.
- **Local transport** is a devolved matter. Westminster develops policy and provides the bulk of funding for local transport in England; in other parts of the UK, this is provided by the relevant devolved administration.

2.2 Governance layers and actors

Governance of the transport sector in the UK is devolved to its four constituents, although the level of devolution varies with transport mode.

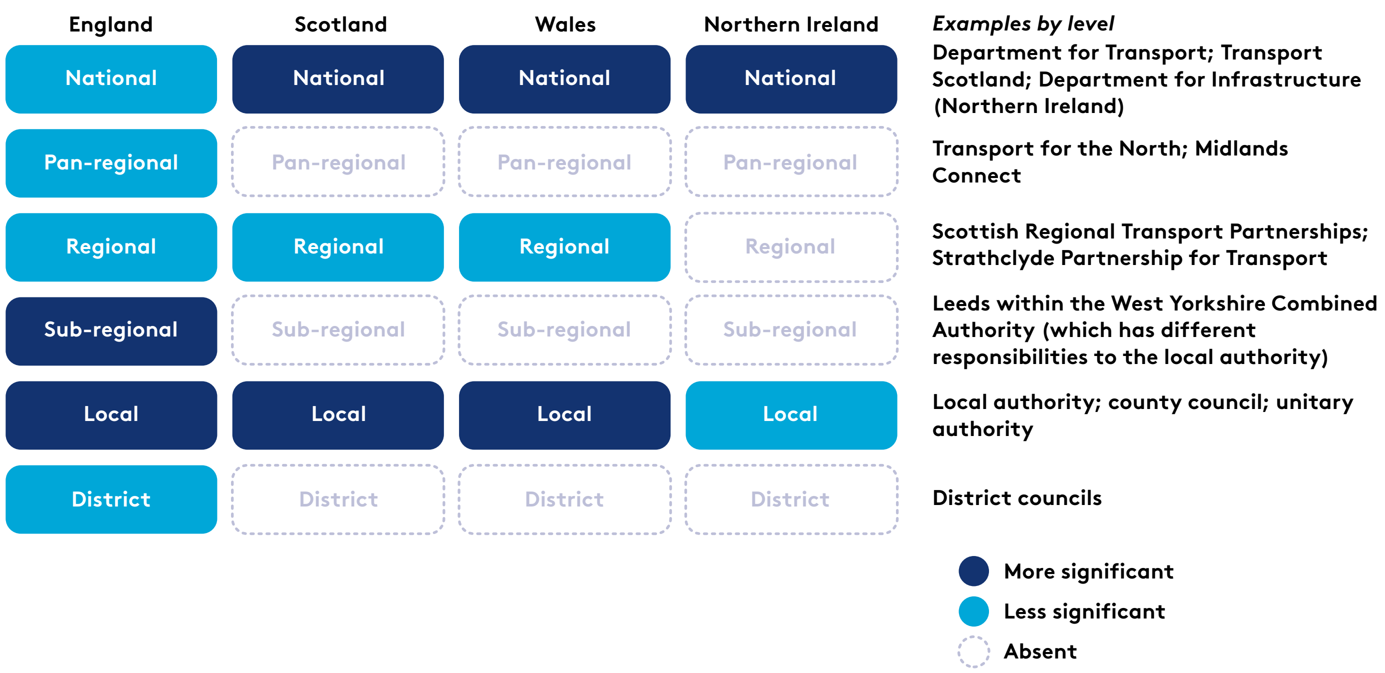
Figure 2.1 illustrates that a multitude of governance structures are found across the UK, rather than one overarching 'governance of the transport system' framework. The most significant layers are identified by darker shading.

- At the simplest end of the spectrum, the Department for Infrastructure (a national authority) oversees all services and infrastructure investments in **Northern Ireland**, and local authorities have limited responsibility for transport.
- In **Wales**, there is national control over matters such as administering concessionary fares for buses.
- **Scotland** has broadly similar arrangements to Wales, operating a two-tier system, but with a larger regional transport governance layer.
- **England** has the most complex system of transport governance, with six tiers at different spatial levels, as well as additional structures around Highways England.

Marsden and Docherty (2018) describe the key public sector actors in the UK transport system, at all levels from global to local, and Figure 2.2 shows how the level of influence from regulation and management varies in different transport sectors.

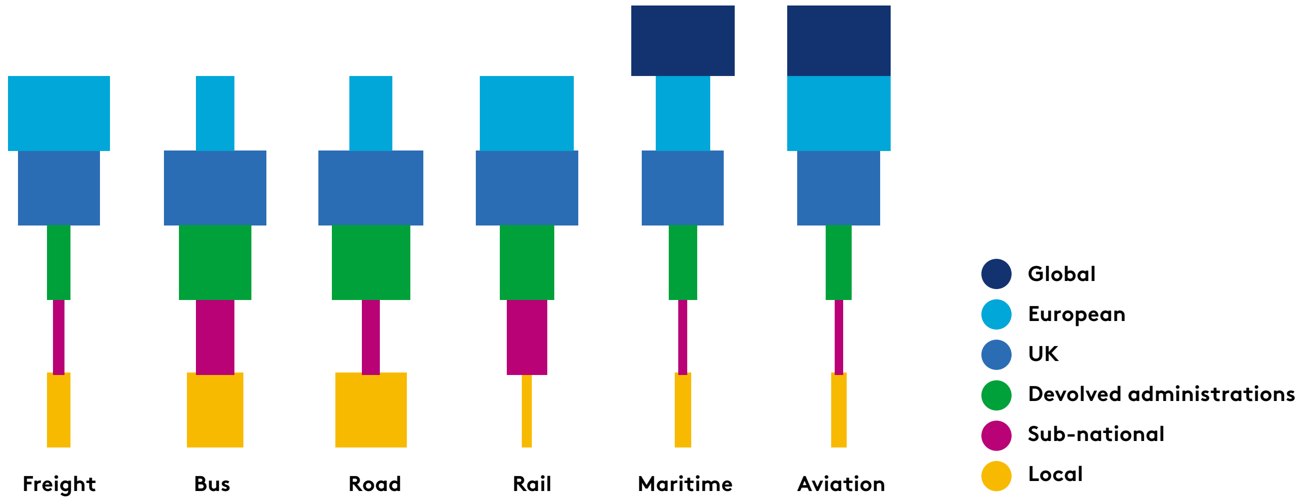
The aviation and maritime sectors are largely privately funded and operated but, due to their global connectivity, all actors must abide by international regulations, such as EU directives. The EU also has significant influence over

Figure 2.1 **Influence of different government tiers across the UK**



Source: Marsden and Docherty, 2018

Figure 2.2 Levels of management and regulatory influence in different parts of the transport sector



Source: Marsden and Docherty, 2018

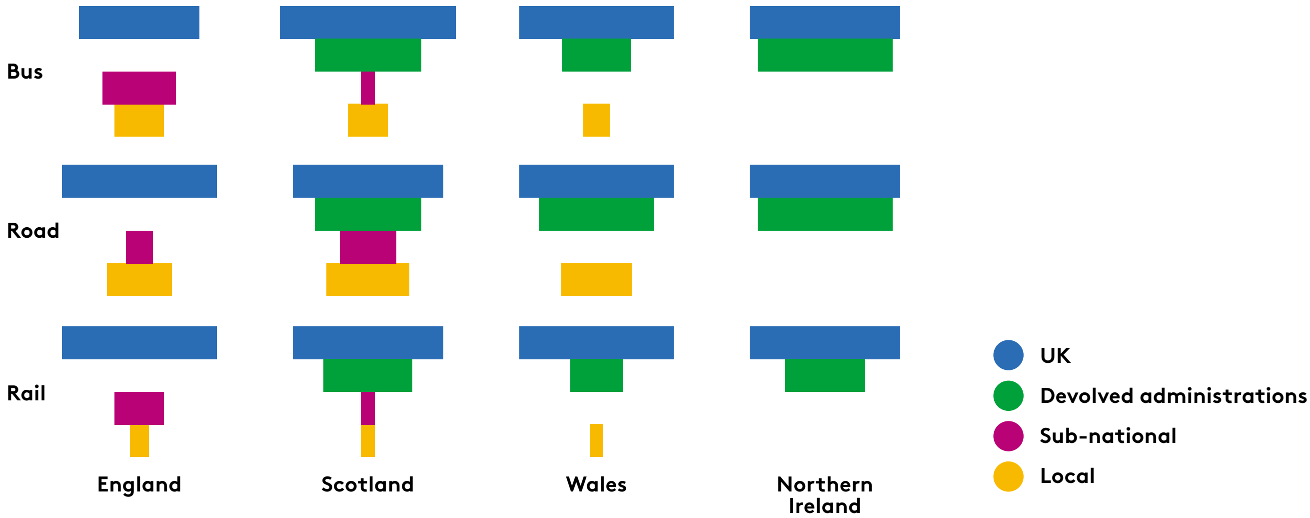
rail, but the UK has often been ahead of the curve on implementing provisions and only some aspects of interoperability apply. For road infrastructure, the national government has much greater influence on investments in, support for and regulation of these services.

Freight, although regulated by and conforming to EU standards, is broadly privately owned and operated. Consequently, government has fewer direct levers to influence it. The need for private freight businesses to make a profit means that the system is broadly effective, but can be inefficient. Freight operators agree service requirements (cost, time, etc.) with customers (shippers). These can differ markedly from optimal vehicle loading. However, government already mitigates some of freight's environmental impact, for example through European emissions standards. It therefore faces choices of whether and how to intervene further regarding the impacts of freight on other users of the transport system (e.g. congestion) (McKinnon, 2015).

As Figure 2.2 shows, local authorities are critical in transport planning, particularly for roads and buses. They cover 98% of the road network in England and have around 300 statutory transport responsibilities (National Audit Office, 2012). They are also involved in the governance of buses and walking and cycling routes. Figure 2.3 further illustrates the complexity of different arrangements and governance tiers between modes across the different nations: this zoomed-in snapshot of Figure 2.2 shows the influence of institutions by country, with the gaps showing the lack of institutions at that particular level. For example, no institutions govern bus, road and rail at sub-national levels in Wales. The width of the bars shows the level which has the most influence.

Adding to this complexity has been a trend towards increasing the numbers of institutions involved over time. One example is the creation of Local Enterprise Partnerships as stakeholders in the transport governance land-

Figure 2.3 Variation in government influence on bus, road and rail across jurisdictions



Source: Marsden and Docherty, 2018

scape; another is city devolution, which has led to a difference in powers and funding agreements between areas. Another example is the differing arrangements between the nine combined authorities; seven of these have a mayor, two do not. Reforms of sub-national governance have added further layers to transport decision-making processes, particularly in England, where several new transport bodies now exist (e.g. Transport for the North, Midlands Connect, England's Economic Heartland and Transport for the South East).

As a result, there are new voices in debates on spending priorities, and also new geographies over which boundary disputes or political disagreements need to play out. It is too early to say whether this increasing diversity of institutional and funding arrangements will improve decision-making. Box 2.1 illustrates some of the complexities faced by different actors and institutions in transport governance, and highlight the tensions between bespoke locally determined decision-making and greater standardisation in regional/ national approaches. Governance arrangements are key in shaping the incentives of different transport providers, and consequently the experience of all transport users. The Swedish example shows how good design of the local Stockholm congestion charge reduced costs for follow-on cities and, in fact, permitted operation that may not have been affordable on its own.

The transport system involves a number of actors – users and providers – including individual travellers, businesses, airports, ports, Network Rail (which owns and manages the UK's railway network), train and bus companies, and local councils. For freight, the number of actors grows further, including complex global supply chains, shipping and storage companies. Often, these actors have responded rationally to the issues and incentives they faced. However, because the transport system and its structures have evolved organically, the incentives of each stakeholder were rarely considered in an integrated way in order to maximise social benefits.

Box 2.1

The complexities of 2018 London

Zipcar is a car-sharing club operating in several cities. When it wanted to establish a network in London, circular trips – those that start and finish at one point – needed permission only from the borough they started in. However, one-way journeys – from one borough to another – would require permission from both. This meant that if the firm wanted to operate across London, it would have to negotiate permissions and operating rules with each of the city's 33 regional areas separately. While this approach to governance gives each local area a level of control, it also adds to the complexity of operating a transport business in London (Shapland, 2018; Zipcar, 2018).

In certain areas of transport, it was concluded that the governance and institutional structures were a key barrier to the most efficient delivery of services (McNulty, 2011). Generally, simpler and more integrated structures produce better outcomes for the system (Marsden and May, 2006; Lowndes and Lemprière, 2018). Taking a systems approach could improve the transport system and bring greater benefits for all.

2.2.1 Critical factors for good governance

As discussed, the transport system is complex, with multiple levels, actors and interdependencies. Optimisation of these individual parts, whether regionally or modally, can lead to suboptimal outcomes. Instead, several case studies (e.g. Marsden and Docherty, 2018) suggest that improving the whole system, in order to enable more positive social outcomes, requires:

- clear goals and vision
- clear leadership
- alignment of stakeholders in the network
- long-term funding clarity (e.g. for construction, operation, maintenance)
- identification of clear needs.

These five factors can avoid problems such as stop-start funding for transport programmes, or a loss of impetus due to leadership changes. They can also ensure there is minimum ambiguity in strategies. Clear goals for the objectives of transport schemes and networks also allow for frank discussions of their merits and the building of consensus among stakeholders.

One way this can be achieved is through establishing one body to oversee the transport system in a city or region. A good case here is Transport for London (Box 2.2), which has most of these elements largely within its control (with some caveats: see Topham, 2016) and has become a world-leading transport authority (NYC, 2008).

Discussions around whether to centralise or decentralise transport governance will broadly reflect the different views of local, sub-national and national governments, and their differing needs and priorities. In a complex system, there will always be tensions among the component parts about the correct balance, for example which modes should take precedence, or how strongly local, regional or national governments should shape transport demand. In theory, agreeing a Transport Master Plan which determines the key performance areas and the key performance indicators could help mitigate these tensions.

Geographical alignment of stakeholder boundaries, and the involvement of fewer organisations, helps parties to reach agreement and identify shared goals. Currently, the geographies of land-use planning, local authorities, Local Enterprise Partnerships and areas where people commute are generally not aligned (Office for National Statistics, 2016). Yet fostering agreement among divergent policy voices over infrastructure spending is likely to remain challenging. As transport system complexity grows out to 2040, this will add to the pressure to integrate the system.

The preceding section illustrates some of the complexity in the system. Good governance can occur without the five factors we discuss in this section; however, their presence makes it easier. Our examples (e.g. Box 2.1) show that in cases with large number of stakeholders whose views need aligning, clear leadership and a clear vision may be harder to achieve.

One further factor behind successful governance is acting at the right time: there are often windows of opportunity for delivering key changes (Kingdon, 2010). Technological changes present a real opportunity to agree a clear, long-term national vision and goals that are aligned with local priorities. This will allow future trends and modes to be shaped, rather than merely responded to. There will be choices and trade-offs, but decisions should be made that improve the whole system, rather than its constituent parts. The establishment of the National Infrastructure Commission in 2015 is a good step towards achieving this, creating an opportunity for government to respond positively to the first National Infrastructure Assessment (National Infrastructure Commission, 2018) by setting out such a vision.

Box 2.2

Travel in the capital with Transport for London

Transport for London is responsible for running the day-to-day operation of London's public transport network, which includes the underground (Tube), buses, trams, some rail services and its riverboat network. It also manages the capital's main roads. Over 31 million journeys are made every day across its network (Transport for London, 2017b) and, according to the 2011 census, 44% of people in the capital commute to work by public transport – much higher than the figure of 16% for England and Wales (Office for National Statistics, 2013).

Key factors contributing to Transport for London's status as an internationally-leading transport body include: its ability to raise local funds; a single governance structure that manages most of the public transport modes in the capital; and an overall strategy that, through the Mayor of London, is integrated with other policy areas (e.g. housing and development) (Wilcox et al., 2014).

2.3 Key governance strengths and challenges in the UK

2.3.1 Strengths

The independent Eddington Transport Study stated that the UK transport system enables a "staggering 61 billion journeys a year" and "in broad terms it provides the right connections, in the right places, to support the journeys that matter to economic performance" (Eddington, 2006, p1). The study also notes, however, that there are still gaps in transport provision and travel remains expensive for many. Thus, the overall social good it achieves is less clear cut than its good connectivity.

There are several factors behind this relatively strong performance. The increase in capital spending since 2012/13, combined with long-term spending commitments on road and rail, were identified as current strengths of the UK's governance of the transport sector (Marsden and Docherty, 2018). Clarity of funding and goals through recent long-term spending settlements aids longer-term planning and resourcing decisions, as well as the delivery of these. One example is the recent five-year settlement on the Strategic Road Network for Highways England, which provides more certainty and ensures that, once started, work progresses without stalling (Highways England and Department for Transport, 2017).

UK has 4th best road safety record in Europe.

Another strength is effective regulation and commitment to operational and maintenance improvements, which has generated good safety records across all modes (Marsden and Docherty, 2018). In Europe, only Norway, Sweden and Switzerland have fewer road deaths per million population (European Transport Safety Council, 2017).

The challenges with introducing a congestion-charging scheme

Paying implementation costs accounted for a high proportion of total income during the initial stages of the London Congestion Charging Scheme, which was planned by Transport for London. These costs were initially 76%, falling to 35% after 10 years (Börjesson and Kristoffersson, 2017). In Sweden by contrast, the Stockholm congestion-charge scheme, introduced in 2006, was undertaken with an eye towards national standardisation. This meant that when Gothenburg, Sweden's second-largest city, introduced congestion charging in 2013, the same system could be used. The established 'back office' procedure for charging could be reused, and some additional toll bridges were easily brought under this system.

The decision to adopt a congestion charge, and how to design this charge, are local matters, but there are benefits to using a common identification technology and payment system. Using the system established in Stockholm undoubtedly reduced costs, and enabled the system to be established in places where it might otherwise have been unfeasible. For example, Gothenburg may have been too small to have established its own charging infrastructure (Börjesson and Kristoffersson, 2017).

2.3.2 Challenges

As this chapter shows, transport governance in the UK remains complex, fragmented and weakly integrated, particularly in England. As a result, aligning funding, strategies and policy levers can be challenging. This makes it harder to achieve integrated outcomes and to optimise social benefits.

Currently, the UK transport system remains largely connected but harmonisation will become increasingly challenging with the uptake of new intelligent and automated technologies (e.g. self-driving cars and buses) and potentially different data standards, which will further complicate the number of modes to consider. However, new technology could also create opportunities to better integrate services, such as 'smart ticketing' (a system that stores a passenger's ticket digitally). These technologies and data could also be used for better planning. Managing the transition with both new and old technologies will pose additional challenges.

A further challenge is that the transport sector has wider economic and social impacts, and links to many other policy areas, for example agglomeration effects for businesses (Graham, 2007) and health benefits from walking and cycling (Panter et al., 2016). As such, it is necessary to consider the direct and indirect outcomes on other sectors when making transport decisions. There are also impacts on other sectors when transport is costly, inadequate or inaccessible, such as unemployment, missed health appointments and limited travel horizons (Lucas et al., 2016).

Integrating transport and land use remains a particularly challenging issue (Department for Transport, 2011). For example, out-of-town developments are attractive to policy-makers on one hand (e.g. due to lower land costs), yet are likely to encourage greater car use and are harder to serve by public transport (see Chapters 4 and 7). The planning system must also balance potential conflicts and negative effects between local, regional and national demands and politics (Cullingworth et al., 2014). Ideally, this should be done in partnership and with a focus on sustainable transport.

Policy implications

- **Setting clear goals and a clear long-term national vision will allow coming transport trends and modes to be shaped, rather than responded to.** Decisions should be aligned with local priorities and made to optimise the whole system, rather than its constituent parts.
- **Aligning government policy levers when intervening** can improve outcomes, deliver value for money, and minimise the burden of a complex governance landscape.
- **Taking a whole-system approach, one not broken down by transport mode, will help to achieve government goals and wider benefits.** There are tools available to treat transport as one system. In particular, measures that reduce modal silos, integrate transport and land-use planning, and ensure that organisational boundaries align better, could deliver significant benefits.
- **A more tailored approach to local and regional transport planning will ensure that the challenges across regions are adequately addressed.** Decentralised decision-making will enable opportunities across towns, cities and rural areas to be seized – but only if funding, layers of operation and strategies are fully integrated. Ways to include both passenger and freight transport users in planning and decision-making could be considered. Different regions will require different approaches to good transport governance, aligned with a clear national vision. This could be facilitated by a simplified governance system.

Trends in the transport system

Key findings

- **Several significant trends indicate a shift away from car use in the UK.** The overall time spent in cars, the number of car trips and the distance travelled by car per person have all decreased since 2002 (Section 3.1).
- **The number of private-hire cars has increased sharply since 2015.** This trend is even more pronounced in London (Section 3.1.4).
- **The use of vans is increasing.** The UK's van fleet has seen the largest growth of all vehicle types, in terms of mileage. However, data about exact uses are sparse; more research is needed to understand the reasons for this growth and to determine its likely impacts (Section 3.1.3).
- **Nearly 90% of freight is still moved by road, and the volume is growing.** Freight and logistics are both important economically in the UK, and the flexibility of road freight makes it an attractive option for these sectors (Section 3.1.1).
- **The growth in road freight causes major impacts, particularly in busy urban areas.** The 'last mile' of freight is becoming increasingly important, as consumer demand for home and local deliveries rises. However, this exacerbates urban congestion and air pollution, and generates the most carbon dioxide (CO_2) per tonne of freight (Sections 3.2.1 and 3.2.2).
- **Maritime freight remains critical to the economy: 96% of goods still arrive through the UK's ports.** In the future, the UK will require even greater automation and digital connectivity to ensure the efficient movement of goods, both through ports and on to the connecting infrastructure (Section 3.2.3).
- **Future transport demand is uncertain: the system responds dynamically to the available infrastructure.** While traffic on motorways is likely to continue increasing, the demand elsewhere is more complex and localised, and therefore hard to predict accurately (Section 3.3).

96%

average proportion of time UK car is parked

15%

of all vehicle mileage is driven by vans

UK logistics sector:

195,000

enterprises

2.5 million

employees

£121 billion

gross value added to the economy

3.1 Current status of the UK's transport system

National road usage is complex: it is not a simple case of growth or decline. For example, while motorway traffic has increased in England by 38% since 1996, and by 15% on A-roads and 12% on minor roads (Department for Transport, 2018, TRA0103), there has been a general decrease in both trips and mileage (per person) for personal transport in rural, semi-urban and urban areas. As this chapter outlines, usage patterns also vary between freight and passenger transport, between rural and urban areas, across different geographical regions and in terms of the type of vehicle.

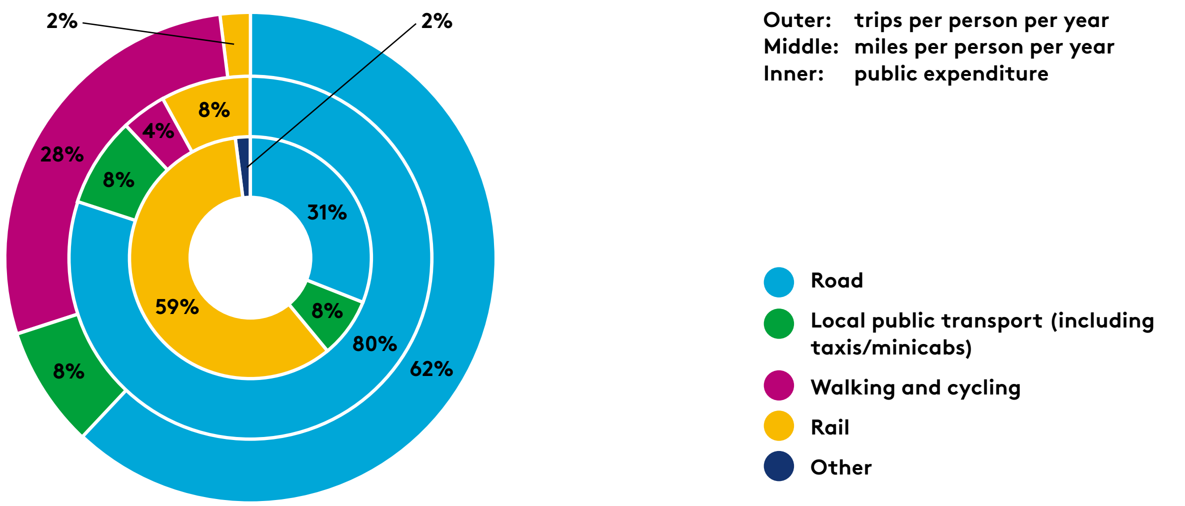
Since 2002, the number of car trips and distance travelled has decreased by 12%.

3.1.1 Automobiles

The UK has seen a growing dependence on automobility during the 21st century, continuing the trend experienced in the 20th century. The national stock of vehicles has risen sharply, increasing by 40% in Great Britain between 1997 and 2017 (Department for Transport, 2017, TSGB0903). This rapid expansion has been driven by urban planning and development being built around the needs of automobiles, their affordability and the accumulating cultural and symbolic value of cars (Gunn, 2018b). Figure 3.1 shows how automobiles and roads still dominate our transport preferences, in terms of trips per person (62% of the total) and kilometres travelled (80%).

Automobiles, specifically cars, dominate the UK's private vehicle use. In 2016, there were 31.7 million cars registered in the UK, and this figure has increased steadily across all regions. Today, 77% of all households have access to a car or van, and the proportion of households having access to two or more cars has risen from 1% in 1951 to 35% in 2017 (Department for Transport, 2018, NTS0205). Unsurprisingly, the number of households without a car has declined from 86% to 24% over the same period.

Figure 3.1 **Modal share of passenger trips, distance travelled and public spend (England)**



Source: Trips and distance: Department for Transport, 2018, NTS0303; public expenditure: HMT, 2017

Despite this growth in car ownership, car travel per person in England fell between 2002 and 2017 (Department for Transport, 2018, NTS0303). The time spent in cars has also decreased, by 8% since 2002, as have the number of trips (by 12%) and the distance travelled per person (by 12%) (Department for Transport, 2018, NTS0303). However, the total mileage travelled in private cars has increased overall, due to population growth.

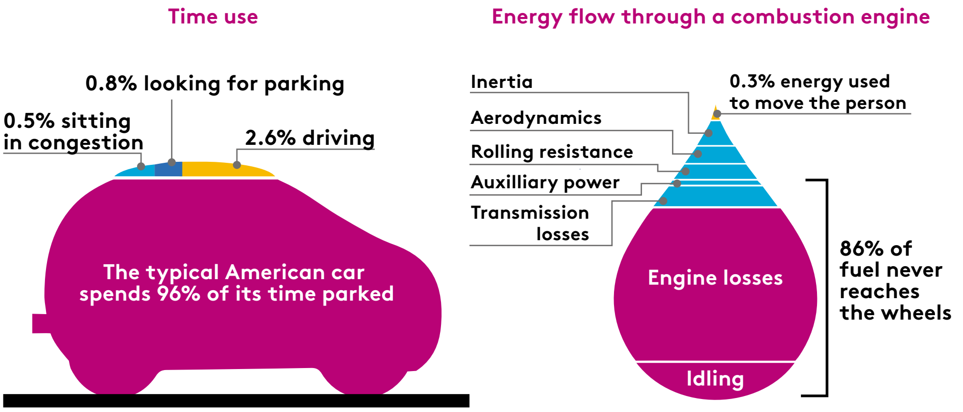
Car use varies with geography. In rural villages, cars and vans overwhelmingly dominate, accounting for 76% of trips in 2016/17. This is significantly higher than in urban conurbations (53%) (Department for Transport, 2018, NTS9903). Higher car use in rural areas broadly reflects that there are fewer public transport services, fewer constraints on car use, and longer distances to employment and services, all of which make car ownership and use more attractive to rural populations.

In Chapter 7 this report will highlight that access to opportunities and patterns of land use help to explain why private car ownership is widespread. But while ownership is attractive for households, for the whole system it is an inefficient way of using assets. The average car occupancy in England is 1.55 people, even though the average car has five seats (Department for Transport, 2018, NTS0905). Furthermore, the average car in the UK is parked for 96% of time (Bates and Leibling, 2012). Figure 3.2 shows that this is similar to USA; it also shows that only 0.3% of the total energy of the fuel consumed by a combustion engine goes into moving the car's occupants (Lovins, 2010).

3.1.2 Public transport

As car use per person has fallen, it might be expected that public transport use has increased. Yet over the period 1995-2017, total national bus mileage decreased by 7%. This national average masks considerable regional variation, however. In England, 51% of all bus journeys take place in London (Department for Transport, 2017, BUS0203a) and during 1985-2017, London saw a growth in bus use of around 94% (Department for Transport, 2017, BUS0103). This rise in bus use can, from 2000 at least, be linked to policies introduced by

Figure 3.2 Typical use of an American car



Source: Heck et al., 2014

Transport for London during that time, and to other governance arrangements that were introduced at the turn of the century (White, 2018).

While bus use has risen in London, it has declined elsewhere. Over the same period (from 1985 onwards), local bus trips outside of London fell by about 40% in England and Scotland, and by 39% in Wales. This decline is potentially concerning. Many bus routes are run by companies for a profit. If bus ridership falls then services are likely to be cut back, or prices raised. This can further decrease ridership, so the cycle continues. Change is not incremental. There are critical ridership thresholds below which it is uneconomical to run bus services, and so bus services may cease on these routes.

Surprisingly, given the growth in London, bus decline was most marked in other large cities. However, there is still considerable variation outside of London; bus use has grown over the past six years in certain areas, such as Brighton and Hove and Reading (Department for Transport, 2017b).

Passengers cover around 60% of bus costs in England, although this figure varies by route (Department for Transport, 2017, BUS0501a). It is important to note, however, that bus services are disproportionately used by low-income groups (Titheridge et al., 2014), partly because their lack of resources can constrain access to alternative modes of transport. Between 2009/10 and 2016/17, total financial support for buses in England decreased by 11% (Department for Transport, 2017, BUS0502a). People reliant on buses find it harder to access key services and large employment centres within a given travel time (Department for Transport, 2018, JTS0101), so any decline in the availability and frequency of bus services particularly affects this group, which includes people on low incomes.

An exception: buses in Brighton and Hove

Bus use in Brighton and Hove has defied the general pattern of decline witnessed outside of London. Passenger journeys increased by 22% between 2009 and 2017 (Department for Transport, 2018, BUS0109a) and 14% of the city's residents use the bus to commute to work (Office for National Statistics, 2011a).

The city council attributes this increase to a range of measures, which include: giving buses priority road space; improving passenger waiting areas and information (including real-time displays); and strong enforcement of bus lane restrictions and other traffic regulations (Prior, 2017). Similarly, the bus companies operating in Brighton and Hove have improved service frequencies, updated their fleets and marketed their services effectively. As a result, 91% of passengers surveyed in 2017 were satisfied with the service (Transport Focus, 2018).

Rail trips in England have increased by 56% since 2002, with a corresponding increase of 23% in the distance travelled per person (Department for Transport, 2017c). This growth occurred despite rising ticket prices and the 2007-09 recession, which demonstrates the influence of other factors on patterns of rail use, such as land use, job opportunities (that are more easily reached by train) and constraints on car use (e.g. parking in some cities).

3.1.3 Heavy goods and light commercial vehicles

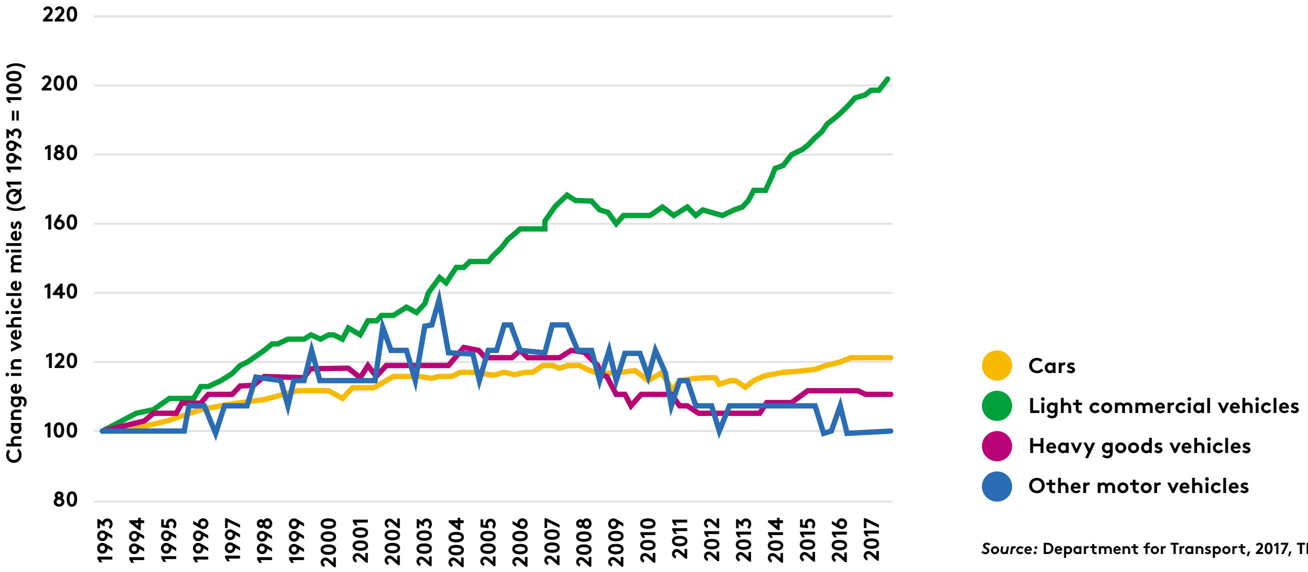
Light commercial vehicles (LCVs), or vans,[2] have seen the largest growth of any traffic segment in the UK since 1993 (see Figure 3.3). LCVs accounted for 15% of all vehicle miles in the UK in 2017: a record share for this type of vehicle, and a 21% increase on the 2007 figure. By contrast, heavy goods vehicles (HGVs) accounted for just 5%, representing a 6% decrease compared to 2007 (Department for Transport, 2018a).

There are several factors behind these shifts. Vans are less regulated than HGVs; their drivers are paid less, meaning they are a cheaper form of commercial transport; and they are increasingly used as a substitute for smaller HGVs (Clarke et al., 2014). Some growth in van use is also undoubtedly due to the increase in online shopping (and thus deliveries), but service trades and food distribution remain key uses of these vehicles (Braithwaite, 2017).

There has also been a gradual shift towards larger HGVs that can carry greater weights. This may be due to their increased volume and decreasing costs per tonne as HGV weight increases. However, the total weight of goods carried by HGVs has stayed fairly consistent (Department for Transport, 2017d). Data on van use are sparse, however, which makes this group a key unknown for future road-use projections (see Section 3.3). As vans are the fastest-growing traffic segment, this data gap needs to be addressed.

2. Light commercial vehicles or vans are four-wheel vehicles constructed for transporting goods that have a gross weight of 3.5 tonnes or less (Department for Transport, 2018b). This report uses the two terms interchangeably.

Figure 3.3 **Change in vehicle miles driven in Great Britain since 1993**



Source: Department for Transport, 2017, TRA2501d

3.1.4 Other modes of transport

The number of drivers working with transportation network companies (e.g. Uber) has been growing sharply in the UK. Across England and Wales, the number of private-hire vehicles has increased by 27% since 2015, while licensed taxi numbers have slightly decreased (by 4%). In London, this change is even more marked, with private-hire vehicles up 40% since 2015, and up 76% since 2013 (Department for Transport, 2018, TAXI0101a). The increasing use of this mode of transport has probably contributed to increased congestion and decreased use of public transport in London (London Assembly, 2017), a trend also seen in several cities in the USA (Clewlow and Mishra, 2017; San Francisco County Transportation Authority, 2017).

Air travel in the UK has also increased. The total number of passengers – both international and domestic – rose by 18% between 2006 and 2016, reaching 247 million passengers (arrivals and departures) (Department for Transport, 2017, TSGB0202b). However, this trend masks a drop in domestic air travel, which has fallen by 15% over the same period to 21 million passengers (arrivals and departures). It also ignores a drop in overall passenger numbers between 2008 and 2012, which could be partly attributable to the 2007-2009 recession. Heathrow is the busiest UK airport, accounting for 31% of total passenger numbers, followed by Gatwick (17%), Manchester (11%) and Stansted (10%).

In 2016, 42.4 million passengers travelled on domestic waterborne routes. Cairnryan to Belfast was the busiest route, carrying 1.2 million passengers (Department for Transport, 2018, SPAS0201). For ferry passengers on short sea routes, Dover had the greatest share in 2016 at 60%, although this represented a 13% decrease over the previous decade. Next were Portsmouth and Holyhead, with a 10% share each (Department for Transport, 2017, TSGB0512).

2 billion tonnes of goods were moved in the UK in 2016, 89% by road.

3.2 Freight

Freight moves around the country by road and rail, as well as air, sea and inland waterways. This complex pattern of movement is shaped by customer demand, supply-chain management, technological progress and the governance of transport systems.

The freight system can be conceptualised in several ways, but one useful approach is to consider how goods are moved, which goods are moved, and where goods are moved. In 2016, an estimated 2,088 million tonnes of goods were moved in the UK (MDS Transmodal, 2018), of which 89% was moved by road. In terms of tonne-km, 76% was transported by road, 15% by water and 9% by rail (Department for Transport, 2018, TSGB0401). For the last 20 years, this modal share by total tonnage has remained stable, but, in terms of tonne-km, from 1996 road and rail have increased their share at the expense of water. In the longer term, road transport has increased its share from 36% of tonne-km in 1953 to 76% today, while rail has decreased from 42% of tonne-km in 1953 to 9% today.

The total mileage of vans has risen by 35% since 2004.

3.2.1 Road freight

Road transport has dominated the UK freight sector for more than half a century. Nearly 90% of freight is moved by road in Great Britain (Department for Transport, 2018, TSGB0401). While rail is cheaper than road for the long-haul movement of bulk goods, road freight offers a level of accessibility and flexibility that rail cannot match in the UK.

Domestic road freight constitutes the 'lifeblood' of supply chains, ensuring that goods move from manufacture and assembly to retailers and consumers. It can be divided into three broad distribution functions: long-haul freight, regional distribution, and urban and 'last mile' distribution (see Box 3.2). Although their definitions may overlap to an extent, they can be broadly defined as follows.

- **Long-haul freight** occurs largely along motorways and trunk routes (as well as major rail corridors), moving goods between ports, factories and national distribution centres.
- **Regional distribution** consists of shorter, more disaggregated journeys, often from national to regional distribution centres and to out-of-town retail sites.
- **Urban and last-mile distribution** connects regional distribution centres with urban retailers and consumers, usually in smaller, more frequent deliveries.

Of the total freight kilometres travelled in 2016, 59% were classified as long-haul, 35% regional and 6% were urban distribution (Greening et al., 2018). Given the nature of each element, larger vehicles are used for long-haul and regional distribution than for urban distribution. Indeed, the majority of road freight is moved in HGVs weighing more than 3.5 tonnes, usually articulated vehicles consisting of separate tractor and trailer units. Yet although long-haul makes up the bulk of mileage and uses the largest vehicles, the wider social and environmental impacts of urban and last-mile distribution are more readily visible to the public, as the growth of freight traffic in busy urban areas can worsen congestion and air pollution.

The LCV fleet, which is the dominant vehicle type used for urban and last-mile distribution, is today split between companies and private owners, pointing to their growing use by freelance workers. The total mileage of LCVs has risen by 35% since 2004 (Department for Transport, 2018a), but only a minority of their journeys are freight movements; their commonest purpose remains the delivery of services, rather than goods (Braithwaite and Drury, 2018). Unlike HGVs, LCVs can perform multiple roles. Their use is a relatively under-researched area, but one survey in 2008 (Department for Transport, 2009) found that only 26% of weekly LCV mileage was undertaken for the delivery and collection of goods, while 53% was for the carriage of equipment. This may have changed in the subsequent decade, however, as the LCV fleet has expanded.

LCVs are usually loaded less efficiently than HGVs, reflecting their frequent use for service purposes. LCVs are also used to travel to and from work.

In general, LCVs are used well below their maximum capacity (Braithwaite, 2017). A Transport for London study (2011) found an average LCV loading factor of 39%, compared to 60% for HGVs (Department for Transport, 2018, RFS0125). This suggests load consolidation or alternative commuting arrangements could decrease the number of LCVs on the road, if desired.

Although the loading factor of HGVs is higher, around 30% of HGV mileage is run by empty vehicles (Department for Transport, 2018, RFS0125). This is explained by many factors, including businesses whose needs vary by geography; increasing time pressures; the distance of distribution centres from population centres; and the challenge of potential coordination across many different companies.

The composition of the goods moved around the UK has remained broadly stable over the last decade. Figure 3.4 shows the commonest goods lifted by HGVs in 2017.

Companies in the logistics sector (e.g. DHL) are a major provider of road freight. In 2017, the UK logistics sector comprised around 195,000 enterprises, employing 2.5 million people and adding £121 billion of gross value added (GVA) to the economy (Freight Transport Association, 2018a). But this sector will face a range of challenges and opportunities in the coming years, which could result in significant transformation. The efficient operation of the freight sector is critical to its economic success, but creates negative social impacts such as pollution that require management.

3.2.2 Rail freight

While rail is cheaper than road freight for the long-haul movement of bulk goods, road freight offers a level of accessibility and flexibility that rail cannot match in the UK. Cost is another factor. KPMG argue that rail freight benefits society by

Figure 3.4 **Five most common commodity types lifted by UK-registered HGVs, 2017**

Rank	Commodity	Goods lifted (million tonnes)	Proportion of all goods lifted (%)
1	Food products	287	21
2	Metal ore and other mining and quarrying	195	14
3	Waste-related products	153	11
4	Glass, cement and other non-metallic mineral products	135	10
5	Groupage	129	9

Commodities are classified using the standard goods classification for transport statistics.

Groupage is when, for mixed consignments, no single commodity makes up 75% or more of the consignment weight.

Source: Department for Transport, 2018c

Last-mile freight delivery

The last mile of freight – the movement of goods from a transport hub to its final destination (usually small urban retailers or consumers) – is labour intensive, accounting for 30-50% of supply chain costs; it also generates the most CO_2 per tonne moved (Dolan, 2018; Ranieri et al., 2018). This is because, compared with long-haul and regional freight, last-mile delivery involves smaller loads, more stops and tighter time windows, resulting in complex routing and incomplete loading of vehicles. These add to the costs and CO_2 emissions per tonne.

But last-mile delivery is becoming increasingly important, not least because the demand for home deliveries is rising and customers are putting pressure on the freight industry to deliver goods more quickly. This is not the only pressure: increasing traffic congestion threatens the reliability of deliveries (around 13-14% of home deliveries 'fail') and contributes to the loss of kerbside parking space for deliveries; there is an increasing number of retailers offering customers free home delivery, which raises demand and competition; and there is rising demand within peak periods (Cherrett and Allen, 2018).

Overall, consumers' demands for faster, more frequent and more precisely timed deliveries – all at ever lower costs – will have environmental and economic consequences. Emerging technologies may be needed to meet these demands (see Chapter 5).

reducing congestion on roads and by reducing carbon emissions, and so it has positive externalities that amount to £500 million each year, i.e. it benefits society more than it costs (Rail Delivery Group, 2018), while HGVs probably pay less than they cost society (MTRU, 2014). Thus, road freight has an economic advantage. This advantage is likely to have contributed to the gains for road freight over rail. This cost point is still debated, though, and strongly depends on assumptions. Given that the turnover of the rail freight industry is around £850 million (Rail Delivery Group, 2015), moves to make it more cost neutral to society are likely to increase the feasibility of medium-distance rail haulage in the UK.

While the choice of mode for transporting goods depends on numerous factors (e.g. cost, time, flexibility, reliability and capacity), rail is often the preferred choice for large-scale, regular movements of freight over long distances. However, this currently presents a challenge, as retail trends are favouring smaller loads and more irregular movements (European Parliament, 2015). Furthermore, changes to the structure of the economy, especially the falling proportion of UK gross domestic product (GDP) attributable to manufacturing, have reduced the demand for rail freight. Manufacturing (defined as production) declined from 25% of GDP in 1990 to 14% in 2013, while services have grown (Office for National Statistics, 2014). Services are generally less freight intensive than manufacturing.

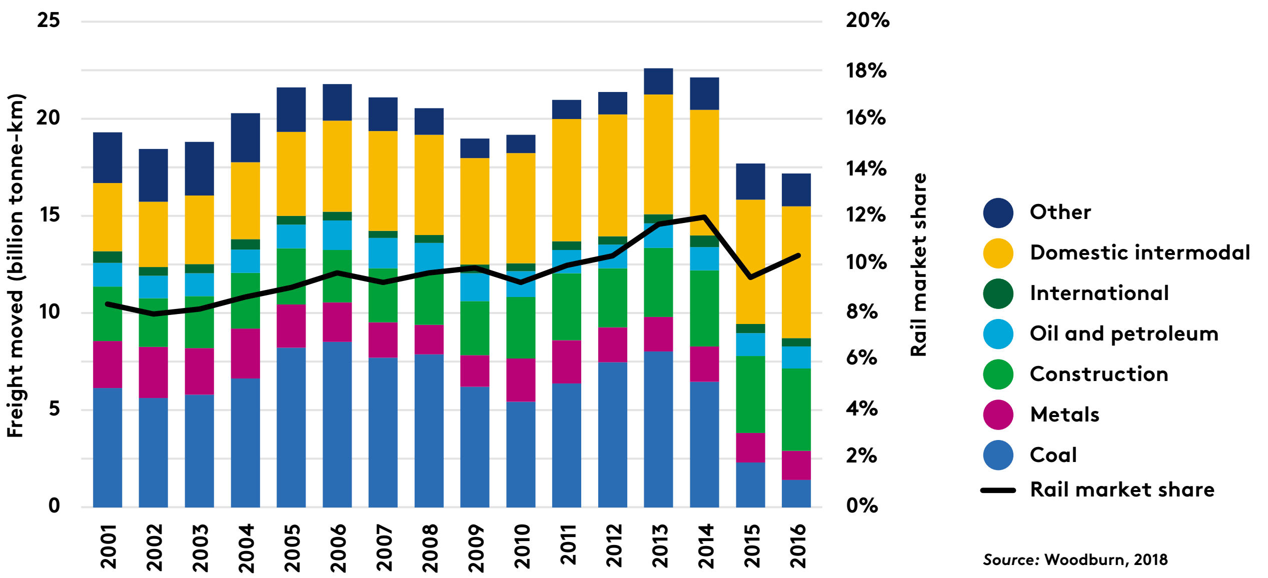
Another recent trend that has contributed to the falling demand for rail freight is the rapid decline in the use of coal for electricity generation, which was largely transported by rail. Figure 3.5 shows that since 2013/14, tonne-kilometres for coal have declined substantially, mirroring a drop in rail's market share.

At the same time, the movement of certain other goods has increased, and rail still carries goods worth around £30 billion every year. For example, domestic intermodal[3] rail freight nearly doubled in volume between 2000 and 2016. This demonstrates how rail usefully complements maritime freight: an estimated 85% of freight trains consist of containers moving to and from ports (Woodburn, 2018).

While the share of domestic long-haul movements made by rail is small compared to roads, there is potential to increase this share, if developments in infrastructure enable this. At present, domestic rail freight principally moves between major national distribution centres, mostly in the Midlands and Scotland. These are largely operated on a contract basis by large supermarket chains and a handful of Scottish logistics operators, with sufficient Anglo–Scottish traffic to fill a daily train (MDS Transmodal, 2018). Technological and organisational change within the rail freight sector has been slow, but the recent renaissance in passenger rail travel could be mirrored, at least in part, by an increase in rail freight volumes – with the right investment, technological developments and policies. Paddeu et al. (2018) report several EU projects that aim to enhance rail freight by deploying higher-capacity wagons, autonomous locomotives, improved transhipment terminals, and the European Rail Traffic Management System (ERTMS) digital signalling system. When rolled out, the ERTMS will unlock up to 40% of additional rail capacity in Europe, making rail freight much more competitive. This is significant, as passenger trains currently have priority on the UK rail network.

3. Intermodal – involving two or more different modes of transport in conveying goods.

Figure 3.5 **Rail freight moved by commodity, and rail's share of the land freight market 2001-2016**



Source: Woodburn, 2018

Another important change needed is the reduction of carbon emissions on rail. Compared to road freight, rail freight produces significantly fewer carbon emissions. However, there is more that should be done. In 2016, 93% of UK rail freight was hauled by diesel locomotives, and 7% on electrified services (McKinnon, 2018). The rail industry should continue to explore how new technologies such as hydrogen fuel cells (Gerrard, 2018), as well as traditional rail electrification, can contribute.

3.2.3 Maritime freight

While some of the UK's waterborne freight is on inland waterways, 96% involves seagoing ships. These journeys include coastwise and one-port movements, and travelling to and from inland waters[4] (MDS Transmodal, 2018). As the UK is comprised of islands, this predominance of maritime freight is unsurprising and UK ports handle approximately 5% of global maritime trade by volume, at some point in its journey (Centre for Economics and Business Research, 2017). The UK's wider maritime sector is the largest in Europe, worth an estimated £14.5 billion (Centre for Economics and Business Research, 2017). Between 2005 and 2015, the volume of goods lifted[5] for domestic and internal waterborne freight remained broadly stable at around 3.6 million tonnes, compared to a slightly higher, but also stable, figure for coastwise freight of 5 million tonnes. Over the same period, the volume of goods moved has remained broadly stable at 0.1-0.2 billion tonne-kilometres, for internal as well as coastwise freight (Department for Transport, 2017, PORT0701). The major inland waterway routes for goods lifted are the River Thames (52% of all waterway goods), followed by the River Forth (17%) and the Manchester Ship Canal/ River Mersey (10%) (Department for Transport, 2018, PORT0704).

The weight of freight handled by major UK ports peaked at 570 million tonnes in 2005, before declining to 473 million tonnes in 2016. A major factor behind this decline was the reduction in North Sea oil and gas exports, as well as a reduction in coal imports, which are all mostly transported by sea (MDS Transmodal, 2018). By contrast, the volumes of unitised freight[6] handled by UK ports have grown. Figure 3.6 shows the total volume of unitised freight by type handled by UK ports (imports and exports) from 2001 to 2016.

The rise of standardised containers has eased the movement of freight between different modes of transport (i.e. from ships to trains to trucks). This is crucial, as maritime freight in the UK exists in a flexible and complex intermodal network. Typically, change in the sector has been relatively slow, and for decades the structure of the maritime sector was fairly static. Ports and ships are costly and long-lasting infrastructure, and investment horizons for maritime freight are thus longer than for other freight modes.

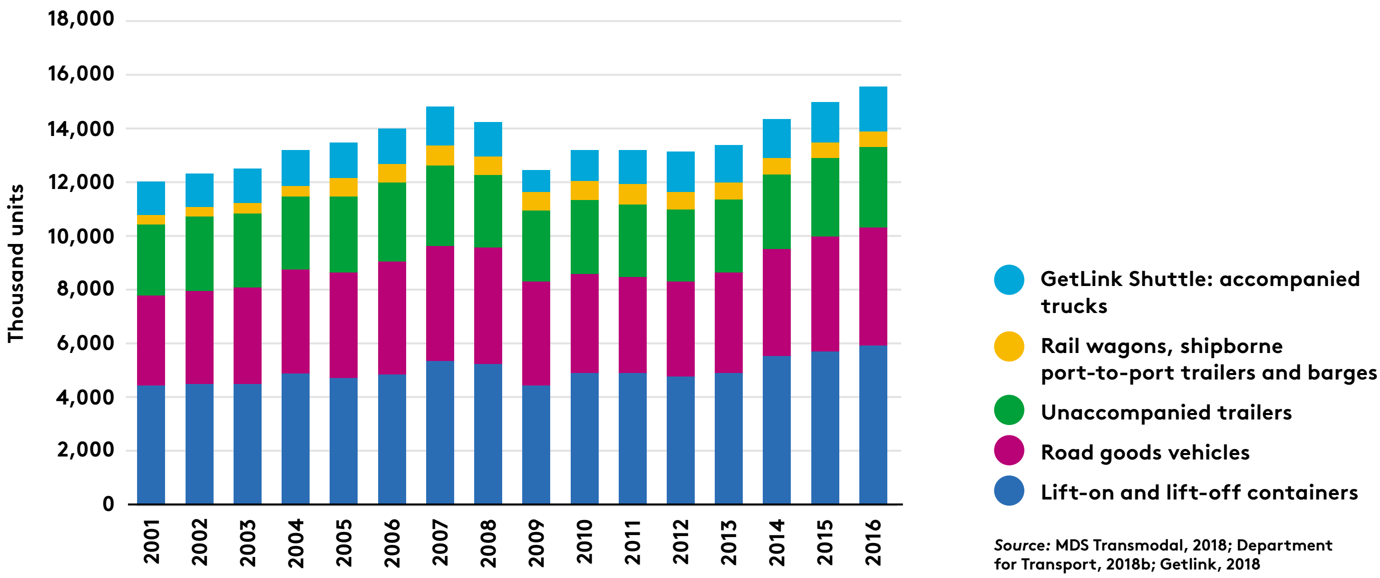
This is now changing due to economic and technical shifts. In order to capture more value, some freight companies, including shipping lines, are pursuing 'vertical integration', whereby they control multiple steps along the supply chain (e.g. terminal services, warehousing, distribution). New market entrants are also emerging and they are often unconventional. Amazon is the

4. Coastwise is traffic carried around the coast from one UK port to another; one-port is traffic to and from offshore locations, such as oil rigs and sea dredging; inland waters is traffic carried by barges or seagoing vessels on the inland waterways network (rivers and canals) (Department for Transport, 2018d).

5. Goods lifted refers to the tonnage of goods transported, while goods moved refers to the tonnage of goods lifted multiplied by the distance travelled.

6. Unitised freight are goods that can be lifted on or off the vessel in large (20 foot or longer) shipping containers (sometimes called ISO containers), or rolled on or off in one of a variety of self-propelled or towed units (Department for Transport, 2018e).

Figure 3.6 Unitised freight traffic handled in both directions by UK ports, by type of unit, 2001-2016



Source: MDS Transmodal, 2018; Department for Transport, 2018b; Getlink, 2018

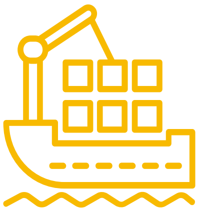
most notable example: it is removing intermediaries from its supply chain by contracting directly with shipping lines (Shead, 2017). In addition, major new shipping routes are emerging, such as China's 'One Belt, One Road' initiative. This involves huge investment in connecting infrastructure across more than 60 countries, inspired by the ancient Silk Road. Such a scale of investment will reconfigure maritime trade routes, as will the new Arctic Sea routes being opened up by the warming climate, which is leading to melting sea ice.

While taking advantage of the opportunities created by climate change, the maritime freight sector has been slower than other freight sectors to confront its environmental impacts. Major economies of scale have been achieved in international shipping, so the cost and carbon footprint per unit moved are low compared with other freight modes – but the aggregate environmental impact is still significant. In 2016, across the EU-28[7], the international maritime sector was responsible for 14% of greenhouse gas emissions from transport (European Environment Agency, 2018). However, the international nature of the sector limits the applicability of national regulations to control greenhouse gases and other pollution.

Nonetheless, there are developments under way that aim to reduce such impacts, notably improvements to ship design and their propulsion systems. One key approach that reduces carbon emissions and improves fuel efficiency is 'slow steaming', meaning a reduction in speed so that ships consume less fuel per unit distance travelled. Over the large distances involved in maritime freight, the additional time is not usually significant, but the environmental benefits and fuel savings are.

Another common approach to improving efficiency is through economies of scale, but the maritime freight may be reaching its limit in this regard. The largest container ships today can carry around 21,000 standard contain-

7. EU-28 – The 28 Member States of the European Union ers, and the consensus is that the maximum a single ship could foreseeably manage is 25,000-28,000 (Mangan, 2018). Instead, future maritime freight will need to be supported by automated 'smart port' infrastructure that allows for smooth and swift intermodal connections for greater efficiency. As supply chains start to self-organise, ships may become able to act as 'floating warehouses' or factories in which products can be assembled and customised in response to demand.



The largest container ships carry 21,000 standard containers, running close to the maximum foreseeable.

3.2.4 Airborne freight

High-value, small-volume goods rely on air freight, which accounts for around 40% of the value of UK imports and exports, but less than 1% of the volume of goods shipped. Air freight services directly and indirectly contribute around £7.2 billion to the UK economy and support around 150,000 jobs (Airlines UK et al., 2018). Airborne freight volumes remained relatively unchanged between 2006 and 2016 at 2.35 million tonnes, with international freight accounting for 98% of the total volume shipped through airports in 2016 (Department for Transport, 2017, TSGB0202b).

Most air freight handled at UK airports is carried in specialised containers in the belly holds of international passenger aircraft, in particular wide-bodied jets operating on inter-continental routes. Heathrow is thus the most important UK airport for freight in terms of tonnage handled, with a market share that has increased from 55% in 2001 to 64% in 2016. East Midlands and Stansted focus on handling dedicated air freighters operated by international express couriers such as TNT and UPS. They transport less than container-load consignments on 24-48 hour lead times, normally feeding European hubs, such as Brussels and Leipzig, for services to the Far East.

3.3 Predicting future demand

3.3.1 Road vehicle demand

As in the USA, car travel per person in the UK has not increased as forecast. Similar to several other Organisation for Economic Co-operation and Development (OECD) countries, it has plateaued over the past two decades (Stapleton et al., 2017). One explanation is that domestically, younger people are travelling less than ever before, a trend that is likely to continue throughout their lives (Chatterjee et al., 2018). This is for reasons that are mostly external to transport (living and socio-economic situations), the age at which a family is started and changes in social interactions (in person versus digital). Chapter 4 discusses this in more detail.

Some argue that motor vehicle distance travelled per capita has peaked and will now fall. It is clear that private car use per capita has lessened or plateaued in multiple countries (Goodwin, 2013), and in some large urban areas (Jones et al., 2018). However, the reasons for this are not well understood. For example, in Sweden the decline is explained to a large extent by GDP and fuel prices, rather than by substantial changes in lifestyles and attitudes to car travel (Bastian et al., 2016). Indeed, recent evidence in the USA shows an upturn in vehicle mileage (Leard et al., 2016). This mixed picture demonstrates the challenges of forecasting demand, and all agree that better understanding is needed.

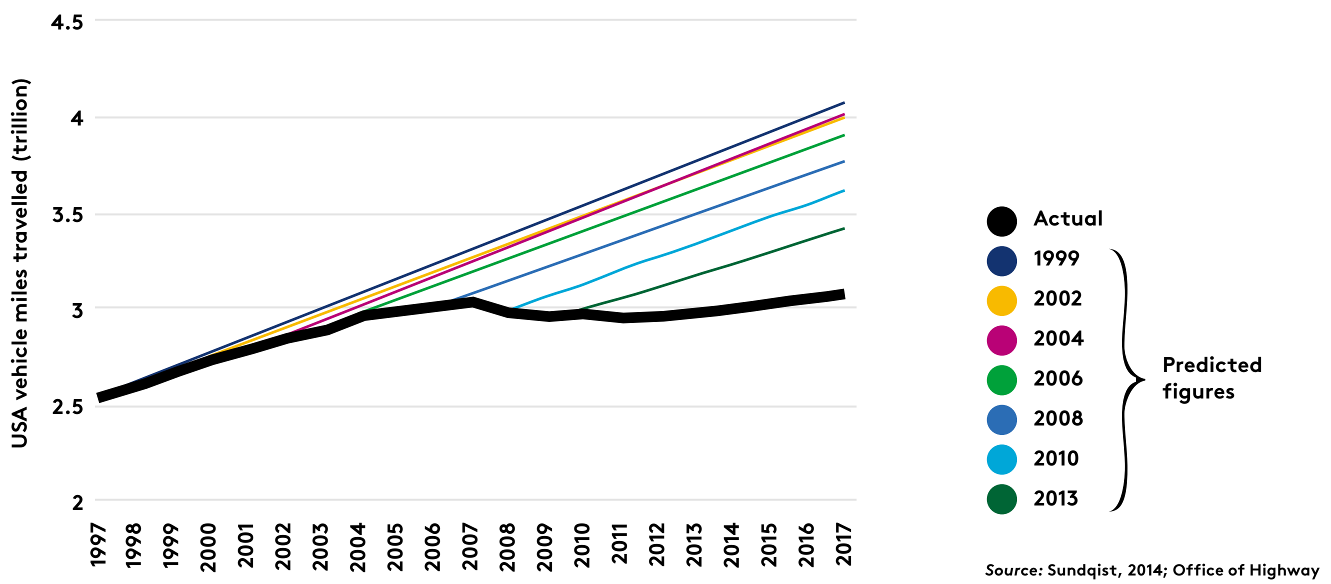
Predictions for future car traffic in the UK vary widely, but many point towards an increase. The Department for Transport (2018g) predicts an increase of 13-37% in vehicle kilometres by 2040 (from 2015) under different scenarios. The size of the car fleet is also forecast to grow, from 30 million cars in 2010 to 44 million by 2040 (Brand et al., 2017). The main driver of this increase is population growth (Department for Transport, 2015a). Over 80% of population growth up to 2041 will be in the over-65 age group (Office for National Statistics, 2018a), a group that traditionally drives less than and at different times to people of working age.

The challenge of forecasting future car traffic is exacerbated by the simultaneous changes occurring in technology, society, and in transport systems, all of which impact transport behaviour (Marsden et al., 2018). Transport systems are complex and accurate predictions are extremely difficult to make. Figure 3.7 highlights this, demonstrating how the actual vehicle miles travelled consistently fell short of predictions in the USA. Given the high uncertainty attached to all predictions, there is a risk of overestimating the growth of private-vehicle stocks, and linear extrapolations are unlikely to consider changing patterns of accessibility, and hence mobility, and their interaction with incomes and economic growth (Goodwin, 2012).

One issue with forecasting future demand is that aggregate trends can mask significant underlying differences. In the UK, for example, motorway use has risen by nearly 40% since 1996 (Department for Transport, 2018, TRA0103)

Car travel per person has plateaued over the last two decades.

Figure 3.7 **Predicted vehicle-miles travelled in the USA, compared with actual vehicle-miles travelled from Federal Highway Administration Travel Volume Trends reports**



Source: Sundqist, 2014; Office of Highway Policy Information, 2018 and the Department for Transport predicts, under a range of scenarios, that it will rise further by 22-47% from 2015 to 2040 (Department for Transport, 2018l). Given the changing trends in society, technology and transport, it is challenging to make any prediction. Models are unlikely to consider the transformative impacts of the changing nature of work, social norms, or forthcoming technologies such as autonomous vehicles, vehicle electrification, micro-mobility and sharing, as all of these are highly uncertain. This highlights the power of using scenarios as a tool for future thinking and decision-making (Chapter 7). At the same time, there has been a general decrease in both the number of trips and mileage (per person, for private transport) in rural, semi-urban and urban areas. These trends have different impacts in different regions, further highlighting the complexity of the situation.

In terms of other road users, bus use may continue to decline outside of London up to 2040. However, given the likely blurring of private-hire vehicles, demand-responsive transport and taxis, a future that combines these old and new non-private transport options is increasingly likely (Enoch, 2015). One encouraging trend for buses is that operating costs have fallen over the past 30 years (see Chapter 1). The introduction of autonomous (i.e. self-driving) buses and taxis may offer further potential reductions in operating costs, presenting an opportunity to offer low-cost public transport with improved frequency and coverage. Driver wages currently comprise around 40% of the total running costs for buses (Warburton, 2015) and 40-50% of taxi and private-hire vehicle running costs (Hara Associates, 2011; Centre for International Economics, 2014; see Chapter 5 for more detail).

2% of all trips are made by cycle.

The annual cycling distance has increased by 54% since 2002, while the number of cycling trips has decreased by 8% (Department for Transport, 2018h); only 2% of all trips made are currently by cycle (Department for Transport, 2018h). If the recent increase in funding for cycling infrastructure is maintained, there is reason to believe that the use of cycles will continue to grow. There have been rapid local successes, markedly increasing cycling rates both in the UK and in Europe (e.g. Stockholm) in less than 10 years (Sustrans and Transform Scotland, 2010). As the cycling environment becomes more attractive, social norms change and cycling increases. This can create a virtuous circle, creating pro-cycling norms that further encourage people to cycle. Greater funding and increased space allocation could, of course, increase the rate of change.

3.3.2 Passenger rail demand

Over the past 20 years, rail demand per person has increased sharply (see Section 1.1.4). Preston and Robins (2013) attribute most of this to internal factors such as demand management, system efficiency and capacity provision. By contrast, Wardman (2006) suggests most rail demand growth comes from external factors such as demographic change and macroeconomics. More recently, Williams and Jahanshahi (2018) see a powerful effect on rail demand from factors external to the rail sector. Their evidence suggests that job growth in professional/technical services, and the increasing housing density near stations, have substantially increased rail demand. This demonstrates the importance of understanding wider changes in the relationships between economy, society and rail demand.

External modelling suggests further growth in passenger rail demand of 45-66% up to 2040, allowing for constraints (Blainey and Preston, 2016). Similarly, the Department for Transport estimates a 48% growth in passenger journeys, and growth of around 60% in passenger-km.[8] If these estimates are accurate, and trends continue without change, then an overall increase in passenger rail use up to 2040 is expected, but at a slower rate than in the past 20 years. In some markets, such as long-distance business travel to and from London, the existing infrastructure may reach full saturation of capacity, or 'peak rail', before 2040. The expected social and technological changes taking place over the next 20-30 years could also significantly change rail demand. The strong influence of external factors, such as the location and density of jobs and housing, patterns of employment and levels of car ownership, complicate predictions of rail demand (Williams and Jahanshahi, 2018).

Despite the long-term growth trend, there has been a recent downturn in passenger rail journeys, which declined by 1% in Great Britain in 2017 compared to 2016 (Office of Rail and Road, 2017a), and by around 2% for London and the South East in 2017/18 (Office of Rail and Road, 2018b). Journeys on the Transport for London underground system (the Tube) have also fallen by 2% year on year (BBC, 2018c). The exact causes of this are unknown.

3.3.3 Freight demand

Freight demand is derived from external factors, notably trade; it is an intermediate step in a process, rather than being required for its own sake. At the same time, the flexibility and agility of the freight sector have shaped both retail and consumer demand. The Department for Transport projects freight traffic will continue to grow until 2040. In a range of scenarios, HGVs will drive 3-7% more miles by 2040. LCVs mileage (of which only a small proportion is freight) is projected to grow by between 15 and 70% (Department for Transport, 2018g).

The demand for freight does not, however, necessarily translate into a need for freight mobility. What people and companies want is access to goods or services. If digital products or services are cheaper (e.g. e-books, MP3 files, streamed films), then they can substitute the need for mobility to access these products or services. However, given the low cost of road haulage per item or per pallet, it is likely that observed freight movements reflect actual demand, with less actual substitution of mobility (MDS Transmodal, 2018). Nonetheless, accessing services digitally will decrease the volume of physical goods that must move to the customer.

8. The first Department for Transport figure was estimated using the Exogenous Demand Growth Estimator (EDGE) model, the second using the National Transport Model (NTM).

Policy implications

- **Out to 2040 a new combination of self-driving private-hire vehicles, taxis and demand-responsive transport could represent the future of public transport on the UK's roads.**
- **An improved understanding of the exact role of vans and LCVs – the largest-growing traffic segment – will be important** in shaping traffic behaviour and mitigating environmental impacts.
- **There are, at present, inherent uncertainties and difficulties in forecasting future transport demand**, due to the degree of technological change taking place, both inside and outside the transport sector.
- **Policy-makers should consider using scenario-based approaches**, including preferred scenarios (i.e. a national vision) to enable them to identify and establish indicators and warnings for further evidence of potential challenges, such as rail saturation or 'peak car' use.

People and the transport system

Key findings

- People are making fewer trips and travelling less per person compared to 20 years ago. However, population growth means that the total distance travelled in the UK each year has increased (Section 4.1).
- Younger people are travelling less within the UK, a trend that appears to continue throughout their lives. This is probably due largely to causes outside the transport sector, including declining home ownership, increasing living costs, digital connectivity replacing some need to travel, and the trend towards starting a family later in life (Section 4.1).
- As personal transport expenditure rises relative to income, the transport burden increases. Among the poorest households, this hardship is often exacerbated by the need to own and run a car, which is costly (Section 4.4.1).
- Walking has declined over the past 20 years, while cycling trips per person have remained broadly stable. Both modes of transport suffer from latent demand: people walk and cycle more when better infrastructure is available (Section 4.2.4).
- Simultaneous changes in technology, society and transport have markedly affected transport behaviour over the last 20 years and this is likely to continue. The changing nature and location of work, land use, housing and online retail growth have transformed transport behaviour.
- People and companies make transport decisions as part of wider choices – accessibility, lifestyle and connectivity – and are strongly influenced by external changes in society. Practical factors – such as the built environment, location, cost, journey times, and availability of infrastructure – currently dominate decision-making and this will likely continue to 2040 (Section 4.3).
- Car dependence has grown partly because the necessary infrastructure has improved, but also as it is seen as a 'superior' or 'easier' mode of travel. Car use is habitual for many and changing behaviour will require both soft and hard incentives (Section 4.5.2).
- Freedom of choice leads to travel behaviours that are good for the individual or group, but not necessarily for the system. The best outcome for the environment, society or the economy is likely to differ from the outcomes from unconstrained individual choices (Section 4.7).

20%

reduction in the annual number of commuter trips per person between 1995 and 2014

since 1993, rail demand has grown even in the face of rising passenger costs

30% | 10%

reduction in the annual distance traveled by 17- to 29-year-olds since 1997

£4–7

benefit per £1 spent on active travel

4.1 Current travel behaviour in the UK

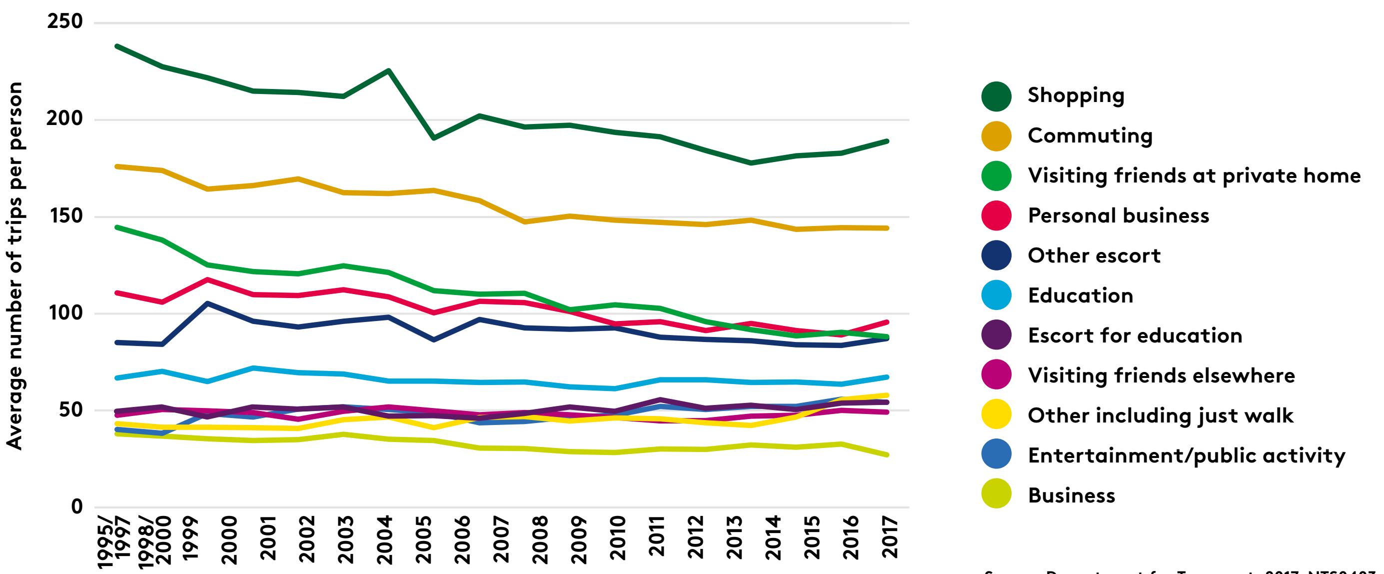
Travel is largely a derived demand. Usually, people do not travel for the sake of it, but because they need to do something at the destination: to work, to shop, to visit friends and family, or a leisure activity. However, the underpinning reasons for travel, such as the need for company, are not generally discernible. Instead, only people's actual travel behaviour is observed. This behaviour is shaped and constrained by many factors: location, connectivity, costs, age, congestion, ability to travel and available transport options. Past experiences and social norms also influence people's mobility.

The activities that people travel for are changing too. Indeed, there are simultaneous changes occurring in technology, society and in transport systems, all of which impact transport behaviour (Marsden et al., 2018).

Since the mid-1990s, the number of trips for most purposes has either fallen or remained constant. The average number of trips per person is falling across all age groups (Department for Transport, 2017, NTS0403), with an average decrease of 13% between 1995 and 2017 (Figure 4.1). In the same period, total distance travelled per person has also fallen (Department for Transport, 2017, NTS0305). Shopping is the reason for the largest number of trips in England, followed by commuting (Department for Transport, 2017, NTS0403).

Patterns of commuting are evolving alongside changes in the nature of contemporary labour markets and broader working practices. England's population grew by 12% from 1995/97 to 2013/14 and commuter trips per person decreased by 20%. So, despite the population growth, the effect was a decrease in total commuting trips of 7%. This is not completely understood, but it partially reflects the changing nature of work (i.e. commuting on fewer days per week, increases in home working and rising part-time and self-employment) (Le Vine et al., 2017).

Figure 4.1 **Average number of trips per person per year, by trip purpose, in England, 1995/1997-2017**

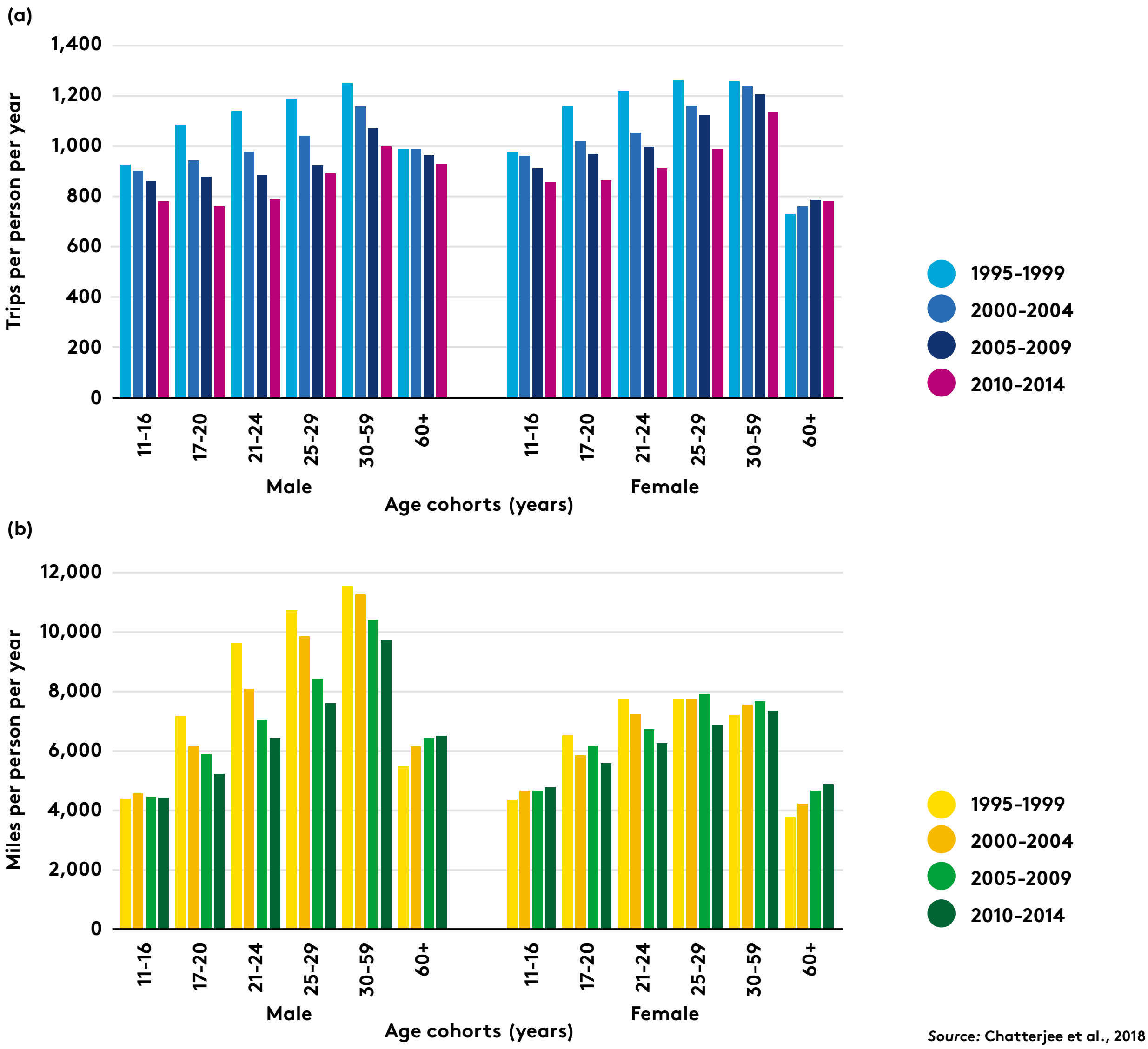


Source: Department for Transport, 2017, NTS0403

Mobility is not fixed, in that social changes, lifestyle choices and changes to transport infrastructure all influence travel behaviour. For example, building a new road usually induces extra traffic (Standing Advisory Committee on Trunk Road Assessment, 1994; Duranton and Turner, 2011), while building new, segregated cycling and walking infrastructure increases the use of these modes (Sustrans, 2018).

Notably, over the last 20 years, young people (aged 17-29) are travelling less domestically. The reasons for this lie largely outside the transport system. As Figure 4.2 shows, there were 28% fewer trips for men and 24% fewer trips for women between 1995-1999 and 2010-2014 (Chatterjee et al., 2018). There are several factors behind this, including:

Figure 4.2 **Trips per person per year (a), and miles travelled per person per year (b), by age group and gender, in England, 1995-2014**



Source: Chatterjee et al., 2018

- more young people are accessing education, meaning that they delay entering the job market, which in turn reduces their ability to buy and maintain a car
- younger people's living costs have risen, including housing, the costs of driving (e.g. petrol prices, parking, insurance)
- people are delaying having a family until later in life (Chatterjee et al., 2018).

The link between accessibility – the ability to access key services (e.g. hospitals, schools) – and mobility also varies across the country. In addition transport provision, access to services, and planning impacted genders differently (Hamilton et al., 2006). Accessibility fell between 2003 and 2013 due to resource constraints, since this includes the financial crisis period (Environmental Audit Committee, 2013). Comparing the time needed to reach eight key local services, the average minimum journey times in England in 2016 were 18 minutes by public transport or walking, 15 minutes by cycling and 11 minutes by car (Department for Transport, 2018, JTS0101). The car frequently offers better accessibility to destinations and services than public transport. This practicality has contributed to the rise of the car over the last century. The relationship is interactive: businesses and services responded to car growth by creating new opportunities and locations for access by car, but increasing car dependence at the same time (Urry, 2004).

4.2 Key drivers of changes in mobility

Clearly, the demand for travel is complex and, in the future, a number of broad social trends are likely to affect mobility. Some major social trends that are already affecting the transport system at different levels are: (1) population growth and an ageing population; (2) changing attitudes and behaviour among younger people (e.g. changing environmental norms); and (3) the growth of the sharing economy and of digital services (e.g. e-commerce and home working). Other external influences play a role, such as changes in the nature of work, family life, education and housing. While these factors are too many to list, the digitalisation of services will likely have a profound impact on the future mobility of passengers and businesses. Whether increased home working reducing the need to travel; the internet of things allowing for more remote maintenance and therefore less mobility of maintenance engineers; or increased resilience of modern technology over older systems – the increased shift of the UK's economy to services combined with digitisation has important implications for future travel demand. These issues are not the direct responsibility of government, but their impacts must be considered when planning the transport systems of the future.

4.2.1 Population growth and ageing

Nationally, population growth is a key driver of transport demand (Department for Transport, 2015b). The UK's population is expected to grow by 11% out to 2040, reaching 73 million people (Office for National Statistics, 2017b). This growth is spread unequally, however. Some areas, including many parts

Between 2016 and 2041, the number of people over 85 will double to 3.2 million.

of London and the South East, may see increases of over 25% (Office for National Statistics, 2015). In other areas, population declines of up to 13% over the same period are predicted, including the west coast of Scotland, Shetland and Orkney, and the western Lake District.

The larger population will increase pressure on transport services and the system overall. Much population growth is likely to be in suburban areas, which are traditionally harder to serve by public transport than cities (Hackett, 2009). Smaller populations may make public transport services, at least in their current form, less economical to run.

The ageing population is another significant demographic trend. From 2016, over 80% of population growth to 2041 will be in the over-65 age group, with the number of people over 85 almost doubling from 1.6 million to 3.2 million over the same period (Office for National Statistics, 2018a). In some areas, up to 40% of the population will be over 65 by 2037 (Office for National Statistics, 2016), while people aged over 65 will become the largest population segment in rural areas by 2040 (Champion, 2015). Older people will also be unevenly distributed across the UK, with higher proportions concentrated in the South West. Ageing and mobility are discussed in more detail in Section 4.4.2. Historically, the over-65s have travelled less, and at different times to the working population, so the nature of travel demand will shift. Older people are fitter and more active than previous generations, aiming for a highly mobile and active retirement (Musselwhite and Chatterjee, 2019). Consequently, the car mileage driven by the over 70s continues to grow (Department for Transport, 2017, NTS0605).

4.2.2 Behaviour changes among young people

At the other end of the demographic spectrum, the changing behaviour of younger cohorts, and expectations of how this will evolve with time, also influences accessibility and hence travel behaviour (Chatterjee et al., 2018). For example, the percentage of young people with driving licences fell between 1992 and 2014, from 48% to 29% among 17-20 year olds, and 75% to 63% among 21-29 year olds (Chatterjee et al., 2018).

Overall, there is a trend towards younger people travelling less. In 2017, the annual distance travelled by 17-29 year olds was around 30% less for men and 10% less for females, compared to 1997 (Department for Transport, 1997; Department for Transport, 2017, NTS0605). The decreased distance travelled is mirrored by a decrease in the number of trips, and these trends are continuing through life, influencing wider social norms around accessibility and travel.

4.2.3 The rise of the sharing economy

Attitudes towards ownership are changing. Younger people, particularly the under-30s, often choose usership over ownership. This is driving the growth of the sharing economy, which was estimated to be worth £0.5 billion to the UK in 2014, rising to £9 billion by 2025, in terms of revenues and wider benefits (Carson, 2014).

Reflecting this shift, car-, bike- and lift-sharing are increasing sharply, although these are from low starting points. Looking towards 2040, the sharing economy will almost certainly grow further, but it will remain of minor interest in the transport sector unless there are strong incentives. Ride/car-sharing is a compromise that most people are reluctant to make, having to overcome barriers of trust, awkwardness, timing and cost. Without clear shifts in these norms, or a large price differential between individual and shared modes of transport, ride/car-sharing will probably remain a minority pursuit (Golightly et al., 2018; Kantar Public, 2018).

4.2.4 Driving positive change through incentives: walking and cycling

Walking and cycling have the most social benefits and fewest negative effects.

Walking and cycling have the most social benefits and fewest negative effects, yet they are often under-represented in people's mobility behaviour. Walking is important as a means of exercise, and as stages in longer multi-modal journeys (e.g. walking from the train station to the bus stop). However, the pedestrian environment is adversely affected by the impacts of vehicular traffic. Recent guidance (Chartered Institute of Highways and Transportation, 2010) highlights the importance of a user hierarchy that puts pedestrians at the top. Future changes in transport technology and urban planning should be considered that make walking a higher priority.

Walking is the second-most used mode of travel for people under 25, who are often otherwise reliant on lifts or public transport (Department for Transport, 2017, NTS0601). However, many parents are reluctant to allow children to walk unaccompanied to school, with 47% of parents citing 'traffic danger' as the main reason (Department for Transport, 2014).

Distance is a key factor in determining the decision to make journeys on foot. On average, 80% of all trips under 1 mile are made on foot (Department for Transport, 2018, NTS0308). Yet even relatively small increases in distance can influence this choice. In England and Wales, 17% of journeys to work are to destinations within 2 km, and 42% of these are made on foot. However, this falls to 7% for journeys of 2-5 km (Office for National Statistics, 2011b).

Travel behaviours are strongly shaped by urban form and the built environment, which influences decision-making and incentivises travel along certain routes or by specific modes (Chapter 7 explores how geography impacts travel behaviour in more detail). For example, the choice to walk (or not) is partly made based on dangers, both real and perceived, and the discomfort of exposure to traffic. On the other hand, people walk more where there are greater street densities (e.g. in urban areas), proximity to amenities and diverse land uses (e.g. restaurants, shops, schools, offices, parking).

Levels of cycling have fluctuated around 4-6 billion passenger-km per year since 1965, but this accounts for less than 1% of the total distance travelled (Department for Transport, 2017, TSGB0101). Cycling distances per person are growing, up 41% between 2006 and 2017. However, these figures may reflect sampling bias rather than the actual picture (Department for Transport, 2018i).

There is large latent demand for cycling.

Cycling numbers are strongly dependent on having a cycling infrastructure that is separate from other vehicles (e.g. designated cycleways) and there is large latent demand for cycling: more people would cycle if conditions were improved, so investment in infrastructure often sharply increases the number of people cycling. This can lead to a change in social norms and, in turn, make further increases more likely. Further to this, attractive walking and cycling environments increase uptake of these modes of travel. Encouragingly, cycling and walking are set to receive a boost of £1.2 billion over the period 2018-2023 (Department for Transport, Grayling and Jones, 2017).

4.3 How behaviour changes

Companies, households and individuals live in a changing environment. From the structure of society to the nature of leisure, from healthcare to work, from the cost and location of housing to social norms around when and if to have children, society continues to change. Many of these influences shape and constrain the range of people's behaviour but are outside the control and choice of individuals. This section discusses the decisions and choices they make.

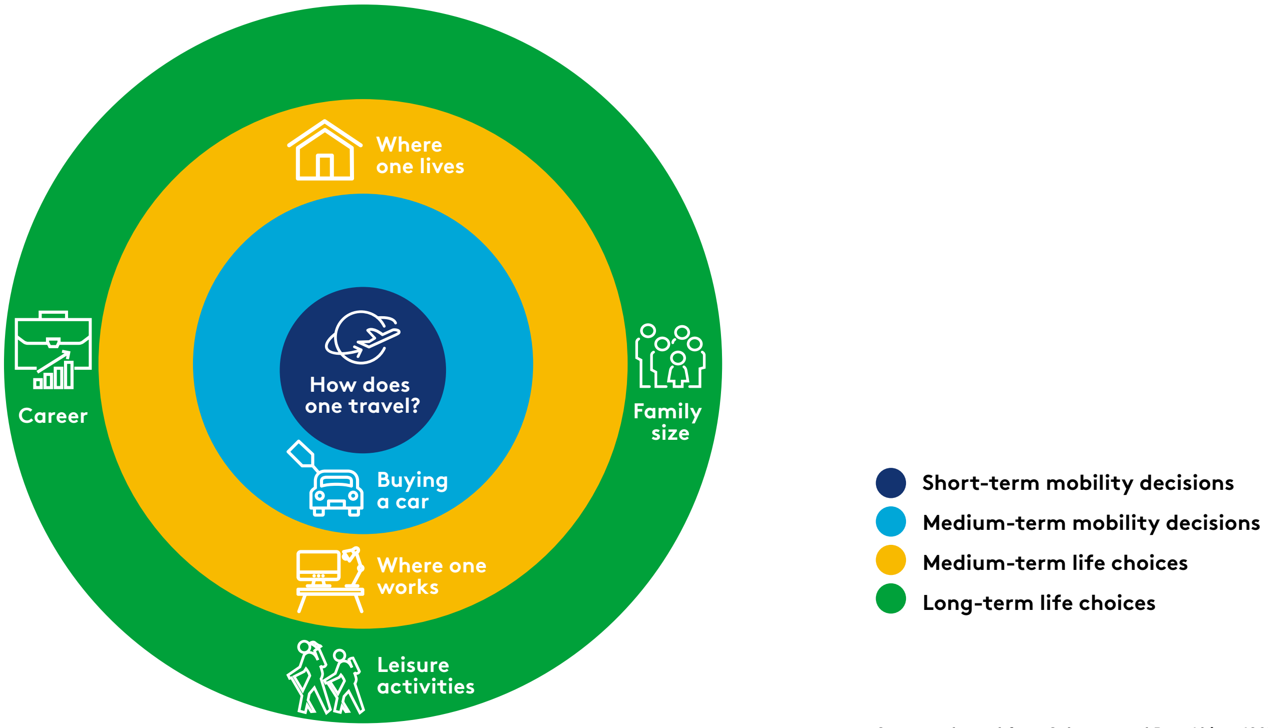
People make mobility decisions as part of a total hierarchy of wider lifestyle choices (Salomon and Ben-Akiva, 1983; Chatterjee and Scheiner, 2015). At the top of this hierarchy, long-term choices relate to (among other factors) family size, career and leisure activities. Next come medium-term choices about location, such as where to live and work. Short-term choices are those made on a day-to-day basis. It is the long- and medium-term choices that influence our mobility decisions. A typical chain of causality goes as follows: the (long-term) choice to have several children will probably result in the (medium-term) choice to live in a suburb, where houses have bigger gardens; living in a suburb in turn will probably result in owning a car – hence, car use becomes habitual.

Travel decisions are made in line with these long- and medium-term choices, and can be grouped into medium-term decisions (e.g. buying a car) and short-term decisions about how and where to travel. The latter can be further divided into three types of journey: (1) mandatory trips (e.g. commuting, travelling to school); (2) maintenance trips (e.g. shopping, medical appointments); and (3) discretionary trips (e.g. leisure, visiting family and friends) (Vovsha et al., 2002).

This simple model (see Figure 4.3) suggests that government can affect mobility decisions by intervening at different stages. For instance, the medium-term life choice of where to live can be influenced by diverse land usage. More parks and playgrounds in inner cities may stop families from moving to suburbs once they have children. Similarly, greater home working reduces travel to work (a short-term mobility decision).

Alongside these lifestyle choices, mobility decisions are influenced by practical, psychological and social factors as well as by demographics and circumstances (Schwanen and Lucas, 2011). Practical factors relate to how well

Figure 4.3 Factors affecting mobility decisions



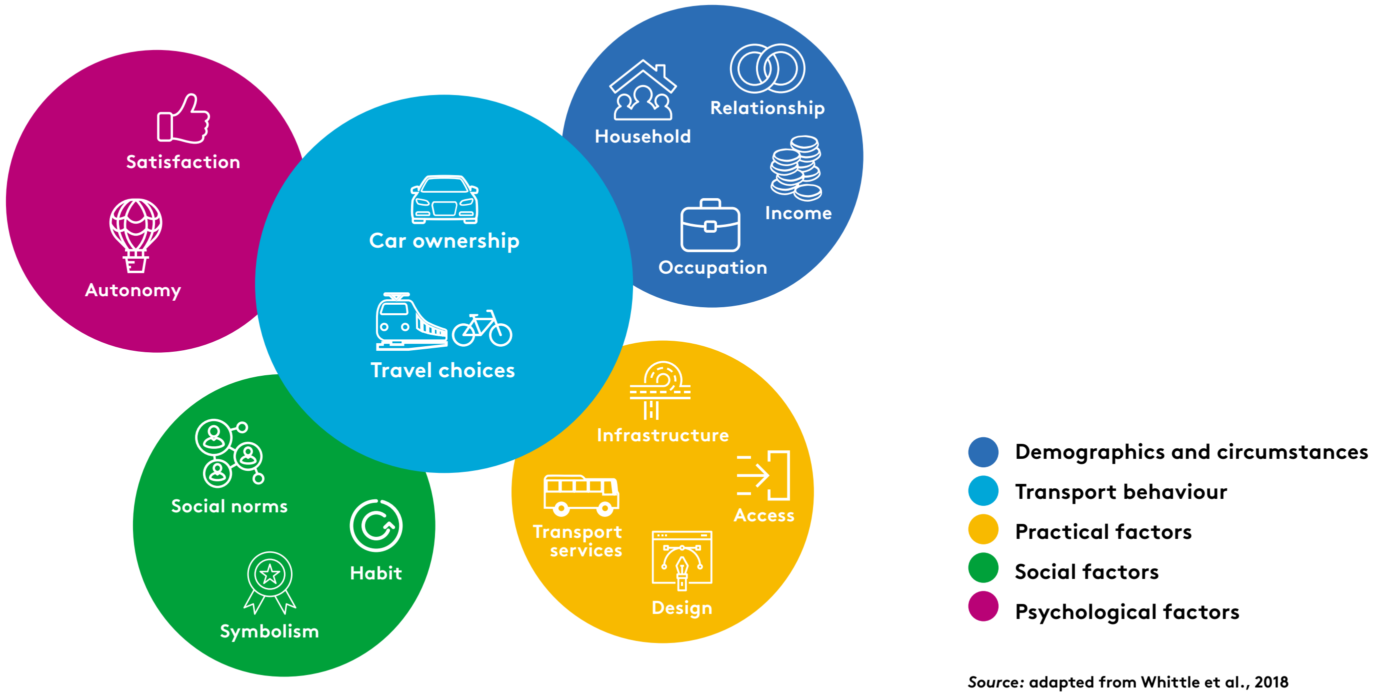
Source: adapted from Salomon and Ben-Akiva, 1983

a form of transport can meet people's practical needs, for example whether the transport infrastructure is conducive to travelling by car or public transport. Psychological factors include emotions such as the extent to which one enjoys driving or walking. Social factors involve how much other people matter in one's choice (e.g. peer opinions). Demographics and circumstances relate to life-cycle events and income. Figure 4.4 illustrates how these factors influence our transport behaviour.

It is unclear which set of factors are the most influential (Whittle et al., 2018) and it is likely that their influence is cumulative (Ewing and Cervero, 2010). However, when households are asked why they change mobility decisions (e.g. changing the number of cars they own), they mostly cite practical reasons (Dalton et al., 2013; Clark et al., 2016a). Although practical motivations appear to dominate, their effects are not always easy to predict or explain. For example, between 1980 and 2014, the cost of private motoring fell by around 14%, while bus and rail fares rose by 58% and 63%, respectively (Stone, 2015). As expected, this incentivised car use and disincentivised bus use – but rail demand rose even in the face of rising cost. This highlights the complexity of the motivations behind mobility decisions.

People also make short-term, day-to-day travel decisions, such as planning and optimising their journeys on a case-by-case basis (Kopp et al., 2015; Shared-Use Mobility Center, 2016). As people often use heuristics – a mental shortcut that allows them to solve problems and make judgements quickly and efficiently – to make travel decisions, they may not always pick the

Figure 4.4 Factors that influence mobility decisions



Source: adapted from Whittle et al., 2018

most economically rational choice (Thaler, 1999; Flamm and Agrawal, 2012). Figure 4.4 shows many of the emotional (how people feel about transport modes) and social factors that can influence decisions.

For the most part, though, daily travel is routine and repetitive: a process best described as habitual (Gardner and Abraham, 2007). Although there are various views on what habits might mean for behaviour (Schwanen et al., 2012), habitual behaviour is, by its nature, resistant to change (Whittle et al., 2018). Once people start a pattern of behaviour, they usually continue with it until particular events or triggers prompt them to change (Clark et al., 2016a). These might be macro- or micro-level events, and triggers that are planned or unplanned (Chatterjee and Scheiner, 2015). Examples include the birth of a child or the introduction of a cycle lane (Transport for London, 2013b; Heinen et al., 2015; Clark et al., 2016b). Such triggers offer 'windows of opportunity' to encourage people to travel differently (Busch-Geertsema and Lanzendorf, 2015; Walker et al., 2015) and potentially in more desirable ways.

4.4 Social factors affecting mobility

4.4.1 Income

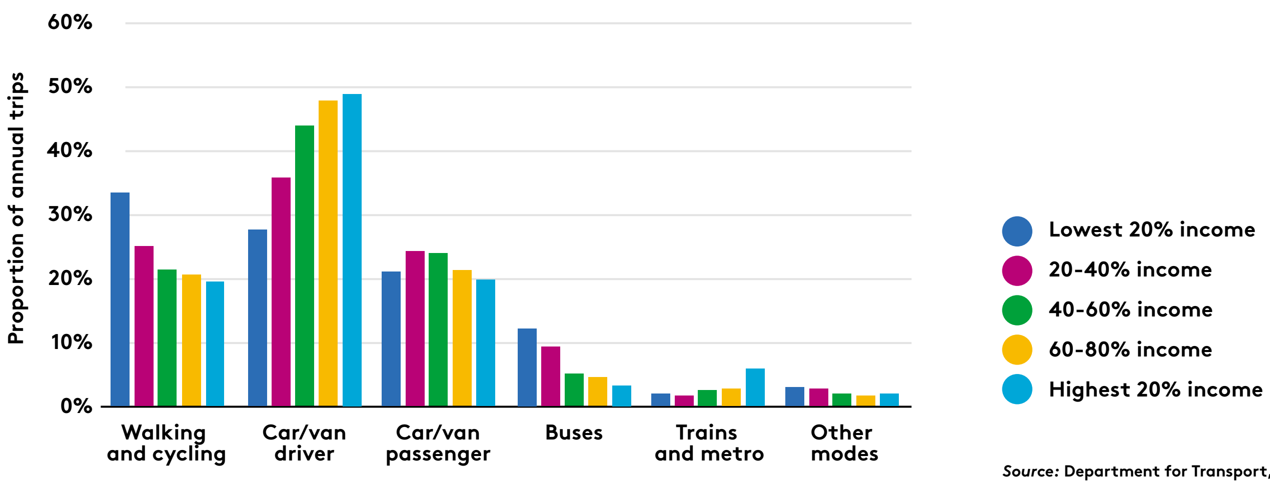
Financial costs are an important factor in mobility decision-making and travellers are often concerned about how to reduce these costs (Gardner and Abraham, 2007; Thornton et al., 2011). However, people's decision-making is not always flawless: while drivers often factor in fuel costs when evaluating car journeys, they probably fail to consider other costs such as the car's purchase price, road tax and insurance (Gardner and Abraham, 2007). This 'blind spot' may be a reason for the continuing rise in car use throughout the 20th century. The consequences of limited transport provision are felt more severely by poorer households, as they have less financial capacity to adapt (i.e. to use alternatives). Figure 4.5 shows that car and van use rise with income, whereas buses are much more likely to be used by the poorest people. Unsurprisingly, buses are also used more by groups who are less likely to have cars, such as those aged under 21 and older people (Department for Transport, 2017b).

The poorest people disproportionately bear the negative impacts of the transport system. People from deprived neighbourhoods are more likely to be injured or killed as road users (Ward et al., 2007). Poorer households also suffer disproportionately from transport-related emissions (Walton et al., 2015; Cairns et al., 2017), as the areas where they live suffer from high volumes of fast-moving traffic, poor quality housing and sparse public transport. These problems worsen mental health conditions (Department of Health, 2002).

As noted, the poorest people have a greater reliance on public transport, so reductions in services have a greater impact on them. People without a car also report having fewer job opportunities (Mattioli, 2016). Furthermore, limited alternatives may force disadvantaged individuals into car ownership (Sustrans, 2012; Curl et al., 2018). High costs can also prevent those with the lowest income from accessing or using certain services (see Box 4.1).

This can lead to car-related economic stress, particularly for those with low incomes and high car-running expenditure: 9% of UK households spend a large proportion of their income (twice the median) on running a motor vehicle and also have a low disposable income (below 60% of the median) (Mattioli et al., 2018). This is not limited to rural areas, or outskirts, but can also affect disadvantaged urban areas (Curl et al., 2018). Sixty per cent of households that are 'forced' to own a car are at risk of poverty and social exclusion (Mattioli, 2017). Once a car has been purchased, it is difficult to relinquish it, even in times of financial hardship (Dargay, 2001). The lowest-income groups may also

Figure 4.5 **Transport choices by household income quintiles, 2016**



Source: Department for Transport, 2016b

Rail use and income

Rail users have a very different travel profile to the wider public. Rail travel broadly rises with income, with the poorest two quintiles making markedly fewer trips than the richest two quintiles (Department for Transport, 2017c). Rail differs from alternative types of transport in other ways too, predominantly because it is used for longer distances: the average journey is 29 miles, compared with 9 miles for the average car journey (Department for Transport, 2017c). The geography of rail use is also different: 64% of rail journeys start or end in London, with much lower rail use elsewhere.

Over half of rail journeys (56%) are made for commuting, a further 10% for business and 23% for leisure (Department for Transport 2017c). This compares with corresponding figures for all journey types of 15%, 3% and 17%, respectively (Department for Transport, 2017, NTS0403). Women aged 31-59 travel considerably less by rail than men. This difference may be explained by the historically different family roles played by men and women.

become increasingly reliant on private-hire vehicles and taxis if the number or frequency of bus services in their area changes (Lucas et al., 2018).

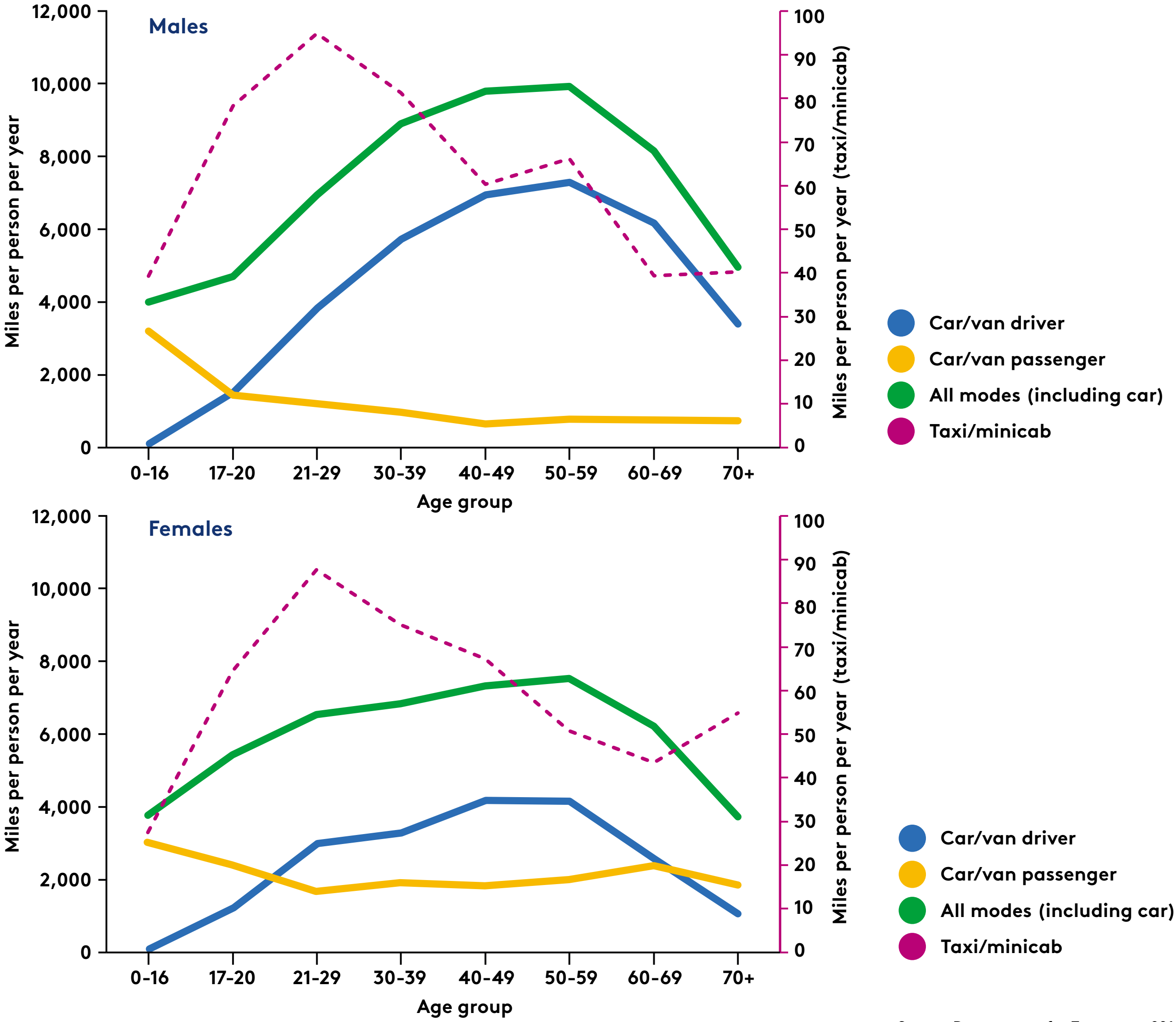
These issues can impact each other. Geographical areas that experience one dimension of deprivation, such as low incomes, often suffer in related dimensions, such as health, employment, education, crime and the living environment (Department for Communities and Local Government, 2015). The net result is that the poorest households can become stuck, not having the skills, transport services or financial means to access jobs in areas where they can earn more (Government Office for Science, 2017a; Green, 2017). This difference in reward for skills is one reason why better qualified people, who are usually more affluent, are able to travel further.

4.4.2 Ageing

As noted, the population is ageing (Chapter 7 reviews the geographical effects of this process) and older people's mobility patterns are also changing. Older people today travel more than their peers did 20-25 years ago, with everyday trip rates higher and activities outside the home being more common (Ormerod et al., 2015). However, this trend is nuanced: car mileage is greatest for people aged 50-59, then falls after 60 as people start to drive less (see Figure 4.6). Transport's socially enabling aspects are particularly important for older groups. Giving up driving is linked to a decrease in well-being and an increase in depression and related health problems, including stress and isolation, and also with increased mortality (Ormerod et al., 2015).

It is therefore important to consider older people's mobility challenges and demands, which differ from other stages of life. One major challenge is safety. Road travel fatality rates – whether walking, cycling or driving – rise

Figure 4.6 Distance travelled by mode, age group and gender



Source: Department for Transport, 2016, NTS0605

sharply for the elderly (Feleke et al., 2018). Most pedestrians over 65 are unable to cross the road in time at traffic lights (Asher et al., 2012), and the walking speed of 76% of men and 85% of women over 65 is slower than the assumed normal walking speed of 1.2 metres per second (Asher et al., 2012). The length of time before traffic lights turn green implicitly favours vehicles rather than pedestrians. Given this power dynamic, as part of its walking plan, London is planning to introduce traffic signals that stop the road traffic as soon as a pedestrian arrives (Transport for London, 2018a).

Historically, pedestrian falls have not been included in road-travel injury data, despite having significant impacts: about half of all pedestrian deaths, and the large majority of non-fatal injuries, are due to falls in public spaces (Methorst et al., 2017). More walkable neighbourhoods – for example, with more even surfaces and the provision of benches, seating areas and other

People use public transport more as they age.

facilities (e.g. public toilets) – would benefit older people's mobility in particular, supporting a modal shift to continued active travel in later life (Ormerod et al., 2015). At present, though, infrastructure is often designed for more able-bodied, younger users – and can therefore be seen as discriminatory.

Accessing key services can also be challenging for older groups. Just under half of over-80s are unable to travel easily to their nearest supermarket, compared with around 20% for 60-69 year olds (Holley-Moore and Creighton, 2015). Hospitals, post offices and banks show similar patterns of declining accessibility with age.

Clearly, older people have different mobility needs to younger people, requiring a different approach to transport provision. One effective approach could be to devise strategies that ensure mobility and connectivity in places where older people are concentrated. Another could be to plan for inclusive transport for older people that recognises that they commonly suffer from more disabilities (e.g. dementia) than those of working age (Department for Transport, 2018j). There is evidence that people use public transport more as they age – but those with a disability are significantly less likely to use public transport (Clery et al., 2017).

It is important to design a transport system that is inclusive for the ageing population, which considers and meets their needs. Adjustments for older travellers, such as 'dementia-friendly design', could improve their transport experience (Local Government Association, 2015). Another avenue is using new technologies, such as self-driving vehicles designed specifically for mobility-impaired users; see Chapter 5 for a more detailed discussion of these options.

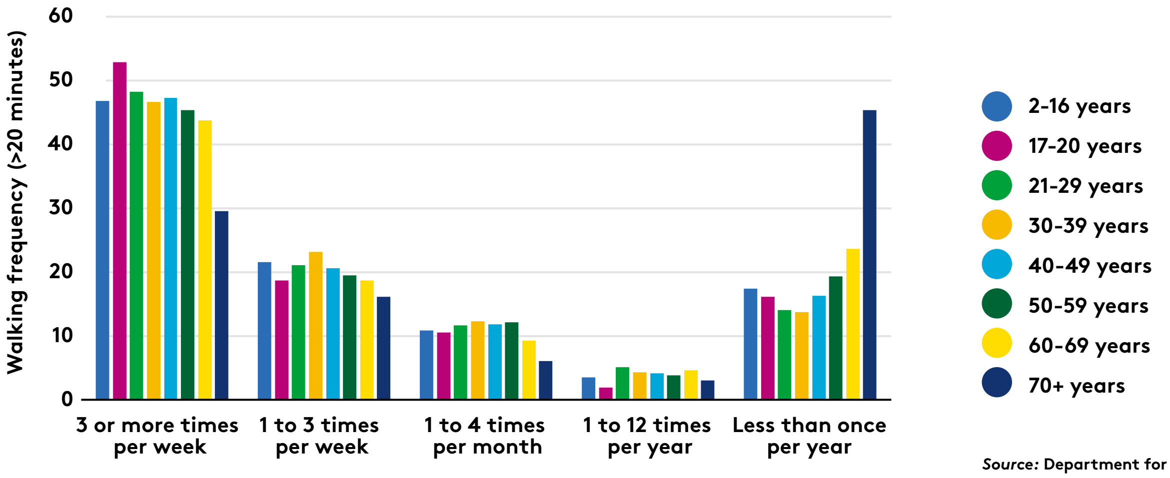
4.4.3 Younger people

At the other end of the spectrum, young people face very different mobility challenges. Access to secondary schools is a key issue for under-16s, with 5% of children unable to reach a secondary school within 30 minutes by public transport. This may seriously constrain their educational choices and limit participation in extracurricular activities (Lucas et al., 2018). Difficulties with transport have also been linked to low participation in post-16 education and increased college drop-out rates (Titheridge and Solomon, 2008). Young people (aged 11-15) living in disadvantaged areas also suffer more from traffic injuries than their peers in other areas, with the risks being higher on main roads and residential roads near shops and leisure services (O'Toole and Christie, 2018).

4.4.4 Walking and cycling

Walking frequency varies across the population. People aged 17-20 are most likely to take frequent walks of over 20 minutes (Figure 4.7), whereas 45% of people aged over 70 walk for this length of time less than once a year. As people age, they walk fewer miles in total, but the amount of walking in relation to other modes of transport increases (e.g. car use, which declines sharply from 60 onwards).

Figure 4.7 Walks of more than 20 minutes in England in 2016 by age group



Source: Department for Transport, 2018, NTS0312

Cycling for leisure purposes is more common than cycling for travel (Department for Transport, 2018k). Men make three times as many trips and cycle four times as far as women, on average. Cycling patterns also vary with age, with 11-16 year old males comprising the largest proportion of cyclists. As people age, cycling rates remain relatively constant, but start declining after the age of 50 (Department for Transport, 2018k).

4.5 Understanding and meeting different users' needs

4.5.1 Different needs, different expectations

Fundamentally, transport users – whether individuals, households or businesses – want a safe, reliable and affordable way of getting to their destination. Yet sometimes people have further expectations of the transport system. As well as simply getting somewhere, people may also want a transport system that can help maintain their health, improve community cohesion and avoid social severance. For example, residents of streets with more traffic have fewer friends and acquaintances on the same street than people living on quieter streets (Hart and Parkhurst, 2011). Busy infrastructure routes, such as railways and roads, can also sever communities. Furthermore, many people want their transport system to contribute towards 'green' goals, although attitudes differ as to how green they wish it to be.

Similarly, companies have complex requirements from the transport system (Lyons et al., 2009). What is good for their employees and for their customers, and what would improve their business, may differ. There are also large differences between businesses, and even within a business. Priorities differ by company size, sector and location, among other factors.

Despite this, transport was not mentioned in the 2016 Small Business Survey's top ten obstacles to success (Department for Business, Energy and Industrial Strategy, 2017a). While businesses do make decisions based on

Business surveys suggest the freight system performs well.

accessibility and connectivity, transport is rarely the primary driver of business decisions. Once decisions are made, however, transport factors – such as site accessibility and the reliability of transport provision – gain in significance (Lyons et al., 2009). For example, the delivery of goods (to and from) is critical to many businesses, particularly in the retail sector, and delays and congestion can cause economic losses. That transport is not more concerning to businesses may reflect how well the freight system currently performs, and the assumption that this efficiency will continue into the future.

4.5.2 Motivations for car ownership

There are many practical reasons for owning a car. Ownership provides on-demand, door-to-door mobility, offering a flexibility unmatched by other modes of transport. This leads to a rise in travel: on average, car drivers make more trips, spend more time travelling and cover longer trip distances, trends which extend to non-driving members of car-owning households. Overall mobility choices can also be directly attributed to levels of car ownership, for example by reducing the propensity to cycle to work (Parkin et al., 2008) or to travel by bus (Paulley et al., 2006).

Segmentation studies find that a significant subset of car owners retain a very strong psychological attachment to their vehicle (Anable, 2005; Thornton et al., 2011). Psychological motives and social factors (see Section 4.3) are relatively less important in future travel choices, meaning that practical motives remain dominant. As an example, young people are driving less, predominantly for practical reasons. They still tend to regard cars as necessary to access jobs, training and services, but they do not particularly value the perceived autonomy, status or prestige that car ownership is thought to offer (Green et al., 2018).

Car ownership is also influenced by socio-economic characteristics, such as life stage and income. These influence where people choose to live, and therefore the type of built environment within which transport choices are made. Car ownership can be explained, therefore, as either an aspect of travel behaviour or as a variable that explains other travel behaviour (Van Acker and Witlox, 2010). For instance, choosing to travel by car may relate directly to its availability, but choosing to buy a car may relate to wider reasons for accessibility which would otherwise be unmet.

The availability of parking spaces, both at home and at destinations such as workplaces and town centres, alongside parking charges, further influences choices about whether to drive, or even whether to own a car in the first place (Marsden, 2014).

4.6 Managing the transport system more effectively

The transport system responds dynamically to change. Interventions that increase the supply of transport options, or that reduce demand, may not be effective in the medium term unless there are measures to ensure that benefits are maintained or 'locked in'. For example, building new roads to reduce congestion may have positive impacts in the short-to-medium term, and economic prosperity is likely to improve initially. However, these changes will not be effective unless there are also measures to reduce car use, otherwise the new roads will simply fill up.

Given the growing, changing and often competing needs that users place on the UK's transport system, it is clear that improvements need to be made to the system as a whole. There are a number of ways in which this can be achieved, all of which are likely to be required in an integrated, complementary set of improvements over time. Broadly, these can be categorised as making better use of the transport infrastructure, and managing demand better.

4.6.1 Better use of the transport infrastructure

Using infrastructure better requires making value judgements about what 'better' means. It could refer to optimising passenger flows, making freight movements more reliable, increasing economic impact, or achieving health, environmental or social outcomes. Another question is: better for whom? People have different, often conflicting, priorities for freight, bus, rail and car; these vary between companies and individuals, the poorest and the richest, and between walkers, cyclists and other vehicle users. There is limited road and kerb space, and the 'best' allocation is contested. These different value judgements and priorities lead to divergent views about what is best for an area, and consequently different regulatory and spending choices.

One major strain on the UK's transport infrastructure is peak travel demand, when the most people are using the system. This varies with time, season and geography, but generally corresponds to morning and evening rush hours. For roads, 7.00-9.00 am and 3.00-7.00 pm are the busiest for car traffic. HGV use rises from 5.00 am and is then broadly steady throughout the

Early-warning signs for road maintenance

A pilot study funded by the Department for Transport, in partnership with York, Wiltshire and Thurrock councils, uses existing council services to monitor the condition of the road network. High-definition cameras are attached to refuse collection vehicles, buses and highway inspectors' vans. As they travel, images of the road surface are collected, then downloaded and automatically analysed. Software highlights areas of concern (e.g. cracks and potholes) to be examined in more detail. This allows problems to be identified and addressed before they get worse.

The system is effective at the local level; for example, refuse-collection vehicles travel along most roads, enabling regular coverage of the local road network. Earlier maintenance is also much cheaper, so this approach saves money for local authorities while improving road conditions – which benefits all road users (Browne, 2017).

Safe track monitoring for rail infrastructure

Network Rail uses Plain Line Pattern Recognition (a high speed video inspection system). This uses laser technology to capture images every 0.8 mm at up to 125 mph on plain line continuous welded rail. This replaces basic visual inspection (track walking). It has been used on over 14,000 miles of track. The PLPR system increases understanding of track condition, giving consistent high-quality measures. This information gives benefits in terms of safety and detailed track status for the whole network.

In addition, earlier maintenance is cheaper, saving money for Network Rail, thus benefitting rail users and funders. Between 2014 and 2019, it is estimated, this will save £4.1 million. PLPR is part of a range of R&D projects that Network Rail predict will achieve £900 million of benefits to asset management over 15 years (Network Rail, 2018).

day; it is also more consistent than car traffic throughout the week (Department for Transport, 2017, TRA0308). Locally, it can be affected by factors such as school start and finish times, while holiday seasons, bank holidays, weekend trips and good weather all produce peak travel flows to different parts of the country (e.g. the South West).

One way to optimise the use of the road network is to ensure that as much of it as possible is always in a good state of repair. Not only do good road surfaces improve journey times, they can also reduce maintenance costs of infrastructure and vehicles.

4.6.2 Managing demand

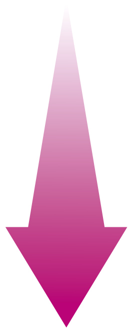
Alongside measures to optimise the use of transport infrastructure, managing transport demand is essential. Demand management covers a spectrum of actions that require, to differing degrees, explicit interventions in travellers' behaviour, as Figure 4.8 shows. At its simplest, demand management involves

Figure 4.8 The spectrum of demand management

Action

- Provide information, e.g. online bus and rail timetables
- Market the business benefits of a shift in transport demand to employers
- Comprehensive programmes with mutually reinforcing services, e.g. public transport, carpools/vanpools, promote cycling and walking, ticket/travel purchase schemes, advice centres
- Offer incentives for switching to alternative modes of transport
- Create disincentives for driving, e.g. limit parking supply, increase parking pricing, road tolls, congestion charges
- Implement laws and planning, and development conditions
- Put a cap on trips or introduce minimum average vehicle occupancy goals

Increasing influence on shaping demand



Source: adapted from Mobility Lab, 2016

Managing demand through gamification

In the **Incentives for Singapore Commuters programme**, participants receive personalised travel plans with encouraged times. For each shift they make to off-peak travel, they receive a cash reward. If they are already travelling at the ideal time, they receive points that can either be used to play a computer game with rewards and cash prizes, or converted into money. Companies can also play for prizes in special draws (Singapore Land Transport Authority, 2018). The scheme shifted demand from peak times to off-peak times by 9-12% (Moraillon and Brick, 2014).

In Reading, **Beat the Street** gamifies walking and cycling. People scan or 'tap' a card or key fob onto 'Beat Box' scanners located around the town to show they have walked to the boxes. The goal is to walk a target number of miles and earn points that add up to prizes for local groups. This scheme increased people's physical activity by 8% (Reading Council, 2015).

In Australia, the **Brisbane Active School Travel programme**, which ended in 2017, saw over 50% of students actively travelling to school, and schools saw an average 23% increase in active travel. This was achieved by the Brisbane City Council working with schools to agree walking routes and to provide bike and scooter skills training, among other initiatives. It included a ramped progression game through which students could obtain rewards and public recognition for active travel (Brisbane Government, 2018).

The **Speed Camera Lottery** in Sweden saw speed cameras installed and fines collected as usual – but a proportion of the fines were given at random to drivers who did not speed. During a very short pilot scheme, there was a 22% decrease in speed (Haggarty, 2010).

providing information and incentives to help people make optimal mobility decisions (Mobility Lab, 2016). At a deeper level, it involves introducing compulsory measures (e.g. a cap on trips) so that alternatives to driving are encouraged. Many areas adopt some policies to shape transport demand, but few do so in an integrated way.

Effective demand management considers the decision-making processes of all transport users and how they interact with technology (see Section 4.6.3). It also involves making value judgements about what counts as acceptable and unacceptable demand. These are context- and geography-specific judgements, and the following sections present some techniques that have successfully changed the nature of transport demand, in the UK and elsewhere.

4.6.3 Managing demand through soft approaches

Softer options include gamification, which means using elements of gameplay to encourage particular behaviours in non-game contexts. Other options focus on changing accessibility, and hence the need for mobility, through measures such as providing online services, as the National Health Service has done (NHS, 2016), or through encouraging telecommuting and home-based or flexible working. For frequent flexible workers, the average commuting mileage is significantly smaller, although they usually make extra trips, eroding around 10-20% of this saved mileage (MVA Consultancy, 2013). Flexible working is commonest for office jobs and managerial roles. For more practical roles, it is harder to work from home or be flexible. Table 4.1 provides additional examples of soft incentives.

While soft incentives can be effective, they are unlikely to lead to substantial change in travel behaviour unless they are accompanied by hard factors, such as those listed in Table 4.2.

Table 4.1 Soft factors to encourage modal shift (by passengers)

Initiative	Mechanism
	Improve the alternatives
Facility and site improvements	• Lockers, showers and changing facilities at workplaces and educational establishments
Regulatory measures	• Encouragement for innovation, competition, diversity and efficiency in public transport regulation
	Management and administration
Institutional support, including school and workplace travel plans	• Incentives for individuals and groups that encourage alternatives to cars • Individual travel plans
Financial incentives	• Public transport subsidies that match or exceed any car subsidies, such as the provision of workplace parking • Charge employees for workplace parking
Alternative work schedules	• Fit work schedules to public transport availability
Support for public transport users	• Guarantee emergency rides home for public transport users • Pool cars and vans for business use when public transport cannot be used
	Technology, information and marketing
Electronic communications	• Modify trip patterns, e.g. as a result of public transport information • Improve home-/flexi-working software and hardware
Intelligent transport systems	• Manage system operations and capacity to prioritise efficient travel
Business and marketing	• Improve public transport information • Special event management that encourages high-quality, competitive public transport and ticketing provision, e.g. for football matches, concerts, conferences • Manage tourist travel with flexible integrated public transport ticket options
Public transport information	• Target public transport information where it is most useful
Gamification	• Encourage particular behaviour and offer rewards

Source: based on Derek Halden Consultancy, 2003

Table 4.2 Hard factors to encourage a modal shift in travel behaviour (by passengers)

Initiative	Mechanism
	Improve the alternatives
Infrastructure changes	• Upgrade stations, build new bus shelters, improve waiting areas • Improve walking and cycling routes and facilities • Reallocate road space from cars to other modes of transport • Design new infrastructure that facilitates safe use by all road users, including children, disabled people and the elderly
Service changes	• Provide more frequent, reliable and cheaper public transport services with improved integration between modes (e.g. buses and trains) • Supply higher-quality public transport vehicles • Reduce public transport fares
Park-and-ride sites and services	• Facilitate public transport use for parts of journeys to avoid congested roads, or to reduce traffic in areas with limited parking
Improve choice through land-use planning	• Ensure new developments have high-quality public transport links • Design places and transport options so that intensive transport users can reach public transport hubs more easily • Use mixed-use development to open up short trip options • Plan car-free housing developments
	Make car travel less attractive
Road-user charges and taxes	• Vary tariffs by time of day and day of the week • Vary tax and insurance based on vehicle mileage
Parking charges and taxes	• Introduce wider charges for parking, and controls on workplace parking
Infrastructure	• Limit the supply of road space in key locations • Limit the supply of parking
Network management	• Reduce speed limits and increase the enforcement of these in urban areas • Introduce traffic-calming measures, such as traffic mazes and traffic cells • Adapt traffic signal timings to favour non-car modes of transport

Source: based on Derek Halden Consultancy, 2003

4.6.4 Managing demand through hard approaches: pricing

Having identified some hard and soft options to change user behaviour, this report now considers the impact of pricing, a hard measure commonly used to manage demand. There are many areas of life in which the same service costs more at different times and in different locations, such as hotels, flights or car rental. In others, the acceptance of pricing depends on the prevalent norms, and changing these can have implications for equality. Case study 'Managing demand through parking pricing' describes two innovative approaches to managing demand through the pricing of car parking, while case study 'Managing demand through road pricing' provides examples of how road pricing, a major approach to managing transport demand, can work in practice.

When effective, road pricing means that high traffic levels are never reached, mitigating the effects of congestion (in terms of delays) during peak

Managing demand through parking pricing

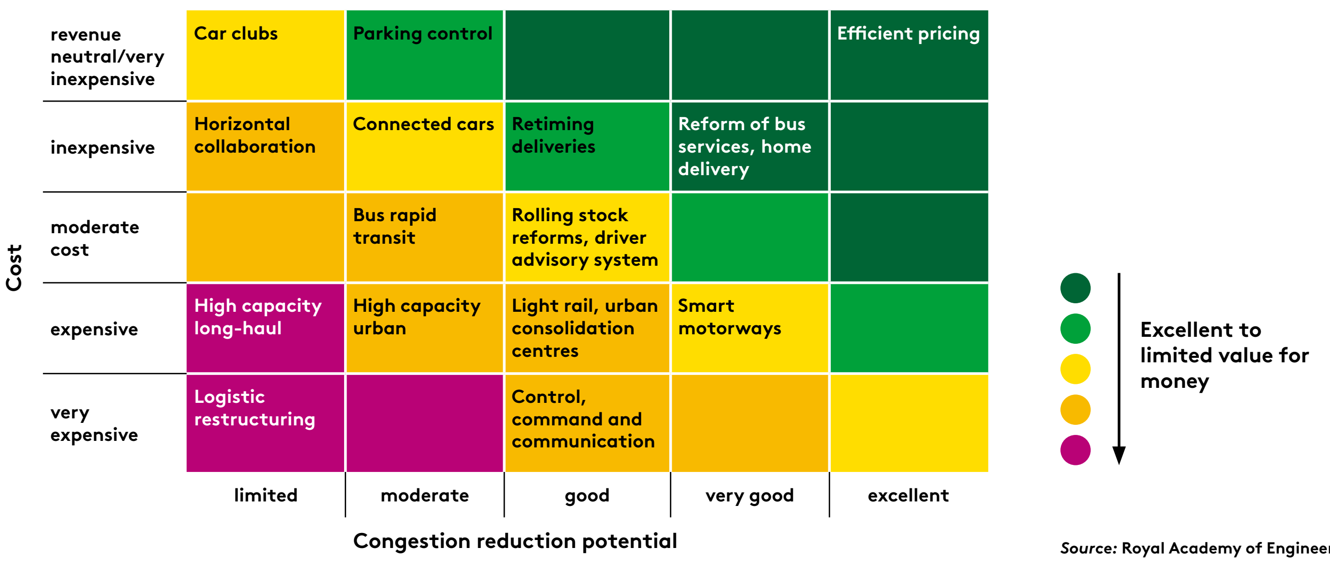
In Nottingham, a **workplace parking-levy scheme** introduced a charge to businesses for each parking space. This reduced the number of employees travelling to work by car and raised £9.3 million in charges in 2015/16, which was reinvested in public transport improvements. Overall, this led to a decline in car miles and a rise in the city's share of public transport to over 40% of all journeys made (Local Government Association, 2017).

The **SFpark scheme** in San Francisco, USA, aims to make it easier to find a parking space. It uses a dynamic pricing system to ensure that some space is always available on every block and in every car park (San Francisco Municipal Transit Authority, 2014). Through technology, prices are automatically increased or reduced depending on demand. The optimal occupancy for any street that can be parked on is 85% (Shoup, 2011), which means people looking for a space can find one quickly – without adding to circulating traffic. Overall, the pilot scheme decreased the distance travelled by vehicles in the San Francisco area by 30% (San Francisco Municipal Transit Authority, 2014).

hours by 'knocking' traffic into off-peak periods. Eddington (2006) stated that road pricing could bring the UK benefits totalling £28 billion a year by 2025, and lead to a halving of congestion. Most transport academics view road pricing as the best tool to allow externalities to be priced into the system and to tackle congestion (Royal Academy of Engineering, 2015).

Figure 4.9 shows that road pricing has low cost and high potential to reduce congestion, compared with other potential measures.

Figure 4.9 Congestion-reduction measures and their value for money



Source: Royal Academy of Engineering, 2015

Managing demand through road pricing

Variably priced lanes as part of a wider road network are one approach to road pricing. Since 1998, the Interstate 15 highway in San Diego, USA, has had a 'high vehicle occupancy' toll lane. Single-occupant vehicles have to pay a fee each time they use this lane. Prices vary in real time, depending on the traffic demand in the lane. They can change every six minutes, with prices rising or falling by US$0.25. Over eight years, this scheme increased the number of carpools in the region by 50%.

On State Route 91 in Orange County, USA, each express lane is variably priced. They carry twice as many vehicles per lane as the free lanes during peak rush hour. Pricing has also allowed twice as many vehicles to be served per lane, at three to four times the speed of the free lanes (US DoT Federal Highway Administration, 2018). Other variable-pricing approaches include discounts for using a bridge during off-peak periods, or if paying electronically.

Congestion charges for entering a particular area are another approach to road pricing. Well-known examples include London, Milan, Singapore and Stockholm, but this can also be effective in smaller cities: Gothenberg experienced a 12% reduction in traffic during charged hours within a year of introducing the scheme.

Currently, automobile users are subsided by society: they cause more harm to society than they pay for in vehicle and fuel duty (Cabinet Office, 2009). Road pricing offers an opportunity to address this. It also allows demand to be dynamically shaped, for example by potentially being used to incentivise more socially or environmentally friendly travel options, such as car-sharing.

Road pricing is not always a popular approach, though, and it is unclear if it is equitable for all socio-economic groups of road users (Royal Automobile Club, 2011). High prices could penalise those on low incomes, or those who do not have flexibility in when they travel. Combining pricing with other measures could create a system of incentives that make it more acceptable to the general public. Despite this, public support for all major congestion-charging schemes has risen over time, wherever they are introduced; a substantial majority of people are in favour of these once they see their efficacy (Hensher and Li, 2013).

Pricing is not only useful for private vehicle use: it can also effectively manage demand for freight. Freight deliveries in some urban areas are not allowed at night, due to the noise that freight vehicles produce, but this leads to deliveries contributing to congestion during the day. Noise levels can, however, be measured and judged for acceptability, to determine if night-time deliveries are acceptable. The Netherlands has a noise-certification scheme

Managing demand through shifts in delivery times

NYC deliverEASE, a programme in New York City, USA, offered US$2,000 to large companies that make many deliveries (e.g. Whole Foods and CVS) to switch their deliveries to off-peak times. This was effective, but it proved impractical to expand the scheme to pay every business (Grabar, 2013). However, this approach could be trialled in the UK, with targets including universities, supermarkets, hospitals and shopping centres.

In a similar scheme, Long Beach and Los Angeles, two of the busiest ports in the USA, started charging a fee of US$40 for moving a 20-foot equivalent unit during peak hours from April 2006 (Sánchez-Díaz et al., 2017).

involving low-noise practices, with equipment and measuring standards to ensure operation is below 60 dBA (Goevaers, 2011).

Shifts to off-peak deliveries can be encouraged through pricing as well, as two USA examples show. However, a small charge, which is often only a tiny fraction of the total load value and shipping cost, may be insufficient to significantly change hauliers' behaviour. Often, a haulier is constrained by external factors, such as the behaviour of the shipper/receiver. A small charge may not be enough to persuade them to ask the receiver to accept off-peak deliveries (Holguín-Veras, 2008).

4.6.5 Managing demand through hard approaches: reassigning road space

Pricing is not the only 'hard' option available to transport planners. Others include reassigning road space for certain users, such as separate lanes for cycles, buses and trams, or high-occupancy car lanes. These require greater intervention, but do not have to be accompanied by price incentives; people may have different motivations for supporting and using these.

These approaches often seek to make optimal use of the available road space by replacing cars with more efficient modes of transport. Regardless of demand or users' preferences, cars with one or two occupants are a spatially- and energy-inefficient way of moving people about in urban areas. Figure 4.10 illustrates the equivalent road space required to move 69 people by bus, car and bicycle.

Measures such as carpools and ride-sharing should slightly decrease the number of cars in urban areas. Similarly, autonomous vehicles that can be shared are expected to slightly decrease the number of cars, in the short term. Once autonomous vehicles are widespread, it is possible that they can be designed to be much smaller. However, the most efficient use of road space at present is pedestrians, then mass transit systems including buses, light rail or cycles; private cars are the least efficient use of urban space. Figure 4.11 reiterates this point, showing how mixed traffic is not a spatially efficient way to move people in a city.

Figure 4.10 **Road space needed to transport 69 people using 1 bus, 69 bicycles and 60 cars**

Source: We Ride Australia

To achieve such a shift away from cars, it is necessary to prioritise the needs of the users of the most efficient modes of transport. Such a user hierarchy, which puts pedestrians and cyclists at the top, is recommended in the Chartered Institute of Highways and Transportation's (2010) *Manual for Streets 2*.

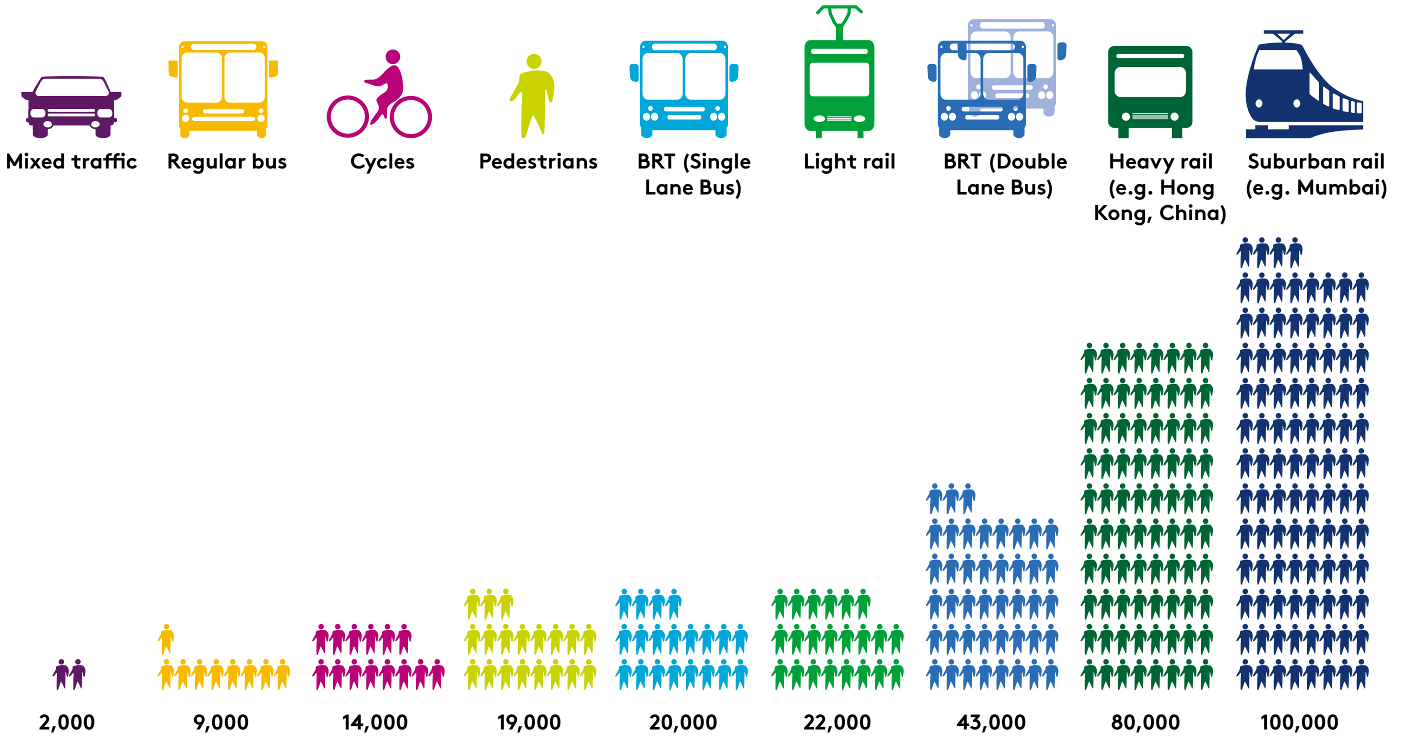
There are well-known examples of how to make urban areas more environmentally, socially and equitably sustainable in terms of their transport infrastructure. Cities such as Amsterdam and Copenhagen have demonstrated how to create economically vibrant spaces by consistently prioritising pedestrians and cyclists in planning and investment choices. As a consequence,

Managing demand by promoting walking and cycling

Barcelona, Spain, is reducing emissions by constraining car use while promoting cycling and pedestrian-friendly neighbourhoods. The city is creating 'superblocks' by joining blocks to create small neighbourhood areas that are then repurposed as dedicated pedestrian and cycling public spaces. Higher-speed traffic and public transport have to go around the outside.

The reclaimed spaces are improving community cohesion, in turn creating incentives to switch from cars to walking and cycling. Barcelona estimates this approach will reduce congestion by 21% in two years. In the Gràcia neighbourhood, cycling trips have already increased by 30%, and driving reduced by 26% (Brass, 2017). This approach is also proving to be inexpensive.

Figure 4.11 Number of people per hour on 3.5 metre lane, by mode



BRT = bus rapid transit

Source: Hickman et al., 2011

they have reaped considerable health, environmental, social and economic benefits (Aguib and Al Suwaidi, 2015; Fishman et al., 2015). This highlights the importance of focusing on people rather than vehicles when designing places, and infrastructure. Case study 'Managing demand by promoting walking and cycling' looks at the approaches being applied in Barcelona.

4.7 Achieving a modal shift

To achieve a modal shift in transport demand, it is important to understand the psychology of the user in the system, the incentives they face, and how these might change in the face of new technologies. As noted, travel behaviour has been strongly shaped by changes outside transport, such as the cost and location of housing and the changing nature of shopping, work and leisure. Once shaped by these external factors, most personal travel behaviour is then habitual (see Section 4.3) and fits into a wider set of lifestyle decisions, with different time frames and windows of opportunity.

As a result, achieving a shift is challenging. For example, benefits from using public transport accrue over time, and even the short-term impacts of reduced public transport prices or better service frequency can take 5-7 years to become evident (Goodwin, 1992; Derek Halden Consultancy, 2003). This is due to the time needed for information about the service to be shared and

A modal shift through behaviour change and transport infrastructure

After the construction of the M74 extension in Glasgow, car use and car ownership increased in the area (Foley et al., 2017). Conversely, in Cambridge, a new guided busway with a parallel pedestrian and cycle path led to increased walking and cycling – and lower car use (Heinen et al., 2015). Both studies provide evidence of how the choice of transport infrastructure investment can affect and change habitual behaviour.

understood, but also due to structural factors, such as where people choose to live and work.

Shifts in demand can be driven by companies. Many companies already have travel plans that actively shape their workers' travel demand. In a series of case studies of companies with travel plans, the median average change was a 15% reduction in commuter journeys and 12 fewer cars per 100 staff. A few cases achieved reductions in commuter journeys of more than one-fifth, with two companies achieving over 50% reductions (Cairns et al., 2002).

Such plans usually use a mixture of positive and negative incentives. Examples include charging for parking, paying people to walk or cycle, improving parking spaces for bikes, providing showers and locker storage (for cyclists), and setting up private shuttle buses. The amounts that companies spend on travel planning per employee vary considerably: the median figure in 2002 was £47, significantly cheaper than the £300-500 annual cost of running a parking space (Cairns et al., 2002). Demand shift also depends on the local cost of living, as land and house prices are key factors in determining how near people can afford to live to their workplace, and thus how feasible walking or cycling are as commuting options.

As well as companies, other external stimuli can lead to shifts in travel behaviour. Case study 'A modal shift through behaviour change and transport infrastructure' highlights how the type of transport infrastructure built can shift behaviour.

While some individuals and companies do make 'green' travel choices, and there are some ways to influence behaviour, the overall trend is that unchecked freedom of choice leads to travel behaviour that is best for the individual or group, rather than for the system. For example, most users will choose car travel if the alternatives (e.g. buses, trams, trains) are not quicker, easier or markedly cheaper.

For any given trip, there may be numerous barriers to shifting to a different mode of transport. Tackling only one or two barriers may have no impact if the others remain: behaviour change is most likely when all barriers have been removed. In light of this, achieving a modal shift is easiest in simple, one-for-one swaps. Trip 'chains' (i.e. the total travel between two places such as home and work, which may include stops for groceries, childcare or entertainment) add to the complexity of switching, as do situations where the car is used for carrying cargo or passengers. Furthermore, barriers to shifting behaviour vary with the type of transport that the user is shifting to; understanding these barriers is essential to achieve a modal shift in travel behaviour.

Car-sharing near rail stations can support integration between modes.

4.7.1 Rail

Research shows that cost is the most important barrier to shifting to rail (Accent, 2009; Stanton et al., 2013). Other constraints include punctuality and reliability, the frequency of trains, and their comfort and cleanliness (Stanton et al., 2013). In addition to personal motivations, there are also practical questions in shifting to rail. The rail network has a limited geographical coverage, and many journeys do not start or end near a rail node. However, people tend to see trains as safer, less stressful and higher status than buses (Thornton et al., 2011).

4.7.2 Bus

Hard factors such as frequency, journey times and cost tend to dominate decision-making regarding bus use. Once these are overcome, soft factors such as real-time information, better-trained drivers and CCTV at bus stops can increase their use (AECOM, 2009).

4.7.3 Car-sharing and lift-sharing

Shared car travel, for example through car clubs, represents a significant change in travel decision-making because it decouples car ownership from car use. Its key attraction is that it apparently offers the best of both worlds – the convenience of a car without the burden of ownership – but it is ultimately a compromise (Kantar Public, 2018). It is not as convenient as having a private car to hand (Golightly et al., 2018) and can be much more expensive on a day-

Opportunities to link clean growth to sustainable transport provision

Picking test cities or towns, and trying to develop 'demand futures' that deliver greener growth and more inclusive cities, could show the value of this approach to housing developers, encouraging a move away from car-dependent planning. Active interventions usually have a high positive cost–benefit ratio of between 1:4 and 1:7. For example, cycling demonstration towns had a cost–benefit ratio of 1:3.5 over ten years, rising to 1:7.8 over 30 years. The Sustainable Travel Towns had a ratio of 1:4.5 on a conservative estimate (Sustrans, 2017b). If taken forward, this would require close cooperation between local authorities and health providers such as Public Health England.

to-day basis. People may also be psychologically attached to car ownership (Belk, 2007; Park and John, 2011), and sharing can mean having to interact with and depend on strangers, whom one might not fully trust (Laurier et al., 2008; Chaube et al., 2010; Nielsen et al., 2015; Hazée et al., 2017).

Fundamentally, the success of shared car travel depends on an effective public transport system that can fill the gaps (Golightly et al., 2018). This is because car-sharing alone might not satisfy all of a household's lifestyle needs. Car clubs are appropriate for maintenance[9] and discretionary trips where there is more flexibility as to when to travel, but less so for mandatory trips such as commuting and school runs. There may also be uncertainty as to whether a car is available when needed: there may not always be enough cars in a car club to satisfy peak demand. This is consistent with evidence that only 3% of car-club trips in London are used for commuting (Steer Davies Gleave, 2017). Car-sharing based around railway stations may support integration between transport modes and increase car-sharing, but depends on the proximity of the vehicle to the station.

Lift-sharing is better suited to commuting because of its predictability and relatively fixed start and end times. It is less useful for shopping or leisure trips, however, which are often taken at short notice. In general, the greatest barriers to sharing lifts with strangers are psychological ones, which can be very high. These are influenced by social norms; for example, hitchhiking (which can be considered as an early form of lift-sharing) was once common, but has declined sharply (Moran, 2009).

4.7.4 Walking and cycling

As stated, methods to increase walking and cycling are well known. Broadly, a mixture of hard and soft incentives is needed, with hard incentives such as separate infrastructure and soft incentives such as the visual interest of the area or route. Many cities accomplish this well; for instance, in Stockholm, the cycling modal share increased from 5 to 9% between 2004 and 2015 in terms of total trips within the region, and from 3 to 9% for trips to or from the city centre over the same period, with bicycles accounting for 11% of commuting trips in 2015. In Stockholm, while not as culturally embedded as in cities such as Copenhagen, cycling is considered integral alongside other sustainable transport modes including walking and public transport (Bastian and Börjesson, 2017).

4.7.5 Switching between road and rail freight

Survey data suggests that customers and service providers perceive it as easier to move freight operations from rail to road than vice versa. Faced with equivalent price increases, both customers and suppliers were more likely to persist with road than rail (Faber Munsell, 2003). Rail freight in the UK is increasing, but compared with road freight, its share has remained broadly consistent over the past 20 years.

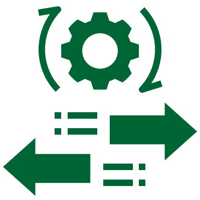
9. Maintenance activities are ones which households do not see as optional (e.g. going to the doctors, food shopping, going to work).

4.8 Mobility-as-a-Service

Mobility-as-a-Service (known as MaaS) is a type of one-stop online interface, comprising an intermodal journey planner, a single payment portal and a booking system for entire end-to-end journeys. Full Mobility-as-a-Service systems integrate multiple modes of transport to provide a single mobility solution. Partial forms include ride-sourcing, route-planning and ticketing apps (Transport Systems Catapult, 2016; Enoch, 2018). Central to the concept is that the overall journey is more important than the mode used, placing the user at the heart. Thus, Mobility-as-a-Service is an example of a user-centric approach to mobility.

Mobility-as-a-Service could provide flexible, tailored mobility with minimal cost, and travel times based on actual conditions at any given time. Its service model could support a move away from car ownership, potentially reducing congestion. It could also provide the data and control for local transport authorities to optimise transport system management (Transport Systems Catapult, 2016). For the user, the option of on-demand travel with real-time information could remove problems encountered when changing between modes, and optimisation of the last mile. It may also create new opportunities in rural areas to run services that are more commercially viable and deliver more affordable mobility to users (KPMG, 2017).

There are indications that Mobility-as-a-Service can have positive impacts on public transport services and active modes, removing private vehicles from roads (UCL, 2018). It is most viable in areas of high population density, where scaling up is more likely and commercial returns are higher. Whim, a Mobility-as-a-Service app run by Mobility-as-a-Service Global, is currently available in the West Midlands and offers packages covering public transport, taxi-share, car-share and bike-share services (Metro Report, 2018). Trials have also been run in cities around the world (e.g. Helsinki) with various degrees of success. Most small-scale Mobility-as-a-Service pilots internationally have been unable to scale up.

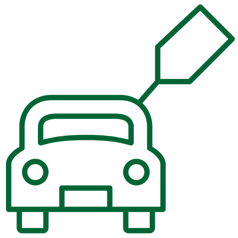


Mobility-as-a-Service can encourage use of public transport services and active modes.

Mobility-as-a-Service is still at an early stage of development. Its cost and scalability, and who will develop it, are unknown. The aspects of Mobility-as-a-Service that are made available will be shaped by market conditions. The extent to which users will want to shift from an ownership to a service model is also unknown (Transport Systems Catapult, 2016).

Mobility-as-a-Service is technologically feasible but requires altering well-established financial and organisational structures and systems, and co-ordination across public and private transport operators, as well as differing regulations (Karlsson, 2016; Enoch, 2018). Prerequisites include open access to transport data, standards and real-time information (MaaS Alliance, 2017). Achieving the required data-sharing practices between different stakeholders in any Mobility-as-a-Service ecosystem will pose a significant challenge. Governments can be active in determining data use and in compelling operators to share data, for example through the Bus Services Act 2017 (Department for Transport, 2018l).

Full Mobility-as-a-Service would allow smooth integration of transport modes and providers, while partial forms can enable limited integration, for example between just bus and light rail services. Some integration already exists. For example, Citymapper provides end-to-end journey planning, but it is limited to cities and does not offer a payment platform. Digital ticketing (e.g. Oyster) is another form of integration, which can encourage the use of different modes of transport, while also providing data to maximise the efficiency of the service (Enoch, 2018).



The 'sunk' costs associated with car use are often not factored into decision-making processes.

Depending on how Mobility-as-a-Service is set up, smaller or shared vehicles (e.g. car clubs, transportation network companies, private-hire vehicles) could be preferred over public transport, potentially worsening congestion. There are also risks around exclusion: Mobility-as-a-Service could price out the poorest or rural transport users, or digital interfaces may not be appropriately designed for older or visually impaired users.

4.9 Going forward

Users of transport systems respond to the incentives they perceive for using certain modes of transport. The culture of car dependency emerged because of these incentives. These perceptions are important, and car dependence is likely to continue for most people because of them (i.e. the car is not only cheaper than public transport, but also deemed superior). Many costs associated with car use are also 'sunk', and not always factored into decision-making processes.

This has implications for making a modal shift to new or alternative transport services. There are also opportunities, for example for Mobility-as-a-Service, where the costs of all modes of travel can be presented clearly to the user (and not hidden, as the sunk costs of car travel are). This could help to challenge, even change, long-standing perceptions.

Behavioural shifts that change demand are unlikely to be significant if driven solely by soft options, though. Soft options clearly have an impact, but to effect significant change, they need to be combined with harder options such as investments in services or infrastructure. The choice as to which demand-management options are optimal may change out to 2040, but the underlying principals will persist (Figure 4.8).

Looking at all modes of transport within a broader region allows decision-makers to take a more holistic approach to demand management. As highlighted, practical motives are likely to gain in importance moving forward to 2040, and the growing importance of practical motives in decision-making highlights the importance of transport and land-use planning (i.e. ensuring transport nodes are accessible to where people live and work).

Inclusive design approaches can improve life for all travellers, not only those who they specifically target. Historical examples of this in the transport sector include dropped kerbs, more intuitive machine interfaces, and access for the mobility impaired, all of which have helped travellers much more broadly than the target group. As the UK's population ages, increasing older people's mobility and access to public transport is likely to have a number of positive effects, on their physical and mental well-being as well as the wider community (Holley-Moore and Creighton, 2015).

Ideally, this kind of citizen-focused approach should be used for designing new apps for mobility services. Operational transport decisions, however, often reflect the challenge of balancing competing spending priorities and values. Most decisions (implicitly) favour one geography, or one social or traveller group, over another. Similarly, the best economic, social or environmental outcomes may differ from those arising from unconstrained individual choice.

In terms of achieving a shift in freight transport behaviour, pricing incentives will generally be too small to change the delivery time at which a receiver accepts a shipment of goods. And, while many companies are interested in environmental best practice, many fail to make actual changes to how they operate. In a similar vein, shared car travel (lift-sharing) is often viewed as a coming transformative innovation due to its environmental benefits. Yet although its numbers are expanding, it is likely to remain a niche choice because sharing is still broadly viewed as inferior to ownership.

Mobility-as-a-Service is promising, but at an early stage of development. The ability to align private and public stakeholders, in terms of both goals and funding, combined with the ability to shift individual behaviour away from car dependence, is as yet unknown: all of the early Mobility-as-a-Service pilots lost money and failed to scale up (Enoch, 2018). It will be worth watching ongoing pilots (e.g. Whim in the West Midlands and Helsinki, and the Rural Mobility-as-a-Service pilot in Scotland) to see if their business models can be made to work. In theory, the move away from focusing on transport type, and towards increased consideration of end-to-end journeys, could be transformative.

Historically, new transport technologies have always had both positive and negative impacts, though government has intervened to regulate and mitigate some of the negative impacts. Examples include the growth of railways, automobility and aviation. Emerging technologies are exciting, but their impacts are uncertain. Scenarios thinking (see Chapter 6) is one approach that helps to consider this uncertainty.

Two changes that will have an impact on the whole transport system are electrification and automation. By 2040, vehicle electrification will have had a positive impact on car/van exhaust-pipe emissions, while electric and hybrid aircraft have the potential to reduce aviation emissions. In July 2018, it was announced that £343 million will be invested by government and industry into researching these technologies (Department for Transport, 2018m). Automation could plausibly challenge the transport system status quo from the 2030s onwards, for trains and buses but also, potentially, for private car-based transport. If automation makes door-to-door travel easier and cheaper, it may well decrease the incentives for active modes of travel, increasing the time people spend in sedentary activities – and thus worsening health outcomes.

E-bikes are one technology that, if adopted, could shape parts of the transport system, and their health implications will depend on usage. They

Shared car travel is likely to remain a niche choice until 2040.

could reasonably replace a car for many trips under ten miles. If the electric motor is used instead of pedalling, then they will have little health impact. Conversely, if they are mostly pedalled, with the motor occasionally used (e.g. on steep hills, with lots of shopping), then e-bikes will have a much more positive impact on health.

Policy implications

- **Travel behaviour can be managed and shaped through both technical and behavioural interventions.** Softer factors (e.g. nudging, personal travel plans, incentives) only have a limited effect in shaping travel behaviour; harder changes (e.g. assigning road space) are also necessary to achieve the scale of change required. Policy-makers need to understand the barriers to change, and people's willingness to change. This is essential to promote behaviour shifts.
- **A range of tools are available for demand management.** These can tackle challenges such as congestion and encourage use of sustainable transport modes. Road pricing is just one of these tools and may achieve desirable outcomes when implemented alongside a suite of demand-management measures.
- **Decision-makers need to make judgements about which journey types to favour in transport policy and funding.** Should the focus be on the needs of the poorest? Those in rural areas? Active modes over automobility? Freight over passengers? Economic gain over social and environmental harm? The metrics used to make these decisions will inevitably favour some groups over others.
- **Passengers' travel choices are insufficiently understood.** Behaviour often results from external factors rather than individual choice. There is a need to better understand the impacts and drivers of change to inform policy development. This is especially important if government wishes to markedly shift user behaviour, for example to Mobility-as-a-Service or more shared transport.
- **Car-sharing can reduce travel distance and possibly car ownership.** Integrating sharing with other transport modes is likely to increase its uptake, but station-based car-sharing will depend on the autonomy and proximity of stations. 'Free-floating' car-sharing and shared self-driving vehicles can help to resolve these problems, but might also encourage car use.
- **Focusing on people rather than vehicles**, helps design better spaces, and is a more technology agnostic approach.


APOSTOLOS
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UKAutodrive
.com
UKAutodrive
.com
AURRIGO
DRIVERLESS TECHNOLOGY
pod
04
POD ZERO

The future of the transport system

Key findings

- The current impacts of intersecting physical and digital technologies are unprecedented. Looking towards 2040, better data and connectivity will provide the basis for new transport modes and support a better, more integrated transport system (Section 5.2).
- There are clear benefits and savings to be made from data being shared safely between transport planners, operators and users. As private sector interests increase, issues of data privacy and sharing are becoming more important (Section 5.2).
- Electrification of transport modes is predicted to increase sharply from the mid-2020s onwards. Currently, it is most feasible for lighter vehicles, such as cycles, cars and vans (Section 5.1).
- Decarbonising road freight will be important in reducing carbon emissions from the transport sector. However, this is a significant challenge due to these vehicles' size and weight, and the distances they travel (Section 5.4).
- The freight industry has established freight-sharing practices and new business models that offer improved efficiencies and connectivity between suppliers and customers. Increased data use and the restructuring of supply chains are helping to drive this shift towards more sharing of resources (Section 5.4).
- Automation offers exciting opportunities, such as improved road safety, cheaper public transport and accessibility for people whose mobility is impaired. However, the time frames for this and other new technologies are unclear, and their impacts highly uncertain (Section 5.5).

£90-130 million

annual economic gain from Transport for London using open data

67%

reduction in CO_2 emissions from using electric vehicles (Gnewt Cargo)

40%

of riders in the Netherlands use e-bikes instead of cars

40%

potential cost reduction from switching to autonomous HGVs

The transport sector is changing fast. This chapter examines emerging trends, connectivity, and automation. It discusses the new technologies and business models that are shaping the transport sector, especially freight, before considering when these and other future technologies might become a reality, and how government can help to shape our future transport system.

Box 5.1

Electric planes

Vehicle electrification extends beyond cars. Current developments in electric and hybrid aircraft include those being developed by Airbus and Rolls-Royce, and the Siemens E-Fan X hybrid concept, which is due to fly in 2020. These technologies could help to reduce the environmental impact of aviation by reducing emissions (Airbus, 2017). This would contribute to the environmental goals of the European Commission's Flightpath 2050 Vision for Aviation, which include reducing CO_2 emissions from aviation by 75%, reducing nitrogen oxides (NO_x) emissions by 90%, and reducing noise by 65% (European Commission, 2011; Rutherford, 2011).

5.1 Electrification

One major way in which the transport sector is changing is electrification. This is a global trend; internationally, CO_2 reduction and regulations are driving electrification. In the UK, sales of battery electric and plug-in hybrid electric vehicles increased to 2.4% of all new vehicle sales in the year to October 2018 (SMMT, 2018).

This growth is, in part, driven by falling costs for electric vehicles. Between 2010 and 2017, the average cost of a lithium-ion battery, which many electric vehicles use, fell from US$1,000/kWh to US$209/kWh (BNEF, 2018). As costs fall further – with forecast prices as low as US$73/kWh by 2030 (BNEF, 2017a) – they are likely to become even more attractive. Owing to high purchase costs, total ownership costs for electric cars are still higher than for fossil fuel-powered cars, but parity is predicted to be reached in Europe by 2023-25 (Palmer et al., 2017) or 2025-29 (BNEF, 2017b). The growth is also contingent on policy.

The energy density of electric vehicle batteries has also improved, by 5-7% per year between 2010 and 2017 (BNEF, 2018). This trend is expected to further increase their mileage range (Berckmans et al., 2017). Charging infrastructure is also becoming more widely available, and by the mid- to late-2020s, range and charging anxiety are expected to be less of a concern – and electric vehicle sales are expected to accelerate sharply. Lower taxes for these vehicles are also driving their uptake. Ensuring sufficient grid capacity, through smart demand management or appropriate infrastructure, will be another issue in relation to their wider uptake.

One attraction of electric vehicles is their environmental benefits. For example, the increased use of electric vehicles will decrease exhaust emissions (a major pollutant from vehicles) and improve air quality. Innovation notwithstanding, non-exhaust emissions will likely continue, however, even if the whole passenger fleet becomes electric. Non-exhaust particulate matter emissions (e.g. tyre wear, brake wear and road dust resuspension) account for approximately 50-60% of the vehicle emissions that contribute to poor air quality (Grigoratos and Martini, 2014; National Atmospheric Emissions Inventory, 2018).

Electric cycles

Electric cycles, or e-bikes, are the largest-selling electric vehicle in the world. Many bike-share schemes have added e-bikes to their offering. These range from Copenhagen and Madrid in 2014, and more recently Brighton, Exeter, Lisbon, San Francisco, Shanghai and Washington DC (Clark, 2018; Thompson, 2018). They are already bringing environmental benefits. In the Netherlands, 40% of e-cyclists use their e-bikes for journeys they previously took by car (Economist, 2018a).

E-bikes are better suited to shorter journeys. In England, 24% of journeys are under two miles, 56% under five miles, and 77% under ten miles (Department for Transport, 2018, NTS0308), which suggests there is considerable potential for their increased use. One barrier is cost: currently, e-bikes cost significantly more than standard bikes, but they will become cheaper as battery costs continue to fall and sales increase, leading to cheaper production through economies of scale.

E-bikes therefore offer a plausible future alternative for shorter journeys. If the electric motor is used constantly, then their health benefits are limited but they remain more energy efficient than cars. If mostly pedalled, then the health benefits will be much more pronounced.

E-bike uptake can be enabled through measures such as clear legislation for permitted bike classes, speed limits, clear permits for electric charging, and sharing data on demand with city transport planners. Safe and separate cycling infrastructure is another fundamental factor behind realising the full potential of e-bikes, and of cycling more widely.

Understanding user behaviour is key. Parkin et al. (2008) showed that car ownership, higher traffic volumes and hilliness all reduce the likelihood of people cycling to work, while a greater proportion of the route being off-road had a positive effect. E-bikes largely remove the challenge of cycling up hills, making them a more attractive option for many than traditional cycles.

24%

of journeys in England are under two miles.

The extent to which electric vehicles decarbonise the transport sector depends on how their electricity is generated. The UK electricity grid has decarbonised significantly in recent years, with increasing amounts of wind and solar power, and decreasing generation from coal. In 2017, the carbon intensity of UK electricity was approximately 266 grams of CO_2 per kilowatt hour (gCO_2/kWh), excluding some decentralised generation; under the National Grid's 'Two Degrees' scenario, this falls to 48 gCO_2/kWh by 2030 and 20 gCO_2/kWh by 2050 (National Grid, 2018).

An increasing number of smaller electric vehicles are arriving on the market. These include electric cycles (e-bikes), e-scooters (Box 5.2), pedelecs and boost boards. There are many advantages to these vehicles. They take up less road space, are less polluting and require lower-cost infrastructure than cars or buses. They are suitable for conurbations, cities and small towns, and their use could expand swiftly with separate infrastructure and clear legislation. E-bikes have the additional advantage of being socially inclusive: they are used by both sexes and the elderly, unlike pedal cycles, which in the UK are favoured by younger males (Parkin et al., 2008; Beecham and Wood, 2014).

There are downsides to electrification, though. For one, it will decrease government tax revenues. At the national level, fuel duty revenue was around £28 billion in 2016/17, or 1.4% of the UK's GDP. Vehicle Excise Duty raised a further £6 billion, and value added tax (VAT) on fuel duty a further £6 billion (Department for Transport, 2017e). The Office for Budget Responsibility (2017) projects that fuel duty will fall to 1-1.12% of GDP by 2030. The faster uptake of electric vehicles could decrease this tax revenue even more quickly.

Another issue is safety, particularly for pedestrians and cyclists. At low speeds (below 10km/h) electric vehicles are much quieter than the internal combustion engines in non-electric cars. This presents a challenge for nearby pedestrians and cyclists, as cars are most likely to be around pedestrians when they are driving at low speeds (e.g. in car parks or when reversing out of driveways). Above 10-40 km/h, this is less of an issue: electric vehicles are only slightly quieter, as tyre noise then dominates (Iversen, 2015).

The spread of electric vehicles may also have a social gradient. New technologies are, historically, expensive at first; only as prices come down do they become more accessible to more of the population. It is important to consider how to equitably share the benefits of electrification, such as improved air quality and lower taxes, and how to fairly mitigate some of the challenges, such as higher costs and access to charging (Department for Communities and Local Government, 2013; Harrison and Shepherd, 2014; Mullen and Marsden, 2016; Reanos and Somerfeld, 2018).

A key challenge will be to ensure that the electricity network operates reliably for all users as vehicle numbers increase, which will include work to modify local electricity distribution networks. It may also be necessary to shape peak electricity demand for vehicles. Without incentives such as smart charging, users are unlikely to charge their vehicles at off-peak times, potentially adding markedly to peak grid load (National Grid, 2017).

Box 5.2

Dockless e-scooters

E-scooters are electrically power-assisted foot scooters that use an onboard battery. Dockless e-scooters are enabled with a mobile phone app and can be picked up or left anywhere. They provide a quick way to travel over short distances (Lorenz, 2018) and so are most feasible for short distances in built-up areas. It is currently illegal to use them on pavements or roads in the UK, but unclear if this will still be the case by 2040.

E-scooters have been introduced in a number of countries worldwide. In the USA, for instance, they are still niche but growing in popularity. But while generally popular, in some areas they are viewed negatively. Reasons for this vary, but complaints include pavement clutter, and riders speeding on pavements (Irfan, 2018; Quain, 2018). In the Netherlands, where the necessary infrastructure is in place, e-scooters have integrated well into the transport system (Quain, 2018).

5.2 Data and connectivity

Data is changing many aspects of our lives. The volume, variety and pace of data use will expand towards 2040, paralleled by an increase in the use of digital platforms and techniques to gather and analyse data (Reinsel et al., 2017). This growth in data will drive – and be driven by – growing connectivity, and it will underpin new technologies and digital infrastructure. Currently, much of the growth of data and computational power is driven by big commercial organisations. There is huge potential for data, as a form of infrastructure and public good, to produce wider social benefits.

The growth in data use will lead to changes in and beyond the transport sector. These include improved real-time situational awareness and demand modelling; closer monitoring of users, infrastructure and vehicles such as on-board vehicle diagnostics in road, rail and shipping; and the ability to maintain transport infrastructure in a more effective, predictive way (i.e. prevention of problems rather than repair).

The share of data collected, analysed and managed by the private sector is growing and its value is increasing. Having access to this data is of importance to local, regional and central government and other companies, who could use it to plan, operate, better integrate and provide services. For the logistics sector and movement of goods through the supply chain, improvements in the optimisation of operational efficiency and customer experience are also likely to be developments through further breakthroughs in data and analytics in the future (PWC, 2016b).

The UK is considered a global leader in open data initiatives (Open Data Barometer, 2015). The economic value and savings these may bring are significant. Open data from Transport for London contributes £90-£130 million to the economy each year. Making this transport data publicly and freely available has had huge impacts, domestically, on driving forward digital innovation. Under Transport for London's open data repository, over 600 travel apps in the UK are powered by this data and are used by over 42% of Londoners (Deloitte, 2017).

Since early 2000s, government-enforced data standardisation, including transXchange, has enabled transport information systems such as Citymapper that users use to plan and optimise journey times (Parkhurst and Seedhouse, 2019). The rise of digital ticketing and payments in recent years, combined with app and web-based platforms to plan and book transport services, has revolutionised how users interact with the system. Future transport underpinned by digital connectivity is likely to provide, arguably, for the first time an opportunity to fully integrate the system.

One significant area where data is changing transport is automation. The convergence of developments such as machine learning, real-time data and artificial intelligence will increase automation in multiple areas: from traffic and network management through to autonomous vehicles (e.g. self-driving cars) and even new modes of transport. This will provide new ways to improve infrastructure, vehicles and whole transport systems (Frost and Sullivan, 2017a) and is discussed further in Section 5.3.

Fifth generation (5G) mobile networks, scheduled to roll-out in the UK from the early 2020s, will enable faster data transfer than current 3G or 4G technology. Autonomous vehicles on the market today are working without 5G but, in the future, its importance may grow. Early models suggest that 5G market coverage will be limited at around 90% penetration (Oughton and Frias, 2016), and this may have implications for data transmission rates from vehicles or infrastructure in isolated areas.

The use of digital innovations to manage assets more effectively has grown in recent years. Specifically, the concept of a "digital twin" – digital copies of physical infrastructure used to simulate, test and respond to the system. Such virtual systems offer possibilities to plan, predict and manage assets using the vast amounts of data captured (National Infrastructure Commission, 2017a) and opportunities to share data between public and private sector organisations.

Real-time data and visualisation offer possibilities to improve safety for all road users. Analysis and mapping of location-based pedestrian and cyclist data transmitted instantly to public bus or vehicle drivers, for example, may play an increasingly important role in visualising smart cities and ensuring safer urban areas (Smart Cities, 2017). Indeed, safety – a key strength of the UK transport system – is one area that will benefit significantly from vehicle, infrastructure and user-based data (International Transport Forum, 2015).

Despite these opportunities for the transport sector, developments such as the Internet of Things (i.e. home appliances, vehicles and devices that connect to the internet) and cloud computing pose challenges to secure communications and could raise the risk of illegal data transfers. Similarly, connected vehicles and transport-management systems offer passengers and companies better information and updates, but also broaden the types of potential threat (Koscher et al., 2010; Checkoway et al., 2011). As systems become more automated, there are further risks if their operating systems, software and defences are not kept up to date. Overall, developments in transport-related technology, systems and services could create a rapidly changing landscape for transport-related crime (Beecroft, forthcoming). There is therefore a need to minimise the cybersecurity threat to companies and individuals, with security measures built in to all new developments in transport connectivity and data.

For personal data, an increased awareness and concern amongst consumers as to how their data is used by third party organisations reflects both the challenge and opportunity faced by public and private sector alike. This is an area of untapped potential, and improving understanding of the benefits of sharing personal data may increase public acceptance of doing so. Around 29% of survey respondents would consider sharing data if it improved their own personal experience. While 43% were content to share data if it would benefit society as a whole (Digital Catapult, 2015). There is some evidence to indicate social concerns around data privacy may be easing slightly overall

(DMA, 2015). Data privacy and guarding remains an important issue and is likely to grow in importance to 2040. This is explored through our future scenarios in Chapter 6.

Data and digital connectivity are also driving social changes. On the one hand, the fast growth of online shopping (discussed in Section 5.4.6) has increased the frequency and number of deliveries. On the other hand, some consumer demand for accessing services, such as films or music, on demand is substituting for receiving physical goods.

5.3 Automation

Automation is technology that allows a process or procedure to be performed with minimum human assistance. It is not binary; rather, there is a spectrum of levels of automation that could be achieved, as Table 5.1 sets out.

Automation already exists in some transport sectors, to various degrees. However, there is considerable potential for this to be scaled up across the transport sector, bringing huge potential advantages, especially in terms of costs.

5.3.1 Self-driving trains

Metro and rail networks are seen as prime candidates for automation, due to the controlled nature of railway traffic. The Vancouver Skytrain has been self-driving since 1985 (D'Souza and Wanyee, 2016); the Docklands Light Railway since 1987 (Transport for London, 2018b); and Line 1 of the Paris metro was autonomous in 2011 (Churchill, 2012) following the success of the first fully self-driving line, Line 14, which opened in 1998.

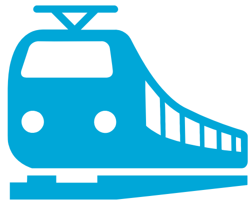
Table 5.1 A simplified industrial taxonomy of automation systems for on-road motor vehicles

Automation level	Description
Level 0	No automation.
Level 1	Automation of one primary control function, e.g. adaptive cruise control, self-parking, lane-keep assist or autonomous braking.
Level 2	Partial driving automation. Automation of two or more primary control functions, which can work together to relieve the driver of control of those functions.
Level 3	Conditional driving automation. The vehicle can control all safety-critical functions under certain traffic or environmental conditions. The driver is only needed for occasional control: If there are issues it cannot deal with in timely fashion, it warns the driver and passes control back to them.
Level 4	High driving automation. Self-driving without human controls, within a well-defined operational design domain, with operations capability even if a human driver does not respond appropriately to a request to intervene.
Level 5	Full driving automation. Self-driving. Automation without human controls in all driving environments that can be managed by a human driver.

Source: Society of Automotive Engineers, 2018

However, the complexity of Britain's rail network, which has many types of trains, signalling and operating patterns, has proven a barrier (Wright, 2017). As an interim solution, the European Rail Traffic Management System (ERTMS), an advanced train-protection and signalling system enabling the semi-automatic running of trains, is being installed on parts of the Thameslink and Crossrail lines in London. It claims to offer 40% more capacity than existing line infrastructure (UNIFE, 2014).

One attraction of self-driving trains is potential cost savings. Pre-automation, each train needed a driver, so every extra train provided meant additional staff costs. Self-driving trains break the link between the frequency of train services and staff costs. If staff costs are lowered, fully autonomous trains can run more frequently with lower additional costs (Walker, 2010). The ratio of staff per asset (i.e. the proportion of staff relative to the total number of trains and stations) is 70% lower in unattended, autonomous train and station systems, compared with fully staffed systems. Even where stations but not trains are staffed, staff savings were still 30%. Self-driving trains also have 4-6% more room for passengers (Cohen et al., 2015).



Self-driving trains have 4-6% more room for passengers.

5.3.2 Self-driving cars

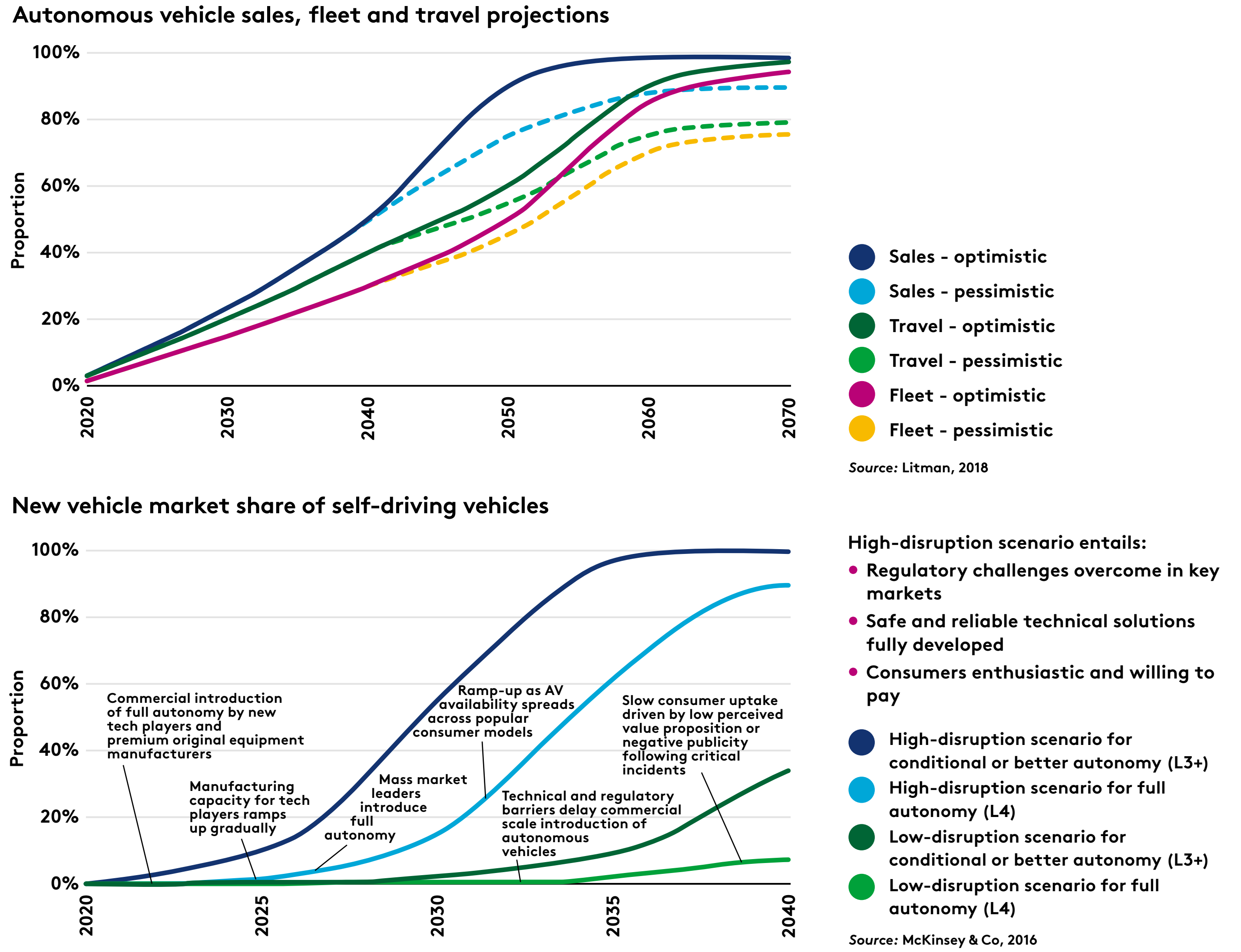
Around 38 million (83%) of the vehicles registered in the UK in 2017 were cars (Department for Transport, 2018, VEH0101). This means that there is huge potential for automation within this particular vehicle fleet. However, adoption rates for autonomous technologies and the future market penetration of autonomous vehicles are highly uncertain as they depend on a variety of factors such as the take-up of autonomous vehicles by premium original equipment manufacturers (OEMs). This leads to significant disagreements between forecasts (see Kockelman et al., 2016; Arbib and Seba, 2017; Munster and Bohlig, 2017). Figure 5.1 shows two different forecasts for the rate at which current cars will be replaced with connected and autonomous vehicles (CAVs),[10] but there are many alternatives (e.g. Bierstedt et al., 2014; EY, 2014; Jones, 2014; Inside EV, 2015; Somers and Weeratunga, 2015).

Initially, self-driving vehicles are likely to be rolled out in 'geofenced' (virtually or software enclosed) areas, before being used in uncontrolled public spaces (currently, for example, autonomous buses in Las Vegas). The first self-driving vehicles are already starting to operate. Waymo launched a self-driving taxi service in a geofenced area of Arizona, USA, in 2018, but as of January 2019, these still had a safety driver, just in case (Reuters, 2018).

In the UK, since 2015, self-driving vehicles have been tested in four English cities: Bristol, Coventry, London and Milton Keynes (BBC, 2014). Furthermore, testing is permitted anywhere in the UK, if abiding by the Code of Practice (Department for Transport, 2015c), without the pre-requirement of informing local or central government authorities (although it is recommended to engage with local emergency services). As such, trials of self-driving vehicles on UK roads are likely to have happened more widely. The technology has continued to develop, and by 2021 there will be trials of an autonomous bus

10. Connected vehicles are vehicles that can communicate with each other and to the infrastructure around them.

Figure 5.1 Different views on future adoption rates of self-driving vehicles



service between Fife and Edinburgh, and self-driving taxis in London (Department for Business, Energy and Industrial Strategy and Clark, 2018)

Even if autonomous driving technologies could begin to penetrate new vehicle markets by the 2020s, public attitudes are likely to affect their adoption (Litman, 2018). A survey commissioned by the Department for Transport in 2017 showed that 49% of the public did not see any advantages to autonomous vehicles (Department for Transport, 2018n). The most commonly cited concerns were fear of equipment or system failure, and cars failing to react to unexpected situations. For governments, it will be important to strike a fine regulatory balance between enabling innovation while ensuring public safety. Engagement with the public by both government and the private sector will be key.

5.3.3 Potential impacts of self-driving cars

There are many potential gains from the rise of self-driving vehicles. They could add up to £2.1 billion gross value added to the UK economy by 2035, and support up to 47,000 jobs (Transport Systems Catapult, 2017). Advanced safety features, such as autonomous braking systems, could reduce road casualties by 30% by 2033 (McAuley et al., 2015). SMMT (2015) suggests a wider economic benefit of £51 billion per year by 2030 due to fewer accidents, improved productivity and increased trade.

If and when fully autonomous vehicles achieve significant penetration of the transport sector, this could help to reduce the distance between vehicles. The availability of new materials could allow for considerably smaller and lighter vehicles. Both have the potential to increase the capacity of roads. HIstorically, when travel times have shortened due to new travel options, the time savings have led to longer distances being travelled (e.g. people can commute further) (Metz, 2016). If this is also the case for fully autonomous vehicles then, without intervention, automation is likely to worsen urban sprawl.

There is no consensus on the impact that autonomous vehicles could have on congestion. Studies predict that the capacity of a given roadway increases markedly once they make up over 50% of the vehicle fleet (Tientrakool et al., 2011; Shladover et al., 2012; Atkins, 2016; Auld et al., 2016; Maurer et al., 2016). Stern et al. (2017), in a limited practical test, found that having just 5% autonomous vehicles decreased stop-start traffic waves and improved fuel consumption. However, improved traffic flows in specific parts of the system may not scale up across the system as a whole.

Furthermore, when considered alongside the projected increase in overall car traffic, some simulations suggest that vehicle automation will worsen congestion. Modelling of four possible scenarios for self-driving vehicle deployment found an increase in the vehicle-kilometres travelled, from 9% where there was limited automation of the vehicle fleet, to around 60% where automation of the whole vehicle fleet took place (Wadud et al., 2016). Another simulation for Lisbon found that automation of the whole vehicle fleet increased vehicle-kilometres by 9-103% (International Transport Forum and Corporate Partnership Board, 2015). If these simulations are applicable to the UK, then increased overall travel demand is plausible.

Additional journeys by empty self-driving vehicles are predicted to be a key contributor to congestion at peak times, for example when empty vehicles leave town centres to return to their collection points. This could be mitigated by ride-sharing or increased use of active transport modes (e.g. cycling, walking) to complement vehicle travel. Costs may also lead to increased overall traffic. If costs are equal to or cheaper than current car travel, then it is likely that self-driving vehicles will encourage extra journeys (i.e. those that are currently undertaken in different modes), for example dropping children off at school. The price per mile of self-driving vehicles depends on assumptions of ownership, cleaning and sharing, with estimates ranging from £0.20-0.25 to £0.60 per mile (Deloitte et al., 2015; Bösch et al, 2017).

Automation could also have negative impacts on those with the lowest incomes, who may be priced out of the early market and therefore miss out on potential advantages (Zmud et al., 2013). Yet some groups may benefit: if accessibly designed, they could facilitate mobility for the elderly, disabled or mobility impaired, prolonging their independence, providing better access to services and increasing social and economic inclusion.

Policy-makers should continue to consider how the UK can best take advantage of the benefits likely to arise from automation. Increased road safety, improved efficiency and more cost-effective transport are all exciting possibilities. There are also new market opportunities for UK industry, such as software development, lightweight technology and digitisation of manufacturing processes, and businesses must decide how to capitalise on these. Yet these need to be balanced against the concerns of the public about these vehicles.

The impact of automation on tax revenues is important. Currently road space is a public good, and the costs of provision are generally covered by users.[11] The benefits of the tax payment are taken by the users of that asset. In a future world with greater private provision (e.g. autonomous or self-driving vehicles and substantial sharing), the transport system would be used much more by large corporations that are extracting some of the value of the asset as profit. This would raise choices in how to extract the right value from multinational corporate interests. Government has power as asset owner and rule setter, if it chooses to exercise that right.

5.3.4 Autonomous buses and private-hire vehicles

~45 %

of costs of a taxi/PHV are the driver.

Autonomy could make buses – or new, demand-responsive transport services – more commercially viable in rural regions, where it is often expensive to provide public transport. Driver costs currently make up a large proportion of the total cost of such services: 40% is spent on drivers, part of the 61% spent on labour in general (Warburton, 2015). Indeed, labour costs make up a large proportion of transport costs for all types of service: 40-50% for taxis and private-hire vehicles (Hara Associates, 2011; Centre for International Economics, 2014; Taxi Research Partners, 2015); 27% for HGVs (Apprise Consulting, 2016); and for trains, between 23-25% (Stagecoach, 2014) and 60% (Steer Davies Gleave, 2015).

Automation could reduce these costs, or eliminate them altogether. This would, of course, have widespread knock-on effects, notably on employment: in the UK, there are approximately 257,000 taxi and private-hire drivers, and 124,000 bus drivers (Transport Scotland, 2016; Department for Infrastructure, 2017; Department for Transport, 2017b); 318,700 HGV drivers (Department for Transport, 2016a); and 20,500 train drivers (ASLEF, 2018). Additionally, up to 950,000 jobs in the wider transport and storage industry are considered at risk from automation over the next 15 years (PwC, 2018). Government will need to consider how best to support these workers (i.e. through reskilling or retraining) from the disruption that automation could bring to the workforce.

11. For clarity, much of the revenue raised (such as fuel duty) is general taxation and is not hypothecated funding. However, users do pay taxes and expenditure is spent on building and maintaining public roads.

Buses equipped with connectivity and automation capabilities are predicted to make up 79% of global sales in 2025 (Transport Systems Catapult, 2017). If by then these enable fully autonomous operation, it could result in an investment payback period of just six weeks. Even at lower cost-recovery estimates, the repayment period would still be much shorter than the operational life of the vehicle, with the average bus age in England being 7.6 years in 2016 (Department for Transport, 2017b). Dedicated bus lanes would make the new services faster, and hence more attractive as a competitor to private cars.

5.3.5 Vertical and short take-off and landing vehicles

Vehicles that can take off, hover and land vertically, or that have a short rolling take-off, could potentially be autonomous. These vehicles could overcome the space constraints in cities and might be viable for short city-to-city and inter-urban journeys, including commutes from the suburbs of larger cities (Holden and Goel, 2016).

These vehicle types are not new: autogyros were used by companies from the 1930s onwards and passenger helicopters from the 1950s. However, for them to be used more widely, there are several barriers to overcome. Cost is likely to be a vital issue, while regulation and certification from air traffic control and the level of vehicle noise are further potential barriers. As a result, timelines for their wider use are highly uncertain and subject to considerable hype.

5.4 Freight

It is not just passenger transport that faces a different future: our freight system is also likely to alter considerably. The freight sector will have to respond to the growing need to decarbonise through new technologies and business models, as well as adapting to changing consumer demands. The scope for electrification in freight is the subject of ongoing research and innovation, and automation is likely to be another significant shaping force.

5.4.1 Decarbonising the freight sector

The UK's freight sector is fragmented and privately controlled, and for most actors, the overarching aim is to maximise profit, rather than achieve environmental or social benefits (McKinnon, 2015). Planning for freight has historically been separate from passenger transport, although both use similar infrastructure. Total freight mileage is less than that of passenger mileage, but its impacts on congestion, air quality, CO_2 emissions and road traffic incidents are still significant.

LCVs have greater negative effects than HGVs on air quality. For road transport-related NO_x emissions, LCVs account for 32%, while HGVs account for 13% (National Atmospheric Emissions Inventory, 2018). LCVs also contribute more to greenhouse gas emissions than HGVs. In 2015, LCVs accounted for 16% of the 120 megatonnes CO_2e of greenhouse gases generated by UK domestic transport, while HGVs were responsible for 15% (Department for

Transport, 2017, TSGB0306). The rapid growth of LCV mileage compared with HGVs since 1990 makes emissions reduction particularly challenging for the road freight sector.

Yet reductions are required by carbon budgets. The UK's Fifth Carbon Budget (2028-2032) does not set sector-specific targets; instead, it requires an overall reduction in greenhouse gas emissions of 57% between 1990 and 2030. The decarbonisation of road freight will therefore be important in reducing carbon emissions from the transport sector.

A range of emissions-reduction measures, both in vehicle development and in logistics, are becoming available. Improvements in aerodynamics, tyres, lightweight materials, eco-driver training and dynamic route-planning can collectively lead to substantial reductions in the carbon emissions from fossil-fuel vehicles. In the longer term, however, alternatively powered vehicles will be needed if the overall 2050 target of reducing greenhouse gases by at least 80% compared with 1990 is to be reached.

Alternative fuels for HGVs are already being explored, with hydrogen and biofuels considered potential routes to decarbonising these heavy-duty vehicles. Other sectors, such as domestic energy, are also considering hydrogen as a fuel. If successful, then a growing hydrogen economy would make its use more feasible in the transport sector, possibly including rail freight.

5.4.2 Electrification of the freight sector

There is potential for electrification of the freight sector. Vehicle manufacturers including BMW, Mercedes-Benz and Tesla have recently announced prototype electric HGVs. Yet decarbonising large freight vehicles through electrification is a significant challenge. Current battery constraints relating to vehicle size, load weights and distances travelled make them unsuitable for many journeys. Increased vehicle weights also tend to increase tyre particulates and road wear (Timmers and Achten, 2016), and so the impacts of greater use of electric freight need to be considered.

The number of electric van models is limited but growing; however, only 0.1% of the 4 million vans (up to 3.5 tonnes) registered in the UK are electric (Clean Air Day, 2018). As well as vans, freight vehicles less than 15 tonnes can be converted to battery power. However, for vehicles over 15 tonnes, there is a trade off between range and battery weight. If the range of electric HGVs is short there is a need for further charging infrastructure around the road network to support electrification (Heid et al., 2017). The exact form of this will depend on the business model adopted, but motorway service stations, rest stops and warehouses/depots with charging points are likely to be necessary.

0.1%
of UK's 4 million vans are electric.

Looking to 2040, it has been suggested that other options might become feasible, such as overhead electrified routes (Greening et al., 2018) or under-road wireless charging (Conliffe, 2017); however, both will be highly dependent on roll-out costs. The power demands imposed by electric freight vehicles will also need to be considered, as these could increase sharply after 2030 (Tryggestad et al., 2017).

As the technology develops, battery efficiency and range will improve, so electric freight should become cheaper. McKinsey & Co forecast that the total ownership cost for all classes of electric freight vehicle will reach parity with diesel vehicles by 2030, and earlier for smaller vehicles operating at shorter distances (Heid et al., 2017).

For other modes of freight transport, the scope for electrification is mixed. At present, 42% of the UK rail network is electrified, but further electrification of rail freight is potentially constrained because few factories, warehouses, industrial premises or terminals have electrified rail connections. This means that electric freight trains would either need to switch to diesel haulage at the start and end of the journey, or run with a diesel locomotive for the whole journey, with a potentially greater impact on CO_2 emissions (McKinnon, 2018). New technologies such as bi-mode, hydrogen fuel cells or batteries could provide a solution to this.

Electrification of merchant fleets will also be difficult. To transport heavy cargo over long distances, electric ships require a reliable energy source. This could be fuel-cell technology, potentially hydrogen, or electric batteries. Both are currently costly, but will become more feasible with additional research and economies of scale. As the technology develops and the market grows, the cost and efficiency of electric batteries will improve (BNEF, 2017a). China, for instance, already uses an electric ship, with a battery powertrain that has a cargo capacity of 2,000 tonnes, to carry coal down the Pearl River (Lambert, 2017). Electric vessels that carry passengers are easier to introduce, because they require smaller batteries and the technology already exists. Norway, for example, has two fully operational electric-powered ferries (Hockenos, 2018).

At a smaller scale, electric cargo bikes are a more sustainable way to move smaller loads than LCVs or HGVs and are suitable for urban deliveries. One study suggests they could potentially carry a quarter of all commercial traffic in city centres (Schliwa et al., 2015). A Department for Transport (2018o) pilot study based in a Sainsbury's store in North London, found that over 96% of orders could be fulfilled with a single cargo-bike drop. In 2018, the Department for Transport assigned £2 million to help grow the sector (Department for Transport, 2018o). Their wider uptake will depend on vehicle cost, but also on developing separate cycle infrastructure that ensures cyclists' speed and safety.

5.4.3 Automation in the freight sector

Automation already exists in the freight sector, but its uptake varies across modes of transport. Ports and some warehouses are highly automated, whereas road freight and last-mile deliveries remain largely labour-intensive. Looking forwards, automation is likely to have an increasing impact on all modes of freight.

An estimated 85-90% of air cargo could be handled by robots, saving up to 60% of labour costs, with a payback on investment of less than 2.5 years (Waters, 2016). DHL (2016) claims that its automated air freight-handling centre in Singapore processes items six times faster than manual workers, and its handling capacity is three times larger. Similarly, the Altenwerder Harbour Container Terminal in Germany is highly automated, achieving operating costs of €55 per twenty-foot equivalent unit (TEU), compared with €70/TEU for a conventional port; €13 of this saving is due to reduced labour costs (Burgers, 2008).

For road freight, autonomous HGVs could achieve cost reductions in the region of 40% per kilometre (DHL, 2014) and increase utilisation rates fourfold (Keeney, 2017). Over ten years, they could save £33.6-47.5 billion on labour, fuel and insurance costs in the UK (AXA, 2018). Repeated long haulage between ports and national distribution centres is a potential early candidate for greater automation, as these have geofenced routes of limited scale and minimal urban driving.

Platooning, where multiple connected and/or autonomous vehicles travel close together (with a lead vehicle driver), could save up to 11% of fuel costs and up to 60% of salary costs (Wadud, 2017), while a suite of autonomous technologies could reduce annual HGV operating costs by 28% (PwC, 2016a). Companies are already piloting autonomous trucks for geofenced routes in the USA, as the longer distances there are more attractive than in the UK (Etherington, 2018; Hawkins, 2018).

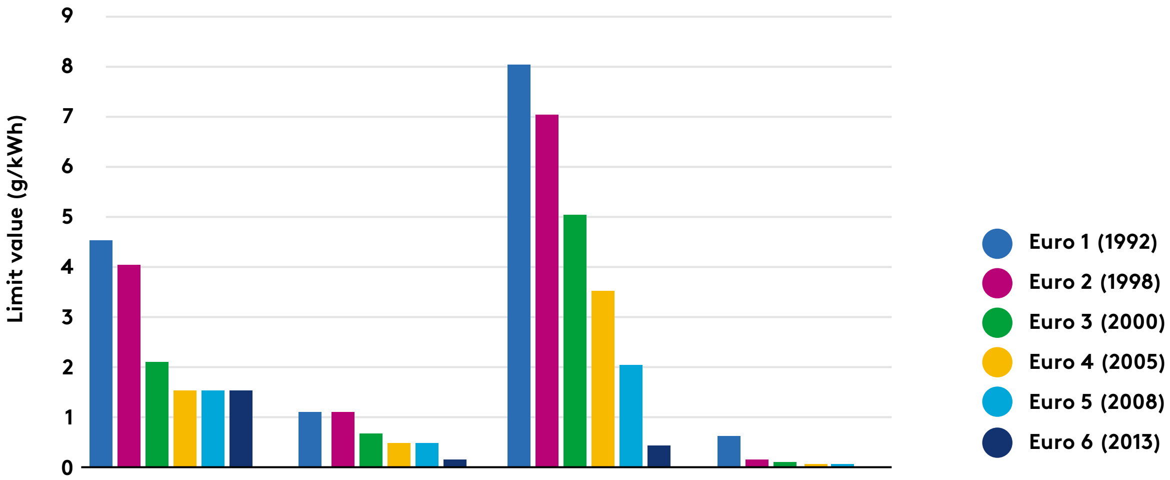
5.4.4 Achieving the shift: barriers and opportunities to decarbonising the freight sector

While automation and other new technologies offer cost savings from reduced fuel and labour costs, their wider adoption is held back by the upfront investment required both in vehicles and infrastructure. Many freight operators are small scale and may not have the cash flow to invest in cost- and emissions-saving measures. For larger firms, freight transport costs are a small proportion of their total supply-chain costs and therefore do not attract much attention or investment. Some may be persuaded to invest as awareness of climate change and its impacts increases in the freight sector; voluntary approaches such as the Logistics Carbon Reduction Scheme (Freight Transport Association, 2018b) enable freight operators to report their current emissions and identify means of reducing them. Radically disruptive technologies, such as those outlined in this chapter, may also help to overcome inertia in the freight sector.

Policy interventions have a role to play in realising this shift. Combined policy measures to reduce air pollution from freight vehicles have included the introduction of Low Emission Zones, also known as Clean Air Zones, alongside EU standards on engines. Six levels of standard have been agreed to date for HGVs, with each subsequent standard further reducing the level of exhaust emissions allowed. Figure 5.2 shows the maximum levels of hydrocarbons, carbon monoxide, nitrogen oxides and particulate-matter exhaust emissions allowed at each EU standard for HGVs, along with the year each standard was introduced.

Dablanc and Montenon (2015) found that freight operators changed behaviour in response to EU Low Emission Zones, for example buying or hiring

Figure 5.2 **Maximum levels of exhaust pipe emissions allowed at each EU standard for HGVs**



Source: Based on Dieselnet, 2018

newer vehicles, organising activities more efficiently, changing routes, and/or only using their oldest vehicles outside of charging zones. Less widespread but notable consequences included mergers and resource-sharing between companies, and the development of new logistics hubs. Compliance levels in the London Low Emission Zone exceeded 97% in 2016 (Allen et al., 2016a), although LCVs were assessed to have lower levels of compliance (Transport for London, 2015).

The introduction of stricter Ultra-Low Emissions Zone standards in 2019 is likely to encourage additional consolidation hubs and a shift to newer vans. Although the newest Euro 6 diesel HGVs are compliant with the standards set by the London Ultra-Low Emissions Zone, policies of this kind have the potential to accelerate the uptake of alternative fuel vehicles and electric vehicles.

Examining the range of carbon-saving measures together gives a clearer view of how carbon emissions from road freight could alter between now and 2040. The roadmap model developed by the Centre for Sustainable Road Freight suggests that exhaust carbon emissions from road freight could reduce by 61-71% from 2010 to 2050, depending on assumptions (Greening et al., 2018). The 10% difference in emissions savings reflects the possibility of lower adoption of alternative fuels, especially electric vehicles, when costs are factored in. Currently, alternatively fuelled vehicles are more expensive to purchase than diesel vehicles, but as gas and electric vehicles gain in popularity, their price is expected to fall.

5.4.5 New business models

Forces beyond automation and electrification are set to shape the freight sector of the future. The increasing connectivity of businesses and customers is enabling new business models to rise up in many industries, some of which fall under the umbrella term of the 'sharing economy'.

Within the freight sector, sharing can be defined as "freight services provision performed by actors working together at the same level in the supply chain, often facilitated by an intermediary digital platform player, that provide added values for all participating entities" (Mason and Harris, 2018). Recent developments, such as those in digital capabilities and improved data-access technologies, are enabling new models of sharing in logistics and could become increasingly common. For example, digital platforms can enhance efficiency by rapidly connecting excess system capacity with demand, or reducing the search and transaction costs associated with sharing. Table 5.2 summarises the sharing options across the freight sector.

Wider data availability and greater use of social technologies (e.g. using apps) could enable the sharing economy to grow further in the transport

Table 5.2 Sharing options in the freight sector

	Freight transport	Last-mile	Warehouse
Main current challenges	• Pressure for smaller, more frequent shipments • Increased customer demand for higher delivery reliability • Increasing utilisation • Maintaining cost control	• Small, frequent shipments including small batch sizes • The need for greater schedule reliability • Short lead times • A lack of real-time communication • The need to integrate multi-channel retail services	• Demand fluctuations • Using capacity intensively and consistently • Low inventory levels • Maintaining cost control
Sharing methods	Consolidation centres that enable fewer, fully loaded vehicle movements	Urban consolidation centres that enable fewer, fully loaded vehicle movements into cities	One-to-one space sharing
	Fourth-party logistics models/ lead logistics providers that allow optimisation across supply chains, through outsourcing freight activities	'Crowdshipping' last-mile deliveries, with platforms that outsource delivery to approved local distributors	Multi-user sharing, managed by third-party logistics companies
	Pallet networks that pool small deliveries of pallets	Piggy-backing and shipments that move freight via the pre-existing movements of people	'Flex' warehouses that allow for seasonal variations in demand
	Agricultural cooperatives sharing machinery	Horizontal collaboration by retailers sharing logistics	On-demand warehousing with platforms connecting unused space with customers
	Joint-venture collaboration between logistics service providers	Other innovative last-mile freight-sharing ideas, e.g. drop-off lockers, in-car deliveries	Self-storage facilities, with platforms for renting storage space in a variety of locations
	Fewer 'wasted' miles through retailer collaboration		
	Filling spare truck capacity		
	'Synchromodality' by using containers to better integrate flows of goods across all transport modes		

Source: Mason and Harris, 2018

sector, including freight. Examples include 'backhauling' (the filling of reverse empty flows with other goods) and 'crowdshipping' (delivering parcels by picking up and dropping them off along routes that were being taken anyway). The potential for these technologies is far greater when they are combined. All, however, require reliable connectivity, security and agreed data standards.

Businesses are increasingly appreciating the benefits of sharing. To date, growth has largely been seen in the 'last mile' element of freight operations, but better data collection and use will continue to drive increased freight sharing, by improving the links between and interoperability of systems and structures. Importantly, the success of future freight-sharing practices will depend on the willingness of actors within supply chains to give up sole control of the process. Modal choices also have a part to play, as sharing approaches enable freight to make use of assets such as buses and cycles (see Box 5.3).

Box 5.3

Freight-sharing and decarbonisation by Gnewt Cargo

Gnewt Cargo, a London-based parcel consolidation micro-hub, conducts its last-mile deliveries using a fleet of 100% electric vehicles, from cargo e-bikes to vans (Gnewt, 2018). Using electric vehicles has allowed Gnewt to reduce CO_2 emissions by 67% per parcel. For clients, using a third-party consolidation hub enables flexible and local delivery routing (Braithwaite, 2017). This helps to avoid delays caused by congestion and parking infringements.

Sharing could also contribute to reducing air pollution, an incentive that should encourage new business models, as well as technological change. The *Freight Carbon Review 2017* estimated that a range of sharing and other measures in the logistics system could save more than 2.5 megatonnes of CO_2e in 2035 (Department for Transport, 2017a). This constitutes approximately 12% of total carbon emissions from HGVs in 2016, representing a significant potential reduction.

While sharing offers real prospects to decrease congestion, emissions and running costs, it needs to be managed carefully to avoid contravening competition laws (Mason and Harris, 2018). There is a real concern about exactly which sharing practices would or would not breach anti-competition laws, as some might be deemed collusion between companies. Simple information schemes offering future-use cases, and whether or not they would be legal, would provide some clarity.

Additional innovative new approaches to strategic planning that can improve the freight sector include dedicated freight drop-off bays, specific turning zones for vehicles, dedicated freight routes, freight on passenger modes (e.g. rural post buses) and space for parcel lockers in residential zones. As noted in Chapter 4, more deliveries could be moved to off-peak times, or they could be consolidated into fewer deliveries – although it is the freight receivers (i.e. customers), rather than the deliverers, that will drive this. Benefits would accrue to the hauliers, whereas the costs would fall to the receivers and shippers. Optimising freight deliveries and incentives with such diverse actors in the freight sector will be challenging.

5.4.6 Changing shopping patterns

One of the fastest-growing parts of the freight and delivery sector in the UK is online shopping. Indeed, the UK has seen the fastest growth of online shopping in the western world. It accounted for 16% of total retail revenue in 2016, compared with only 4% in Spain, 13% in Germany and a European average of 9% (Braithwaite, 2017). There is no sign of this levelling off and the expected continuation of this growth in e-commerce has implications for freight transport and customer delivery models. In the future, there will be increased pressures on retailers to provide multiple delivery options to homes, stores or collection points, with smaller, more frequent, deliveries likely to become more common (Frost and Sullivan, 2013).

Data collected by Ofcom shows that in 2014/15, there were 11,765 UK-registered parcel firms that moved around 1.9 billion items (Allen et al., 2016b), excluding same-day-only couriers or Amazon Logistics. The parcel market is dominated by small enterprises, with 87% having an annual turnover of less than £250,000. However, bigger companies have a large majority of next-day services in terms of percentage of parcels handled. Larger online retailers and delivery companies are aiming to disrupt this market with new automation technologies. Amazon, for example, has pioneered the use of drones (see Section 5.5.1), as well as offering unattended delivery options such as click-and-collect and locker banks.

There is potential for the majority of parcels to be delivered by automated systems by 2026 (Joerss et al., 2016). A combination of self-driving vehicles – in the air and on the roads – will permit faster, more cost-effective deliveries. Achieving this, however, will depend on realising savings in labour costs, self-driving vehicles being appropriately regulated and the public accepting these new technologies. Irrespective of the technology deployed, one of the major challenges facing the freight sector as a whole will be delivering goods over the last ten metres of the journey, from the delivery vehicle to the customer's address, and into their physical possession.

One retail sector that faces specific challenges is online groceries. This sector is more labour-intensive and harder to automate, as a key element of the service is picking irregularly shaped and delicate goods such as vegetables and fruit. As a result of this and the ever-growing downward pressure on the prices people are willing to pay, losses are common as delivery charges fail to cover costs. Ocado, the UK's main online-only grocery retailer, did not make a profit until 2014 and in 2015, its net profit margin was just 0.01% (Allen et al., 2017). The one- or two-hour delivery windows, which are often what customers demand, greatly limit efficient planning of delivery routes.

5.5 New technologies in the freight sector

5.5.1 Unmanned aerial vehicles

Unmanned aerial vehicles (UAVs), or drones, are suited to the delivery of high-value, lightweight parcels, especially time-sensitive items. As such, they are most viable for last-mile, rural and lower-density urban areas, and to and from local delivery centres providing they have safe landing zones.

Initial roll-out has been in rural and less densely populated areas. Several cities already permit the use of drones to move goods to local delivery centres before being delivered by a person to the destination. Examples include Guangzhou (Golnazarian, 2018), Reykjavik (BBC, 2018a) and Shanghai (81UAV, 2018). Being comparatively small, drones avoid established challenges around the lack of landing sites in cities (Hern, 2016). Taking a different approach, Amazon has conducted trials on using drones for last-mile delivery (Amazon, 2016). They may also prove useful in longer-distance, larger deliveries: JD, one of China's biggest online retailers, has started developing drones that can carry a tonne or more (McDonald, 2017).

In terms of their potential to disrupt the freight sector, it is estimated that 15-16 drones would be required to replace one van (McKinnon, 2017). Nonetheless, the value of drones to transportation could be up to US$13 billion globally (Mazur et al., 2016) and their use for package delivery could reduce greenhouse gas emissions and improve energy efficiency in the freight sector (Stolaroff et al., 2018).

Additional UK legislation will be required before they can be more widely used, and their uptake will be contingent on their efficacy, battery power and cost. Trials of drone delivery by Amazon in rural Cambridgeshire also demonstrated the need for landing space, which is rarely available in dense urban environments. Space constraints in urban areas mean droids (see next section) may be more suitable, and several companies are already operating these in London (Hunt, 2018).

Away from delivery, some companies are using autonomous drones for inventory management (Jackson, 2017). This saves them considerable time and money, when compared to human equivalents checking the stock in large warehouses. It also responds to the growing use of digital supply chains.

5.5.2 Autonomous ground-based vehicles

In the future, small autonomous ground-based delivery vehicles, or droids, if legal, could travel on pavements and in pedestrianised areas. These could become movable parcel lockers and reduce the number of missed deliveries in urban areas (Joerss et al., 2016). Six-wheeled droids that can carry up to 10kg of cargo have been deployed in eight cities (Espinoza, 2018). Customers are notified on arrival and can unlock the compartment containing the delivery with a smartphone. However, droids need the customer to be at the destination to take the delivery, which is not the case for around 13% of deliveries (Cherrett, 2018). They will also require significant capital expenditure to develop, and public acceptance and regulation may need to be addressed (Hunt, 2018). Issues to overcome include ensuring pedestrian safety, and their ability to cross roads, climb stairs or press buttons (be that door bells, or traffic light cross buttons).

These ground-based delivery vehicles are most suitable for urban and suburban areas with medium to low population densities, as they require enough people to generate demand and enough pavement space. San Francisco passed legislation to restrict numbers of delivery robots because of the pavement congestion they caused (Wong, 2017).

5.5.3 Narrow-diameter tunnelling

Narrow-diameter tunnelling offers various possibilities for underground transport. This could be for light rail, trams, bus rapid transit or pipelines designed for either passengers or freight. Construction would alleviate surface congestion and avoid causing traffic jams in the way that building another road lane would. Smaller tunnel diameters will also reduce the cost of boring by three or four times (Economist, 2017; Bliss, 2018). The concept of an underground logistics system is gaining some traction, with China developing and implementing transport pipelines that facilitate last-mile deliveries (Chen et al., 2017).

Historically, narrow-diameter tunnelling was used in the 1900s in London to deliver mail. London's Mail Rail was constructed in response to a report that suggested that London's low traffic speeds caused delays in mail delivery (Dangerfield, 2014). The Mail Rail ran throughout the 20th century, carrying 4 million letters a day during the 1980s; it was decommissioned in the early 2000s, though, because its operating costs were deemed too high (Dangerfield, 2014).

5.5.4 Power-assisted suits/powered exoskeletons

A wearable robotic suit makes lifting heavy loads far easier: one military example makes objects 17 times easier to lift than their actual weight (Bender, 2014). While currently limited to military use, they could be more widely used in the coming years, for example in freight-handling warehouses or by individuals lifting heavier loads to and from vehicles. Decreasing the physical strength needed to handle objects potentially widens labour market diversity.

5.5.5 Other new freight technologies

Digitisation of manufacturing processes is another promising area. This offers new solutions to the challenges of warehousing and transporting goods, for example by reducing the amount of paperwork needed for international shipments. This simplification is needed: Maersk revealed that a shipment of avocados from Mombasa to Rotterdam in 2014 involved over 200 communications and 30 different parties (Economist, 2018b). To resolve these issues, distributed ledger technology offers the potential to considerably reduce the number of communications and time spent sending documentation. It also offers another method of tracking goods flows through a supply chain in real time. However, distributed ledger technology may prove hard to implement in the transportation of goods, because all stakeholders will have to abide by the same standards. Given the multitude of suppliers and their geographical dispersion, it will be hard to achieve a compromise over which standards to use.

Additive manufacturing technologies, such as 3D printing, could also have an impact on the freight sector. However, views differ about their relative impact on freight miles (Mangan and McKinnon, 2018). On the one hand, ING (2017) estimate that widespread adoption of 3D printing will lead to a decrease of almost 25% in world trade by 2060. On the other hand, a report from the World Economic Forum argues that 3D printing will not have a significant impact on global trade (Lehmacher and Schwemmer, 2017).

Other innovations offer the freight sector opportunities to save time and costs in the coming decades, as well as greater flexibility and faster responses to changing demands. Wang (2018) identified six emerging technologies likely to have a major impact on the freight sector: cloud computing; the Internet of Things; social technologies; artificial intelligence; big data and analytics; and immersive technologies.

5.6 Predicting inception dates

As this chapter shows, there is a wide range of emerging technology in the passenger and freight transport sectors. For policy-makers and future planning, it is important to consider when these could become a reality. But this is difficult to determine: there are large uncertainties and disagreements around all of these technologies. They are highly dependent on progress in research and costs, and do not take into account legal, regulatory or public opinion constraints. Table 5.3 presents current indications, and two of the future scenarios presented in Chapter 6 (Individual Freedoms and Technology Unleashed) show how government decisions and social values could markedly slow down or speed up the adoption of these technologies.

5.7 Why might government potentially intervene in the system?

Predicting the emergence of future technologies and their impacts is inherently difficult; for example, research does not always lead to commercial innovation. As the array of actors, technologies, business models and operational rules evolves, so in turn do the relationships between user, provider and government. Looking forward to 2040, and given the scale of changes we are facing in the transport sector, it is clear that government intervention could play a significant part in routes to adoption, to mitigate market failures, maximise equitable benefits to cities and drive industrial policy goals.

Government can support emerging technologies in a range of ways (Government Office for Science, 2017b). These range from catalysing and spurring innovation and skills, through to setting standards, fiscal incentives and providing platforms. Table 5.4 summarises the reasons for intervention and the issues that need consideration, many of which will persist in 2040. The scenarios in Chapter 6 explain in more detail how government decisions will be critical in shaping the future and in permitting, or not permitting, future transport technologies.

Table 5.3 Reported technology inception dates

Technology	2025	2030	2040	Notes and references
Electric cars	Emerging	Widespread	Widespread	Element Energy (2013)
Level 4 passenger vehicle automation	Niche	Emerging	Widespread	(Underwood, 2014); (Automotive Council UK and Advanced Propulsion Centre, 2017)
Level 5 passenger vehicle automation	Developing	Niche	Widespread	(Automotive Council UK and Advanced Propulsion Centre, 2017; London Assembly, 2018) Contrarily some claim L5 is unachievable (Wolmar, 2018)
Electric LGVs/vans	Emerging	Widespread	Widespread	Element Energy (2013)
Electric HGVs	Niche	Emerging	Emerging	<15 tonnes (Heid et al., 2017)
Level 4 truck automation	Developing	Niche	Widespread	(International Transport Forum, 2017a)
Level 5 truck automation	Developing	Developing/ Niche	Emerging	2042 self-driving trucks common (Transport Topics, 2017); 2035 (Frisoni et al., 2016)
Truck platoons	Niche	Emerging	Widespread	Truck Platoons 2021-2030 (Frost and Sullivan, 2016); 2022 (European Automobile Manufacturers Association, 2017); truck platooning on highways 2025-2030 (Frost and Sullivan, 2015; Underwood, 2014)
Flying cars	Developing	Niche	Emerging	2035, wider commercial applications (Frost and Sullivan, 2017a)
Delivery drones	Niche	Emerging	Widespread	(Walker, 2017)
Droids (ground-based drones)	Niche	Emerging	Widespread	(Yole Développement, 2016)
Hyperloop	Developing	Niche	Niche	2030 first scheduled to complete in Saudi Arabia (Virgin, 2018); Dubai 2022 (Reuters, 2017)
Autonomous underground trains	Niche	Niche	Emerging	London 2030 (Beard, 2014); although technically possible since 1967 Victoria line (Preston, 2017)
Autonomous overground trains	Niche	Niche	Emerging	1980s, DLR/Vancouver sky train for metros; 2022-2024 in France (Atelier BNP Paribas, 2017); currently semi-autonomous on Victoria, Central, Northern and Jubilee lines (Verdict, 2017); 2023 in France (Tarantola, 2017)
Autonomous freight trains	Niche	Niche	Emerging	Already used in Australia (Thompson, 2017; Railway Gazette, 2017; BBC, 2018a)

Without intervention, freight demand will remain fragmented and other urban transport is likely to be negatively affected. Urban consolidation centres, where the freight deliveries for a city are brought together, are a possible solution. Studies have found that these centres decreased CO_2 emissions per parcel by 54% in London (Browne et al., 2011) and decreased delivery movements by 75% in Bristol (Rhodes et al., 2012). However, at present they often

Table 5.4 Rationale for government involvement in transport governance

Need for intervention	Key issues
Public policy	
Set the overall policy direction	Increase recognition of the role of transport in supporting economic growth, social progress and health.
Consider environmental, economic and social externalities	Tackle climate change, air quality, congestion, road and vehicle safety, social exclusion and inequity, which are not adequately addressed through market forces.
Coordinate transport, land-use and economic goals	Plan to accommodate growth in cities while maintaining or improving accessibility; this requires interventions that balance freight, passengers and land use.
Set standards on, and communicate with the public about, transport system operation	There are needs to define levels of service and reporting on how these are met, justify that the spending of taxation is efficient, and manage disruptive events.
Balance the needs of different transport systems and users	Improve decisions made on spending on infrastructure and maintenance, road space allocation, and legal frameworks on rights.
Market failures	
Conditions for a free market do not exist	Manage monopoly infrastructure providers and limited service competition, to prevent collusion.
Act as a provider or procurer of services that are not profitable	There are needs to ensure basic levels of service to communities, evening and weekend services, and for school and hospital transport.
Problems of coordination between modes	Influence competition between public transport operators within and between modes, and ensure that ticketing is integrated.
Basic standards of operation and rules of movement	Improve the interoperability between systems, data and the standardisation of laws and enforcement.
Investment as policy	
Fund the provision and maintenance of infrastructure	Set general and mobility-related taxes and charges at various levels of government, in order to fund infrastructure and subsidise some services; government can borrow at lower rates than the private sector.
Support the adoption of transport innovations	Promote innovations that are sometimes expensive in their early stage adoption or require additional infrastructure; these can be supported by government subsidies, investment or new regulation.
The state is an aggregator of risk and has primary accountability	Ensure that government ultimately remains the guarantor when private provision of public services fails, and retain accountability via the ballot box.

Source: modified from Docherty et al., 2018 run at a loss and companies are not mandated to use them. Local authorities face a challenge in deciding how much to shape freight demand, balancing the savings in terms of decreased deliveries and emissions against benefits to citizens and the costs of providing these and other solutions.

Government also plays a role in spurring innovation and supporting technology development. This is likely to be important in areas where barriers inhibit private sector investment in innovation, or there is a wider social benefit from directing innovation (e.g. reducing environmental impacts). This is a key priority of the Industrial Strategy (Department for Business, Energy and Industrial Strategy, 2017b). Table 5.5 shows how government could intervene at different points in a technology lifecycle, or grow the innovation ecosystem (Government Office for Science, 2017b). Transport-specific examples include the work spurring CAV test beds, in which government acted as an *innovation facilitator* (Innovate UK and Centre for Connected and Autonomous Vehicles, 2017). Similarly, funds for electric buses and subsidies for electric cars, encouraging greener transport, show government acting as a *fiscal incentiviser* (Department for Transport and Ghani, 2018).

5.8 Looking to 2040

The transport system, and people's travel demands, will continue to grow in complexity, due to the increasing diversity of transport and journey type. This chapter has outlined how the growing trends in automation, electrification and the connectivity of transport, alongside the growth of the sharing economy, can meet these demands.

Table 5.5 Government policy levers for supporting emerging technologies

Early intervention	Market framing	Adoption and integration
Catalyser Analyse value chains to identify which technologies present opportunities and long-term value to the UK	Regulator Ensure regulation is sufficiently agile and permissive to enable technology interactions and innovative applications	Intelligent customer Develop a procurement environment that encourages big business to engage with small and medium-sized enterprises in public contracts – allowing them to demonstrate capability and build commercial links
Innovative facilitator Create test beds for developers to try out applications in real-world settings, assess scalability and engage with the public	Standard setter Use insights from 'living labs' to develop UK standards – setting the global agenda by 'showing, not telling'	Platform provider Scale-up deployment of proven technologies in national infrastructure, the NHS and other public services
Skills planner Prepare for growing demand for workers with multidisciplinary technical skills, and mitigate the impact of robots and machine learning replacing unskilled and graduate-level roles	Fiscal incentiviser Deploy financial and other mechnisms to stimultate innovation and market growth	

Source: Government Office for Science, 2017b

Automation is a key technology at all levels, while even small-scale electric vehicles, such as e-bikes, could have a significant impact in reducing congestion and environmental pollution. Data are a key underpinning enabler of many processes, and how we deal with data-sharing and data privacy as a society will increasingly be an issue in the transport sector.

These issues make government and social responses important. New approaches, such as Mobility-as-a-Service and transport-sharing models, will need to meet local objectives but without (inter)nationally agreed data standards, their roll-out risks following a different approach in each local authority. This would create a patchwork of different regulation and data standards, making it more challenging to do business.

New transport services – whether autonomous trains or vehicles – will generate considerable data about everything from road conditions to passenger numbers. By default, these data are likely to be generated and kept by companies (Wilder-James, 2016). Public authorities and other companies would benefit if they had access to these data to inform their decisions. There is a need to ensure the right data are collected, with the correct data standards. The data then need to be shared securely, taking into account privacy considerations. Getting this right could save society billions of pounds (National Infrastructure Commission, 2017a).

Data standards and secure data sharing could save billions of pounds.

Given that transport is a system, a clear governmental vision is critical to improve the system and enable wider positive social outcomes. Yet, as Chapter 2 describes, transport governance arrangements have grown more complex over time in England. Further devolution of transport planning and strategy will add complexity at a time when transport provision and mobility demands are becoming more complicated. Industry and public organisations must cooperate to realise the benefits and avoid worsening congestion, poor air quality and social exclusion.

Too narrow a view (e.g. of each mode independently) will lead to suboptimal outcomes for the system as a whole. By contrast, clear system-level goals will allow government to shape new mobility trends and allow better outcomes for citizens. Finland offers an example of how governments can simplify regulations and reconsider the whole transport system (ITS International, 2017).

While national perspectives are required, local authorities will be increasingly important in shaping transport, as much travel behaviour is local. They must balance ongoing maintenance backlogs with the resources required for operational transport delivery (Ames, 2017). This balance becomes more challenging as travel complexity increases (National Audit Office, 2018).

Policy implications

- **Automation offers exciting possibilities for greater efficiency, but may bring unintended social impacts.** These include urban sprawl, increased congestion or a need to reskill the workforce displaced by this change. Further research will decrease the uncertainty around the impacts of automation.
- **Left to the market, new transport service provision or new business models may not be equitable, either socially or geographically.** Policy-makers could seize local and national opportunities, and consider ways to mitigate any negative impacts of new transport modes or services.
- **Policy-makers could also consider where government goals can be more effectively achieved by new technologies.** This may include the impact of technologies on the rest of the transport system.
- **There are increasing numbers of opportunities to improve efficiency and integration of transport using data.** Local, regional or central government authorities accessing this data will be key to delivering benefits, as the share of privately owned data increases.
- **Carbon emissions from freight are likely to fall, even without policy intervention, but this process will be slow.** To speed this up, regulatory or financial incentives, potentially with new technologies, could be used to encourage firms to invest in emissions-reduction measures.
- **Both central and local authorities can support the opportunities arising for the freight industry.** They could, among other things, facilitate collaboration between companies and clarify legislation. They could also lead by example, for example by requiring their procurement and deliveries to use consolidation facilities, or by supporting the roll-out of connecting infrastructure.
- **There is an appetite for automation in the freight sector.** Realising this would need enabling regulations for drone and droid deliveries, as well as to smoothly integrate platoons and self-driving vehicles into the wider mobility system.

How to think about the future: scenarios for 2040

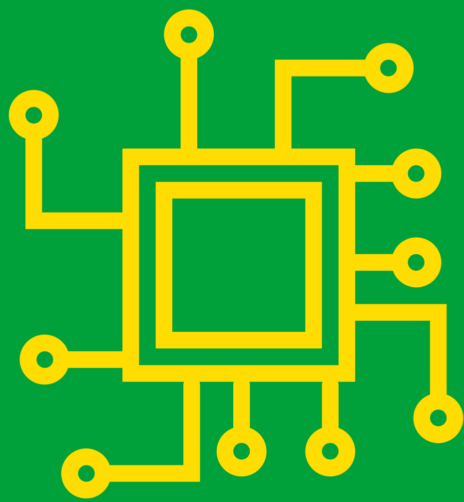
Key findings

- Current trends in the transport system could have positive impacts in the future, but could also negatively affect the poorest people in society, or those in certain places, or reduce the potential for physically active travel. Technology offers exciting opportunities to shape these trends, but government could also consider how to maximise the productivity of existing infrastructure (Section 6.1).
- Exploring different futures using scenarios, and testing policy options under these scenarios, can help deal with uncertainty and mitigate the unintended consequences of new transport modes, technologies or trends. This process leads to decisions and policies that are more resilient and – importantly, given the inherent uncertainties we face – more flexible (Section 6.1).
- The convergence of innovation in physical and digital technologies could transform the public benefits of the transport system. This will depend, however, on careful ongoing mitigation of data risks and understanding how these influence public acceptability.
- Decision-makers will need robust data. This will be required for understanding user behaviour and the likely responses of users to new technology, among other things (Section 6.1).
- Future transport technologies offer economic opportunities for the UK. However, there will be a corresponding need to reskill workers at risk of losing their jobs to automation; this must be considered when planning future shifts in the passenger and freight transport sectors (Section 6.2).

Trends Unmodified

Individual Freedoms

Greener Communities



Technology Unleashed

6.1 Future scenarios

We face uncertainty about how mobility will develop. The further into the future we look, the less certain we are. Given the innovative trends in physical and digital infrastructure, this is a time of change. Using standard planning tools, it is difficult to deal with high uncertainty. By contrast, using scenarios approaches can help policy-makers to make decisions that are more resilient in different futures. They can help them to consider which outcomes are desired, and to identify the kind of future they hope to steer the transport system towards, or away from. Scenarios can also be used to test current policy, and to develop new policies that are more resilient to possible futures.

6.1.1 Methodology

This report developed four scenarios using insights from a cross-governmental workshop combined with evidence collected from the rest of our work. This aimed to identify the critical uncertainties that will influence mobility in the UK between now and 2040. That is, the areas that are most important in shaping the future and which of these have the greatest level of uncertainty. Building on these, future timelines and policy decisions were constructed for each scenario. Rather than a 2x2 grid, a central scenario was built with three different futures diverging from it (Figure 6.1). The critical uncertainties used were transport users' willingness to share data and adopt new technologies, and the extent to which transport will be shared or used exclusively. Other important uncertainties built into the scenarios included: future levels of automation; future rates of electrification; the extent to which physical mobility will be replaced by online alternatives; future use of active transport; the relative roles of public and private actors; future levels of social inequality; and the trade-offs between individual choice and overall social and environmental values.

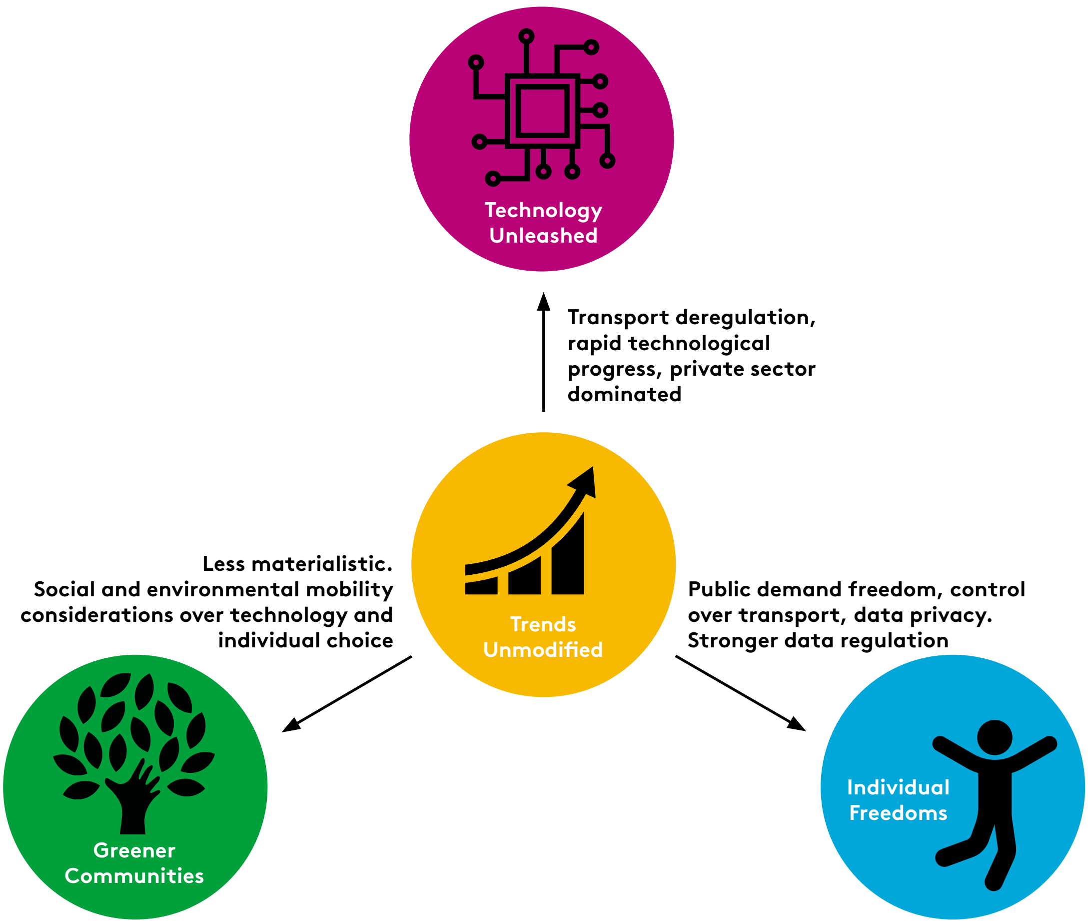
The qualitative scenarios that were developed demonstrate four diverging possible futures: Trends Unmodified; Individual Freedoms; Greener Communities; and Technology Unleashed (Figure 6.1). This chapter provides an overview of these scenarios and the implications of each for government, including the important choices that it could make to shape future patterns in transport and mobility.

6.1.2 Trends that will shape the transport sector of the future

Some trends are common across all scenarios. The UK population is expected to reach 72.7 million by 2040 (Office for National Statistics, 2017b). Our population is also ageing: over 80% of population growth to 2041 will be in the over-65 age group, with the number of people over 85 almost doubling from 1.6 million in 2016 to 3.2 million in 2041 (Office for National Statistics, 2018a). Where these people live will also alter; there will be continued urbanisation, as cities grow to accommodate an increasing proportion of the population.

Rural transport provision in particular may struggle to meet the demands of an ageing population. Left to the market, new mobility services will tend to

Figure 6.1 **Four qualitative scenarios demonstrating divergent possible futures**



operate in more densely populated areas. This could leave some people underserved or priced out and may exacerbate problems with accessibility in rural areas and small towns.

These national trends will occur within a changing global picture. Climate change will place increasing pressure on the natural environment. The UK will become a lower-carbon economy, with a target to reduce greenhouse gas emissions by at least 80% by 2050, relative to 1990 levels. There will also be a shift in global economic power and trading relations. Emerging economies such as Brazil, China, India, Indonesia, Russia and South Africa are growing rapidly, decreasing the dominance of today's developed nations.

Many of these trends will affect the transport sector. The growing and ageing population, combined with current capacity constraints and the expected shift to electric vehicles, could increase congestion and escalate its associated costs. Rapid changes caused by new business models or changing transport provision may mean government has to respond quickly to ensure beneficial outcomes are realised.

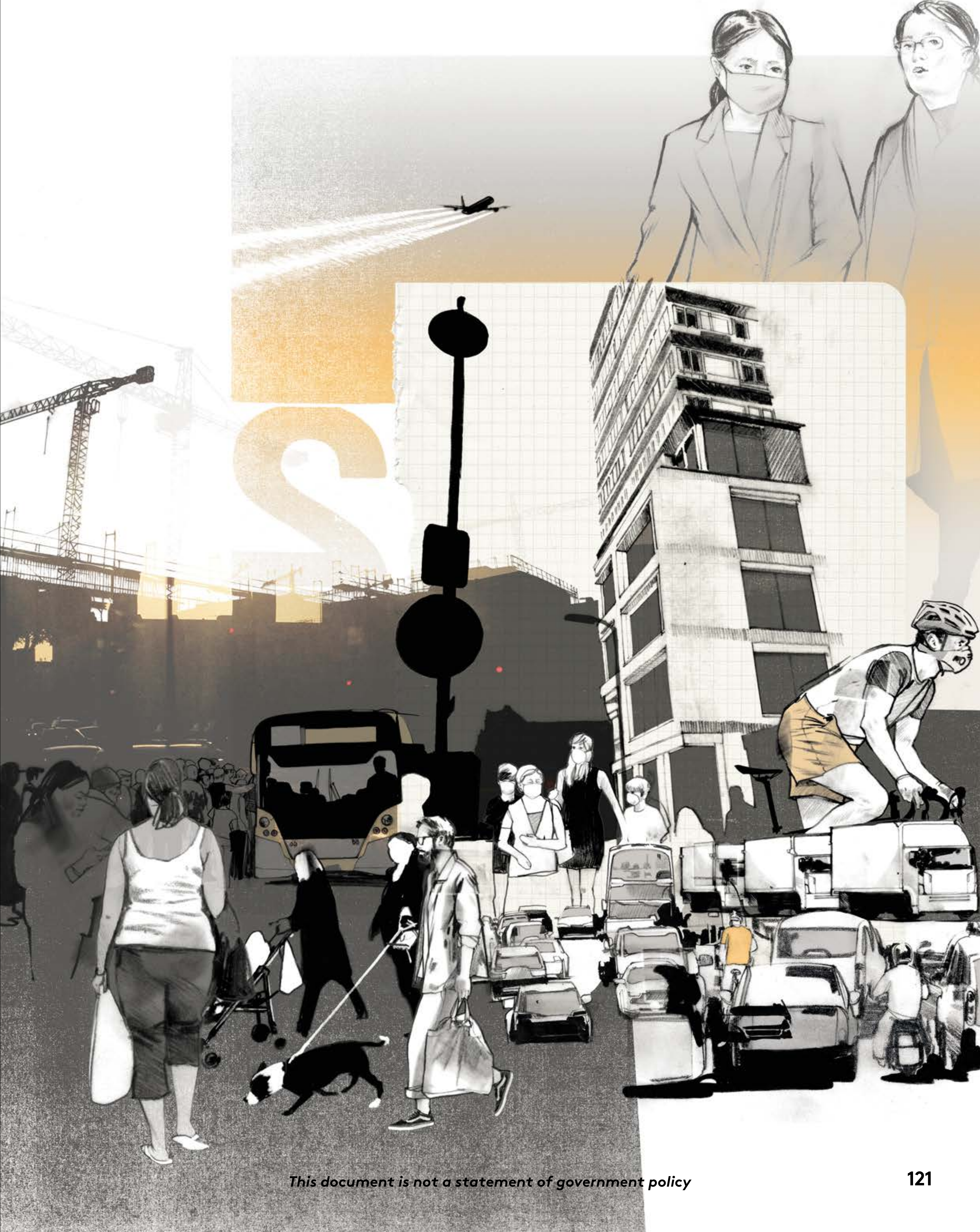
Trends Unmodified

Government is reactive to changes in mobility and a directed approach to reaping the benefits of new technologies in transport is limited

- Uneven use of data and new technology
- Transport sharing is mostly limited to narrow demographic groups, especially young urbanites
- Decarbonisation of transport is patchy, with gaps in electric railways
- Innovation is market-led and incremental, so government avoids losing money from backing the wrong actors
- The UK is less successful in attracting and nurturing global investors
- Automation is deployed, but uptake is limited to roughly a third of passenger miles
- Ride-hailing apps have reduced public transport use in urban areas
- High car dependence and limited active travel contribute to a range of health challenges
- Self-driving HGVs are an investment barrier for small, family-run road haulage businesses, but provide competitive advantage to larger companies, leading to industry consolidation

Hypothetical fictional timeline to 2040

2039	Private car use reaches record high, driven by forced car ownership in poor, suburban and rural households with limited public transport or sharing opportunities
2038	Open water transit via Arctic sea routes is now possible for several months each year, changing UK port competitiveness
2036	Shared transport modes have become well established among young urbanites, but are scarcely used outside this demographic
2033	30 year review of progress since Social Exclusion Unit report on transport and social exclusion finds increasing inequality in access to services and impact of traffic
2031	15% of passenger miles travelled in autonomous vehicles, although almost exclusively in privately owned AVs among the highest socio-economic groups
2030	Rail freight companies replace the Class 66 diesel locomotives at the end of their asset life with more diesel rolling stock, due to key gaps in the electric rail network precluding investment in electric alternatives
2029	Trips for commuting begin to fall, due to changes in working patterns
2027	Facing barriers such as availability of data and fragmented transport governance, the market-leading MaaS provider goes out of business
2026	A major online retailer invests in fleet of 5,000 autonomous, electric HGVs
2025	Electric vehicle use has become more common in affluent areas and sales achieve roughly equal market share with internal combustion engine vehicles (ICEVs)
2023	First autonomous vehicles that operate without human supervision begin driving on UK roads, two years behind government ambition and geofenced within parts of cities
2020	Free wifi on almost all trains and minimum connectivity standards for train operating companies enacted later than government goal



Individual Freedoms

The public demand freedom, independence and control over their transport and are concerned about data privacy

- The collection, use and trade of personalised data by companies is tightly regulated, to preserve individual privacy and liberty
- Non-data-driven technologies thrive, including road and rail electrification, which reduce emissions
- There is no major transport sharing except among established work, friend and family groups
- Active travel, considered liberating and untraceable, has increased, improving sustainability and health of transport
- Safety concerns have prevented the development of AVs that do not require constant supervision by the driver
- Freight consolidation centres ease the pressures of last-mile freight in urban areas
- Congestion has worsened, due to private car use and limited automation
- Use of private electric vehicles grows, as availability of models and charging infrastructure increases

Hypothetical fictional timeline to 2040

2039	Long-distance travel has reduced but local travel has increased as people only trust those near them
2037	Felixstowe, Southampton and London fall out of the top 20 busiest ports in Europe, as competitors embrace data-driven innovations
2036	Private car ownership reaches all-time high and continues to rise
2033	Organisation for Economic Co-operation and Development (OECD) Obesity Update reports that UK has the second highest rate of obesity in OECD countries, due in part to the inactivity caused by car dependency
2032	Major car manufacturers have abandoned AV research and development in the UK, demand is curbed by safety and privacy concerns
2029	Personal Data Act curbs the collection, storage and trade of personal data by private companies
2027	In the fourth major cyberattack in three years, a ride-sourcing app is hacked, releasing users' personal data, including payment information and trips
2025	Congestion costs the economy £30 billion per year in lost time, exceeding the cost of £22 billion a year predicted by the Eddington Transport Study
2024	Enhanced programme of electrification of the rail network included in plans for Control Period 7
2020	#MyData campaign gains momentum, protesting the extent of personal data that is allowed to be collected, stored and traded by private companies
2019	A large-scale trial fails to demonstrate the potential for a successful, commercially viable MaaS offering

Greener Communities

Society is less materialistic and prioritises the social and environmental aspects of mobility over new technology and individual choice

- Data sharing and new technologies are constrained to uses with clear social and environmental benefit
- Transport sharing is widespread, as private car ownership falls and use of private AVs has been restricted
- Transport largely decarbonised, with electrification of rail and widespread uptake of EVs
- Concerns over jobs and ethical issues have limited the uptake of intelligent automation and the associated safety and efficiency gains
- Mobility-as-a-Service (MaaS) has been successfully rolled out and adopted across demographic groups
- High energy prices and demanding environmental regulations slow growth in UK productivity and the trade deficit widens
- Road charging has increased transport sharing, leading to reduced congestion on the roads
- Active travel has significantly grown, improving air quality and providing health benefits

Hypothetical fictional timeline to 2040

2039	United Nations Economic Commission for Europe selects UK as example of best practice in a report on sustainability in transport
2038	Domestic aviation passenger numbers reach lowest level since 1990
2035	Car club and ride-sharing trips overtake the number of trips in privately-owned cars
2034	Institute for Fiscal Studies announce that income inequality between London and the rest of UK has reduced to pre-2007 levels for the first time
2033	Rail's share of the UK freight transport market exceeds 20% for the first time
2031	Private AVs banned for all users except blue badge holders
2029	The first nationwide, fully intermodal MaaS product becomes available
2027	Home working has increased, contributing to a marginal decrease in demand for travel
2023	Walking journeys increase to 300 per person per year and cycling journeys at double the 2013 level, ahead of government's 2025 target
2022	Road charging is introduced to reduce congestion and provide funds to subsidise shared modes
2021	Local authorities lose Supreme Court battle to try to force companies owning ride-sourcing and route-planning apps to freely share data
2019	Following successful trials, fully intermodal MaaS is rolled out in London, Birmingham, Manchester and Edinburgh

Technology Unleashed

There has been deregulation in transport and related industries, while rapid technological progress is dominated by the private sector

- Data is widely shared, driving new transport technologies irrespective of social, environmental or privacy concerns
- Transport sharing is sporadic and used only when alternatives are more expensive or involve a longer wait
- Private cars dominate passenger transport and are swiftly replaced with AVs once these become available
- Social equity challenges exist, so many are priced out of reaping the advantages of new technology
- Government attempts to address social and environmental issues with technological solutions, but has limited success
- Active travel reduces overall, but e-bikes grow in importance, especially among women
- Productive time in AVs drives increases in long commuting and urban sprawl
- Technology increases efficiency in freight, but jobs are lost, and employees lack the skills required to move to newly created jobs

Hypothetical fictional timeline to 2040

2039	80% of passenger miles are travelled in AVs
2038	Almost no internal combustion engine vehicles on UK roads, well ahead of government's 2050 target
2035	Unmanned aerial vehicles carry out a significant proportion of parcel deliveries in rural areas and a small, but growing number in cities
2034	Marches to protest job losses due to automation and worsening wealth inequality draw huge crowds in a number of major UK cities
2033	Government introduces tax breaks for companies who freely share certain types of data
2031	As a fast-growing tech hub, London's population reaches 12 million, exceeding Greater London Authority's projection of under 10 million made in 2017
2029	European Train Control System digital signalling in use on almost all of the UK rail network
2027	Healthcare professionals, academics and charities launch a major national campaign, lobbying government to tackle the worsening obesity epidemic and cite inactivity and AV dependence as key contributing factors
2023	Despite increases in home working and online shopping, the number of trips per capita have increased
2022	Government introduces new vehicle duty framework, incentivising AVs
2021	As the first fully autonomous vehicles hit UK roads, government announces a review of the barriers to their widespread deployment for mass passenger transport
2020	Development of further smart motorways begins

Other emerging trends, such as the shift from ownership to usership (e.g. paying for services in both transport and more widely in society), may bring incremental changes on their own, but their cumulative effect could be transformational. For example, a rise in the use of electric vehicles, increased lift-sharing and a decline in private car ownership would lead to revenues from fuel duty decreasing.

Technological progress will be another major shaper of future transport scenarios. As automation develops, it is likely to have positive impacts on road safety and emissions per mile, and improve accessibility for less mobile people. Yet it is plausible that, without intervention, there could be negative impacts such as increased congestion, urban sprawl and lower use of public transport. Congestion could also be worsened as the price of vehicle batteries falls, the uptake of EVs will reduce travel costs and potentially induce further demand. By contrast, if self-driving vehicles or Mobility-as-a-Service trips remain expensive, they may only be affordable for the wealthiest travellers. There will be further impacts of technology on society: automation will create new jobs, but is likely to decrease the role of drivers in the transport sector.

As discussed in previous chapters, different sectors of the transport system will face unique challenges. Demands on the freight system are changing rapidly. Without intervention, LCVs will contribute further to congestion in and around urban centres, as rapid delivery services continue to grow. Meanwhile, scenarios that explore ways to decarbonise road freight suggest that if government takes no action in this regard, CO_2 emission reductions from road freight by 2040 may only be 61% (compared to 1990 levels), making it harder for the UK to meet its 2050 target (Greening et al., 2018).

Travel behaviours are expected to change. Car-sharing and ride-sharing will grow, but are unlikely to be transformative without clear incentives from government or industry to boost their uptake. These are currently constrained by their low ease of use, cost, social norms and potential risks (perceived or real) of travelling with strangers. One potential future outcome – driven by the possible decline of public transport, combined with the wider limitations of the transport system, and users' habits and unwillingness to share – is a UK dominated by privately-owned self-driving vehicles that increase congestion and urban sprawl.

As discussed, a decline in active travel – notably walking and cycling – could mean that the negative health impacts of an increasingly inactive population persist. These include problems linked to obesity and coronary heart disease. Obesity was responsible for around 30,000 deaths in 2017, depriving individuals of nine years of life on average (Public Health England, 2017). This may be worsened if cheap self-driving vehicles enable more door-to-door travel (i.e. reducing the need to walk to bus stops or train stations) and increasing amounts of sedentary time. Active travel is not the only solution, but it can help mitigate these risks. Levels of active travel are already low by historic standards, but the significant latent demand for this mode of transport means there is potential to increase it (Grous, 2011), if the right incentives and infrastructure are put in place.

The rapid uptake of new modes of transport, Mobility-as-a-Service and automation are all heavily dependent on public acceptance and, particularly, people's willingness to share data. This trajectory is highly uncertain and could easily be influenced by data practices in other policy areas. Examples include health, identity data and the use of personal data by social media companies. Data leaks, breaches or misuse by companies, individuals or governments could strongly change perceptions of the information environment.

None of these issues is wholly avoidable. Government faces clear choices as to how to respond to each, and new trends and technologies will bring new ways to respond, while also influencing emerging situations. The four scenarios highlight some of the choices and trade-offs.

6.2 Implications for government

These scenarios show that the future of the UK's transport system involves many variables that will be highly influenced by government decisions. These include support for technology and pricing schemes and incentives, as well as fundamental uncertainties that are less open to government intervention, such as public acceptance of new technologies and concerns about data use and the degree of sharing. The relationships between these are highly complex, but government clearly has the power to shape the future to some extent – or to choose not to shape it and allow market forces and personal choice to determine the future. Some of the choices that government faces will have potentially huge impacts; these include the following.

How tightly should government constrain data use?

The 'Individual Freedoms' scenario expects individuals to value their liberty and privacy, and so choose not to trust companies with their data. These limits to data-sharing constrain the roll-out of Mobility-as-a-Service and the rate of automation.

Should government incentivise sharing behaviours?

The 'Greener Communities' scenario is driven by people prioritising environmental and social values over individual freedom of choice. This sees an increase in the use of shared transport, decreases in congestion and CO_2 emissions, and improved air quality – but at the cost of flexibility and personal freedom. This scenario aligns with evidence from simulations in Helsinki and Lisbon, in which shared demand-responsive transport reduces passenger CO_2 emissions and congestion by a third (International Transport Forum and Corporate Partnership Board, 2015; International Transport Forum, 2017b). However, car-sharing and ride-sharing are unlikely to take off without significant government or industry stimulus (see Section 4.2.3).

Should there be a national vision for the transport system?

The 'Trends Unmodified' scenario shows that if decisions are made incrementally as the system evolves, the adoption of new technology is likely to be patchy, and good practice will only be focused on certain areas or systems; government leaves investment choices to the private sector. This new technology will be poorly integrated and some places and people may be left behind. This demonstrates the importance of having a clear national vision, combined with a systems approach, to achieve the best outcomes for all citizens. Households, businesses, regions and modes trying to make optimal decisions in isolation are unlikely to result in the best outcomes for the transport system as a whole.

How should new mobility technologies be introduced?

The 'Technology Unleashed' scenario has the UK swiftly adopting new technologies, but with growing inequality and job losses (faster than for other scenarios) due to automation. New technologies are usually expensive and likely to roll out first to early adopters with higher incomes. Then, as the price falls, they become more available to the less affluent. Government could consider reskilling people in advance of coming automation, particularly in passenger transport. The rise of automobility in the last century left behind some women, ethnic minorities and those who could not afford a car (Gunn, 2018b). History, alongside this scenario, raises important questions: who may be left behind by new technologies? What will the implications be for them, and for the geographies that are excluded?

What if transport demand is flat?

Our scenarios assume that a growing population will increase transport demand, but it is possible that younger cohorts will travel less in the future, meaning transport demand will not increase. While not described in detail, this report includes this possibility to challenge the thinking behind these scenarios.

Other key decisions for government to consider include:

- How much to constrain travel demand?
- Which social activities should or should not be enabled by transport?
- What vision does it have for how people travel?
- How to incentivise system designs that benefit both transport and health?

Having considered what the future could look like through these scenarios, Chapter 7 looks at how the challenges vary in different geographical regions.

Geography of the transport system

Key findings

- **Transport challenges vary with geography, and different regions require specific solutions.** Local authorities are central to delivering these solutions, but their in-house investment in expertise varies considerably across the country (Section 7.2).
- **Public transport provision and use is highest in urban areas.** The high density of infrastructure makes cities more attractive, and potentially more profitable, for innovators and technology companies (Section 7.1.1).
- **The rapid growth of freight and last-mile deliveries in urban centres presents environmental challenges.** These include congestion and air pollution (Section 7.2.1).
- **There is significant variation in the use of different modes of transport between smaller cities and towns.** However, buses remain the main form of public transport in these regions (Section 7.2.2).
- **In rural areas, people depend on cars as public transport is often limited.** Without private vehicles, their access to employment, healthcare and education would be constrained (Section 7.2.3).

the car's modal share in UK cities is among the highest in Europe

24%

higher spend by rural vs urban households, as % of disposable income

80%

proportion of rural dwellers who live within 4km of a GP surgery (compared with 98% of urban dwellers)

7.1 Relevance of geography

Different regions have different characteristics – physical, social, historical, economic and cultural – and these lead to variations in the transport system, in terms of the challenges it faces and the infrastructure present. Tackling the many specific issues cannot be achieved through a single approach; cities, towns and rural areas all need targeted strategies and policies to unlock regional growth and overcome their specific challenges. Yet transport is intrinsically interconnected. This creates a tension between the need for targeted local solutions, the benefits to society of integrated policies between regions and the need to consider the differing priorities of passengers, freight, housing and land use.

This chapter examines the challenges facing three settlement types: urban conurbations, smaller cities and towns, and rural areas (section 7.2). It looks at a range of issues, including car use, land use, funding and transport availability.

7.1.1 Trends in car use and public transport use

There is a large variation between different parts of the country – notably between London and the rest of the country – in terms of the transport modes that dominate, the distances people travel, and the number of trips undertaken. These trends also vary between type of region.

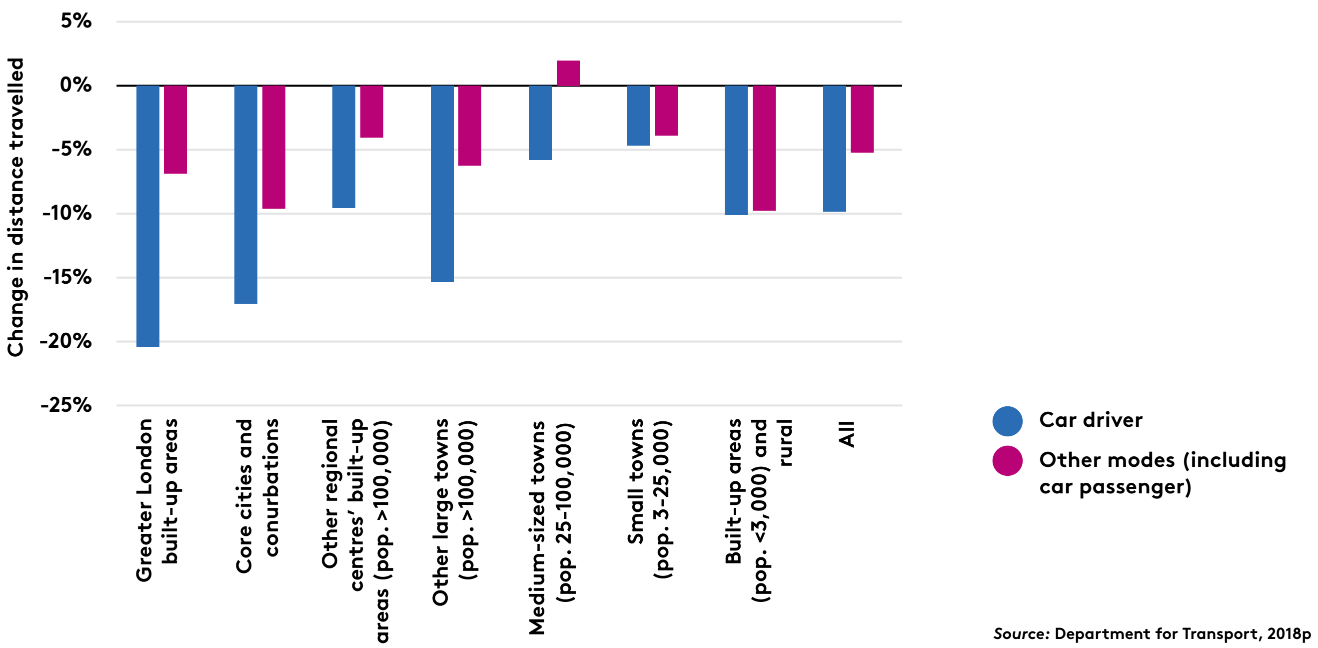
Broadly, as settlement size decreases, people take more trips in cars and use public transport less (Department for Transport, 2017, NTS9903). In rural areas, services are more spread out and there are fewer public transport options. As a result, the average number of car miles driven each year is 1.8 times higher than for people living in conurbations, and constitutes 30% of the country's overall car mileage. However, there has been a reduction in car-driver miles per person since 2002 across all settlement types in England (Department for Transport, 2018, NTS9904).

As areas become more built up, total miles travelled and car-driver miles per person decrease (Department for Transport, 2018, NTS9904). For example, in 2016/17 London residents travelled the shortest overall distance, at 4,608 miles per person, of which 51% were in a car on average. By contrast, rural residents travelled the longest distances, at 10,055 miles per person, with 88% of these in a car (Department for Transport, 2018, NTS9904).

Overall, though, people are travelling less. Figure 7.1 shows time-series data from the National Travel Survey between 2002-2005 and 2011-2014. The figure illustrates the reduction in car-driver miles and total distance travelled across nearly all types of region. For car miles, this reduction was largest in London; for other modes of transport, the greatest change was seen in built-up areas below 3,000 people, and in core cities and conurbations.

The rail sector bucks this trend of less travel. The distance travelled by rail increased in all geographical areas of the UK between 1996 and 2014 (Independent Travel Commission, 2016). Much of this is due to growth in London, which saw a rapid increase between 2008 and 2014 despite increases in

Figure 7.1 **Distance variation across rural-urban classifications, England, 2002-2005 to 2011-2014**



Source: Department for Transport, 2018p

rail fares. Unsurprisingly, London also represents the largest number of rail miles per person per year. By contrast, rail travel in rural areas has remained broadly stable since 1996 (Independent Travel Commission, 2016).

7.1.2 Land use and the transport systems

There are many relationships between land use and transport, and these are often well established. Patterns of land use in and between settlements have shaped mobility patterns across the UK. Often, this is in the form of constraints: in urban areas, for example, the built environment often limits where new transport routes can go. These constraints are locked into the urban landscape; transport infrastructure is long-lived, and retrofitting it to new pressures and trends can be costly and impractical.

In other places, land-use patterns encourage car travel. For example, where streets are dangerous, polluted or noisy, they discourage people from walking or cycling; poor access to public transport also pushes people towards car use. Increased car use has further consequences in these areas, contributing to environmental and public health issues, such as pollution and obesity. Similarly, some places have a tendency to contribute to obesity – the so-called obesogenic environment (Jones et al., 2007). Factors such as a poor pedestrian environment, a lack of access to healthy food and the extent to which neighbourhood design encourages or discourages active travel all have a strong impact on people's choices, and hence their health outcomes.

Land-use and transport planning also affect people's access to services and low-cost housing. For those without a car, access to services (e.g. healthcare, schools, shops) depends on where these are located (land use) and also the transport options available to reach them (transport). The planning system for any region must therefore consider both land use and transport provision, and how these can positively influence each other. This is essential, as inequalities in the provision of transport services can limit people's access to these services and to jobs; this in turn influences where people live, which can contribute to issues such as over-demand in some areas and depopulation in others.

7.1.3 Funding for the transport sector

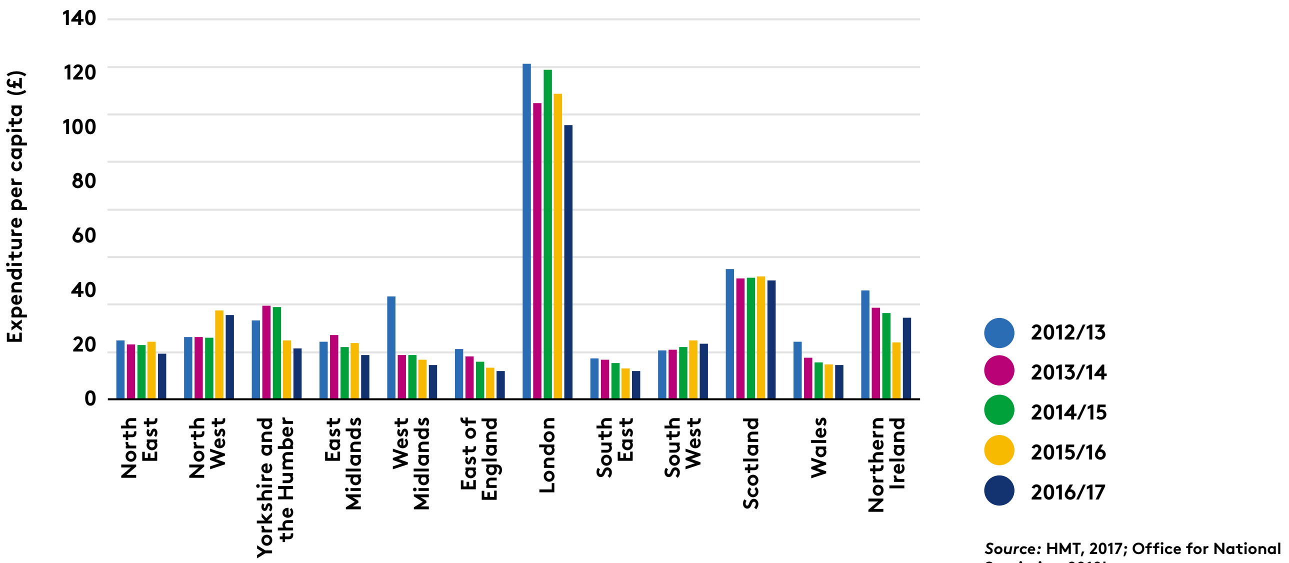
Another factor driving regional differences is the level of funding available. London spends significantly more on public transport than other UK regions, and it also has the highest revenue (HMT, 2017). This reflects the size of the transport infrastructure in London, such as the vast network of surface and underground rail lines, as well as the size of the resident population (House of Commons, 2018). London also spends the most per head (Figure 7.2) (House of Commons, 2018). Spending per head is calculated based on the resident population, however, so it does not take into account the large number of in-commuters and visitors who use London's transport network each day.

7.1.4 Local travel preferences

Local travel varies widely in smaller cities and towns across the UK. In Brighton and Hove in 2016/17, there were 172 bus journeys per person, compared to an average of 47 for England as a whole (Department for Transport, 2017b; see Section 3.1.2 for further details).

While residential density plays some role in observed travel behaviour – densely populated places generally have more public transport infrastructure, leading to higher use – it cannot fully explain it. Travel behaviour is also influenced by a range of cultural, socio-economic and demographic factors (Royal

Figure 7.2 Government local public transport spending per head by region, 2012/13-2016/17



Source: HMT, 2017; Office for National Statistics, 2018b

Town Planning Institute, 2018). This emphasises the need for a targeted approach to transport planning, one that reflects localised differences.

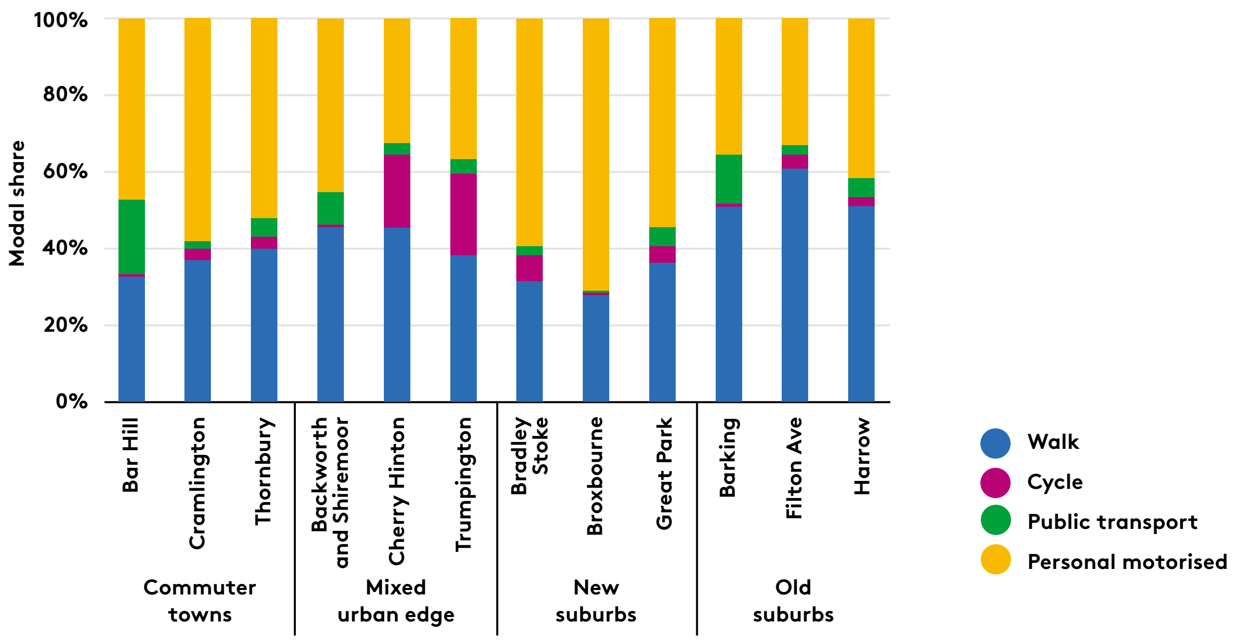
There is evidence that suggests that high levels of car dependency and low levels of active travel are more common in towns that grew sharply in size during the 1980s and 1990s, when land use favoured allocation to road space. By contrast, older towns have higher levels of active travel and lower car dependence. This can be seen in Figure 7.3, which illustrates difference in mode share between a range of places that represent newer and older suburbs, and with commuter towns and mixed urban edges. This trend is an example of what is observed elsewhere in the UK, and reflects how the spatial constraints (closely linked with the age) of an urban area influence the available transport infrastructure and resulting travel behaviours.

7.2 Current transport challenges

Comparing different types of settlement helps us to understand their specific transport challenges, as well as the opportunities that they may present. This section looks at the challenges and opportunities in three settlement types (Office for National Statistics, 2011b).

- Urban conurbations are agglomerated urban areas. The six urban conurbations in the UK – London, West Midlands, West Yorkshire, Tyneside, Merseyside and Greater Manchester – are home to 39.3% of the total population.
- Smaller cities and towns are those with populations of over 10,000, but that have less than 26% of their inhabitants living in nearby rural settlements or hub towns; these represent 43.6% of the population.

Figure 7.3 Modal transport split by type of built-up area using example towns



Source: Royal Town Planning Institute, 2018

- Rural areas are settlements with populations under 10,000 and include small towns, villages, hamlets and isolated dwellings; they comprise 17.1% of the population.

7.2.1 Urban conurbations

Cities are constrained by their limited space, but, in part due to their higher population densities, they contain more hard transport infrastructure (e.g. urban or underground trains, trams). As a result, larger cities such as Birmingham, London and Manchester provide greater public transport coverage than other settlement types, and its use is higher.

Higher population densities also mean that, in general, distances to jobs and services are shorter. Similarly, due to the ready availability of workers, major employers are often already present in urban conurbations. Despite this, cars are still the main way of getting to work in major UK cities other than London. At least 75% of commuters travel by car in Birmingham, Leeds, Liverpool, Manchester, Newcastle and Sheffield (Guardian, 2018), and the car's modal share in UK cities is among the highest in Europe (Figure 7.4) (National Infrastructure Commission, 2017b).

In London, by contrast, cars account for only 30% of commuter trips, with public transport the dominant mode. Factors behind this include the high quality of public transport, which is linked to it being well funded; there are also several barriers to using a car, including the congestion charge and the difficul-

Air pollution in towns and cities

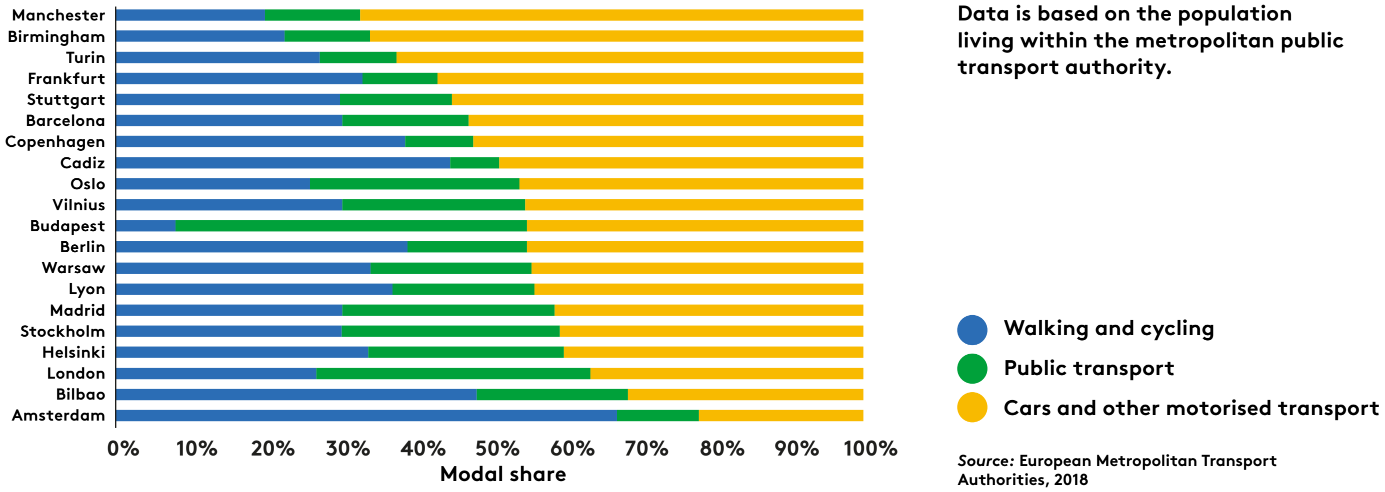
Levels of almost all air pollutants have decreased across the UK over the last five decades (Department for Environment, Food and Rural Affairs, 2018). However, air pollution in urban conurbations, smaller cities and towns remains an issue. For example, while NO_x levels have decreased since 2000, diesel engines still markedly impact air quality in urban areas outside London, with taxis, private-hire vehicles and buses making up a larger proportion of emissions. It is estimated that nitrogen dioxide (NO_2) and $PM_{2.5}$ (also emitted from vehicle exhausts) contribute to 40,000 premature deaths per year (Royal College of Physicians, 2016).

While all 43 of the UK's ambient air quality reporting zones,[12] except for the Greater London Urban Area and South Wales, were within the safe limit value for hourly mean NO_2 in 2015, only six of these complied with the annual limit for average NO_2 (Department for Environment, Food and Rural Affairs, 2017).

Local authorities are required to implement Air Quality Management Areas to tackle air pollution. All 33 of London's local authorities have done so, but only 209 out of 293 have in the rest of England have, and only 14 out of 32 in Scotland (Scottish Government, 2018) and 11 out of 22 in Wales (Welsh Government, 2018).

12. See Annex C of Department for Environment, Food and Rural Affairs (2017) for a map of these zones.

Figure 7.4 Modal share of trips in selected European metropolitan areas



Source: European Metropolitan Transport Authorities, 2018

ties of parking. However, in London and other conurbations, car use rises with distance from the city centre. Car use in inner London is 20%, Greater London 35% and Outer London 45% (Transport for London, 2018c).

Transport can cause significant economic stress, especially where household spending on transport is a significant proportion of income. This burden is closely tied to people's income, where they live and how easy it is for them to access jobs and services. The cost burden is larger for people on the outskirts and less accessible areas of cities (peri-urban areas). It is worsened by factors such as urban sprawl, poor access to public transport and negative exposure to vehicle traffic (Lucas et al., 2016). In London, the widespread availability of low-cost public transport means personal transport spending is lower, despite high concentrations of low-income groups. In the Greater Manchester and the West Midlands, by contrast, those spending the most on transport relative to their income are widely spread, but more concentrated in these peri-urban areas (Lucas et al., 2018).

Another challenge in urban conurbations is last-mile deliveries (see Chapter 5). These have a disproportionate impact on the environment and on businesses. In particular, the rapid growth of LCVs adds to congestion in dense urban areas, where the demand for goods and services is high. Last-mile deliveries also worsen air pollution, generating the most CO_2 per tonne moved (Ranieri et al., 2018). These effects are increasing much more in outer London: LCV traffic in central London rose by 1% between 2000 and 2015, but by 22% over the same period in outer London. The low LCV figure for central London is in line with the general trend for traffic in central London (Transport for London, 2016).

7.2.2 Smaller cities and towns

Smaller cities and towns experience some of the challenges found in larger conurbations, for example congestion at peak times and poor air quality.

However, these issues are compounded by the relative lack of hard infrastructure compared to conurbations, and the more limited options for freight, as consolidation of resources is more difficult at smaller scales.

The lack of hard infrastructure (e.g. railways) means public transport is largely bus-based. There is a large variation in modal shares between different towns and cities, reflecting the level of available infrastructure for public transport. There is also significant variation in trends between towns, small cities and urban conurbations (Department for Transport, 2018p). Many small cities and towns have developed more car-dependent behaviour than urban conurbations. The costs of, and returns from, rail, light rail, road, trams, and cycling and walking facilities also vary between different towns and cities (Eddington, 2006).

However, there are some general trends. The lower population density (compared to urban conurbations) can mean that rail and light rail services are not economically viable, given the costs of building the necessary infrastructure (i.e. railways) and operational overheads. Bus transport often offers a lower-cost option in such places, as it can use existing roads. It is especially attractive when it has designated road space (e.g. bus lanes) or its own prioritised route (bus rapid transit). Increasing bus services is often a more viable alternative than building new road or rail networks. However, if bus services to a town or small city decrease for any reason, the lack of alternative public transport options may reduce some people's access to economic and social opportunities.

As Chapter 2 highlighted, the structure of the UK's transport governance system is complex. In smaller cities and towns, this represents a further challenge: decision-making about transport infrastructure can involve local authorities, combined authorities (corporate bodies made up of two or more local councils that work on common issues) and Local Enterprise Partnerships, along with central government. Overall responsibility for transport infrastructure lies mostly with central government, which is a complex landscape in itself, and delays here can impede decisions that would benefit transport systems at local levels (Institute for Government, 2017).

More decision-making has been devolved to local authorities, through initiatives such as the establishment of sub-national transport bodies (e.g. Transport for the North, Midlands Connect), while metropolitan areas with elected mayors also have responsibility for certain transport decisions. But while generally viewed as an effective approach, outside of London only 22% of the population live in a combined authority area with a mayor (National Audit Office, 2017). There is also a balance to be struck between more devolved (by geography) decision-making powers and larger geographical areas that, for instance, cover increasingly large travel-to-work-areas.

7.2.3 Rural areas

Providing a public transport service that meets the accessibility needs of all rural users is a major challenge, given the range of different needs and the barriers to providing a reliable, cost-effective transport system. For example, people in rural areas usually have to make longer journeys to reach services. On average,

50%

Rural residents travel 50% further per year than urban residents.

people in the most rural locations travel almost 50% further per year than those living in urban areas (Department for Transport, 2018, NTS9904). Limited public transport and declining local services are major factors behind this relatively poor accessibility in rural areas, and help to explain the car-dependent behaviour often found (Scottish Government, 1998). This may also contribute to a greater desire to work from home or have a home-based business: 13% of people living in villages and remote dwellings mainly work from home, compared with 5% in urban areas (Office for National Statistics, 2011a).

The rural transport network faces further pressures. There are difficulties in integrating transport services, given the dispersed nature of residents, and the low population density in rural areas makes it difficult to operate profitable commercial local transport services. Demand is also low, due to the tendency towards car use.

As a result, subsidies are often needed to run public transport services in rural areas. Maintaining subsidies becomes more challenging in times of constraint, though; for example, over the period 2012-2017, spending on local public transport decreased (HMT, 2017). This includes bus services, and overall, the UK trend outside of London is a decline in these. Local authorities have an obligation to secure certain services that are not commercially viable but necessary for social reasons; however, this contributes to less funding being available for other rural bus services.

It is not just the number of routes served that affects accessibility: the low frequency of many services makes it less likely that they meet people's requirements for work, education or health appointments (Commission for Integrated Transport, 2008). Lucas et al. (2018) calculate that around 5.5% of children in England and Wales cannot reach a secondary school within 30 minutes by public transport, although these are mainly in more rural areas. Limited public transport may also constrain people's access to healthcare in rural areas (Shergold and Parkhurst, 2012), with 80% of rural dwellers living within 4km of a general practitioner's (GP) surgery, compared with 98% of urban residents (Porteus, 2018).

Where accessibility to transport is low, lower-income households in particular may struggle to access services. Rural households spend more than urban households on transport: 19.5% of disposable income per week at 2017 prices, compared with 15.7% for urban households (Office for National Statistics, 2018b). The rural population is also ageing, and a lack of affordable transport can be an issue for older people, one compounded by low accessibility and personal mobility issues (Department for Transport, 2012).

The lack of regular, reliable and affordable public transport can also affect young people in rural areas, worsening their job and education prospects. Two key limiting factors affect their ability to choose alternatives (i.e. private vehicles): having a driving licence and being able to afford a car (Shergold and Parkhurst, 2012).

The most rural locations receive slower and significantly more expensive freight deliveries (Moyes and Morrison, 2015).

7.3 Future opportunities

There is no one-size-fits-all solution to the contrasting transport needs found across the UK. A targeted approach is required, supported by a clear national government vision for transport. This will help different geographies – urban conurbations, small cities and towns, and rural areas – to pursue integrated outcomes and ensure alignment between different types of transport, through the various layers of governance (local, regional and sub-national).

New trends, business models and innovative technologies offer potential solutions to some of the challenges outlined across different geographies. Some are more likely to succeed in higher-density areas, or in areas with younger populations, and these could be targeted for roll-out. Others, such as remote-working technologies or diversifying land use, if shaped and implemented carefully, could reduce the overall travel demand.

However, with these solutions there is a risk of further isolating other groups, such as older, disabled and poor people, in both rural and urban areas. Technology alone will not bring about sustainable changes in mobility for everyone and history has shown that poorer communities are often left out of mobility revolutions (Gunn, 2018b). A better understanding of specific barriers and a willingness to change are also needed, as behaviour-change interventions are essential to target both individual (Chapter 4) and structural factors in the system (Chapter 2 and 7).

Rural households spend more than urban ones on transport.

7.3.1 Urban conurbations

Mobility-as-a-Service (see Section 4.8) is more likely to succeed in larger cities, because denser conurbations with more fixed infrastructure offer more multi-modal transport options. The younger populations found in larger cities increase the likelihood of its uptake. People are also more willing to use shared modes of transport (e.g. lift shares) if they have a good public transport network to fall back on (Golightly et al., 2018).

The benefits brought by Mobility-as-a-Service can be more fully achieved by:

- ensuring it is equitable and contributes to poverty reduction, for example by subsiding socially beneficial journeys as part of a mobility package
- clarifying the regulations about the use of private-hire vehicles
- harmonising data standards to provide the private sector with more certainty when developing Mobility-as-a-Service or sharing models, and allowing for flexibility in implementation at local levels; the Department for Transport is already undertaking pilot work in this area, and plans to build on successful projects
- maximising the benefits from harnessing new digital technologies, and minimising the negative impacts, by managing transport demand and use of vehicles
- ensuring people in suburbs are not excluded from new opportunities.

Congestion and air pollution are major challenges affecting larger urban areas, but these may be reduced by the trends towards vehicle automation and electrification (see Chapter 5). However, accompanying digital and physical infrastructure are needed to realise these benefits. There is some progress here: local authorities are already implementing Clean Air Zones, for example. There are also a range of measures for cleaner urban freight deliveries, such as urban consolidation centres to receive goods and group them into fewer, fully loaded vehicles for last-mile deliveries. Sustainable modes can be used for some deliveries in urban centres, for example rail or water-based connections or deliveries by cycle, though the geography and distances involved will determine the viability of these. Greater use of electric vehicles for deliveries would also improve air quality.

7.3.2 Smaller cities and towns

Smaller cities and towns are generally more compact than conurbations, which means walking and cycling are practical ways of getting around. Consequently, e-bikes are likely to succeed here. Many journeys are short and, for city journeys, an e-bike will often be quicker than a car. E-bikes also increase the attractiveness of cycling in hilly areas. However, both soft and hard factors are needed to maximise this uptake, such as separate cycling infrastructure augmented by a campaign to promote cycling (see Chapter 4).

Autonomous buses could increase the efficiency of public transport services, but the challenge is to find the right balance between coverage (how large an area to serve) and ridership (how many people to serve). Demand-responsive transport increases service flexibility, but is more useful for improving coverage than increasing ridership. For example, a 'dial-a-ride' bus service had typical usage of 0-3 passengers per service hour, compared with a suburban bus of 10-40 people per service hour (Walker, 2018).

Away from high-density areas, fixed-route services can serve more people than flexible demand-responsive routes. However, as with first- and last-mile transport, demand-responsive services could feed into main transport networks, in a 'spoke-and-wheel' arrangement. For example, a Bristol bus company is launching 'My First Mile Pilot', a small, shared private-hire vehicle service. Booked using an app, it takes people from near to their homes to a bus stop on a well-served route into the city (and back home again afterwards). This was established after analysis of anonymised mobile phone data showed that many people commute on this route (Yong, 2018), demonstrating the opportunities offered by a data-rich approach to transport planning. And there is scope to pursue this further: smart ticketing generates significant operational data which is seldom used (Bryan and Blythe, 2007). Furthermore, local authorities must be prepared for the challenges associated with new technologies that will affect transport and land-use planning (see Chapter 5).

7.3.3 Rural areas

Better transport is critical to ensuring good accessibility for rural communities, which they need to thrive. A number of options are already in place: sharing modes of transport, such as rural car clubs and community-based transport services. Fully autonomous vehicles could prolong independent travel later in life, providing freedom and independence to people who can no longer drive (Ormerod et al., 2015). This may be particularly important in rural areas, where the population is ageing rapidly.

Autonomous transport could also be deployed to good effect in rural areas, filling the gaps in the public transport network and increasing availability, affordability and accessibility (Institute of Mechanical Engineers and Age UK, 2017). However, research shows that even if drivers are replaced by automation, many users prefer someone on board for safety, assistance and companionship (Center for Global Policy Solutions, 2017; Comfort, 2018). It will be interesting to see if this attitude changes as autonomous vehicles become more prevalent. Dynamically-routed autonomous buses could also improve people's access to services while reducing the need for transport subsidies, as they mean buses are more targeted to need, so fewer underused routes are operated.

Digital connectivity is a key enabler for rural areas.

Digital connectivity and infrastructure are critical for innovative services to be cost-efficient and successful. Digital platforms may increase the reach of demand-responsive services (e.g. car/ride-sharing or demand-responsive buses) and enhance the independent mobility of people in rural locations (Transport Systems Catapult, 2015). The uptake of digitally enabled transport services is linked to users' willingness to adapt to new technologies, however. Few citizens in rural areas currently use digitally based on-demand or sharing-based services. It also depends on the right digital infrastructure being put in place. Dynamic routing in rural areas and the roll-out of CAVs will need supporting infrastructure. Measures to encourage the use of digital platforms, such as demonstrations or pilots, need to be implemented alongside the services.

Rural areas can also benefit from new technologies in the freight sector. For instance, the larger spaces around properties could allow for freight deliveries by UAVs. Currently, rural locations are an expensive part of the freight network and are hard to access. Hard infrastructure is not necessarily needed for aerial or even ground-based unmanned vehicles, and they avoid exacerbating ground-based congestion.

Policy implications

- **Across urban, peri-urban and rural areas, effective land-use planning is critical for integrating freight and passenger transport with housing and economic priorities, among others.** Policy-makers need to plan buildings and infrastructure that allow for sustainable travel options, healthier lifestyles and smoother delivery of goods. Doing this at the start is cheaper than expensively retrofitting transport infrastructure to cope with future demand.
- **Rural areas present a significant challenge to transport planning, but also opportunities to provide healthy, sustainable transport for older people and isolated groups.** For example, dedicated infrastructure for active modes, notably walking and cycling, improve health, reduce physical inactivity and sedentary lifestyles, change transport behaviours, and contribute to reducing air pollution and congestion.
- **To increase the uptake of cycling and walking in urban areas, investment in hard infrastructure (e.g. separate cycling or walking networks) and softer factors are both necessary.** Internationally, some cities are already doing this well. The design of places and spaces that contribute to better health outcomes for citizens should be considered alongside new infrastructure investments, as laid out by Public Health England (2018).
- **Cleaner transport modes for freight deliveries in urban areas are available.** For example, electric cargo bikes and urban consolidation centres can mitigate some of the environmental issues associated with the growing freight sector.
- **New service models such as Mobility-as-a-Service are likely to increase, especially in larger cities, and there is growing private sector interest in these.** Going forward, it is important to maximise the benefits from new technologies and minimise the potential negative impacts, for example by levelling the playing field for operators and ensuring equitable service provision for users.
- **Common data standards between regions will ease the roll out of business models.** This could improve data sharing, and ultimately support decision making.
- **Accessibility remains a key policy challenge in urban outskirts and suburban areas, despite the rise in new forms of mobility.** Density and geography strongly dictate costs of provision, and potentially who and where will be left behind.

Conclusions, challenges and opportunities

Summary of main findings

Chapters 1 and 2 highlighted the challenges faced by the transport system over the 20th century. Government innovation at that time was often hampered by path dependency – old infrastructure, fixed capital and inherited working practices – which made it harder to tackle problems (Divall et al., 2016). Today, the transport system faces many similar challenges: congestion, pollution, transport poverty and urban/rural disparities. The future of these challenges depends on the policy choices made, but will also be shaped by further factors: changing travel behaviours and new technologies, among others. These will combine to shape the public's relationship with data, technology and transport, and their appetite for and acceptance of technology options.

Although the transport system today faces many pressures, challenges and opportunities, there are some overarching facts and trends that shape the current context for decisions about the future.

Transport is vital. It enables the efficient movement of people and goods and is an essential part of a productive economy. This has significant regional implications. It is also important for social cohesion, health and well-being as it allows for personal choice, freedom and access to opportunities.

For historical reasons, transport governance is complex and fragmented. This makes it challenging to integrate outcomes for different modes and regions, and to coordinate investments to support a joined-up transport system.

Automation and electrification of vehicles are coming. These developments will offer positive benefits in terms of reduced emissions, improved road safety and increased accessibility. However, there will be negatives too: due to vehicle electrification, revenues from fuel duty will decrease. Left unchecked, further unintended impacts on the transport system are likely. The potential impacts of automation on the livelihoods of the driving workforce needs to be anticipated, for example. Automation could also increase travel demand, with knock-on effects on car use, urban sprawl and congestion. By considering all uses (private, public and freight) and users, and how they interact with new technology and connect using data, government can shape the future in a positive direction.

There are good reasons for government action. Our scenarios (Chapter 6) demonstrate four plausible futures for the UK, in which different social and governmental choices interact. They highlight that different attitudes – among the public and government – to new technology, data-sharing and shared transport could lead to very different outcomes. Aspects of the trajectories to these scenarios represent policy choices for government.

Summary of scenarios

Our **Trends Unmodified** scenario highlights a world where the private sector leads, and government is more reactive than proactive. It envisages autonomy leading to a marked decrease in public transport, and congestion rising. In this scenario, uptake of new technology is patchy, with some areas doing so enthusiastically, and others less so. Government avoids betting on one future clearly, and so does not risk backing technologies that ultimately may prove to be a flash in the pan.

It is plausible that the coming trends will worsen social exclusion. Our **Technology Unleashed** scenario highlights a world where there has been rapid technological progress. Some new technologies are rolled out to wealthier consumers first, worsening inequality between regions and between rich and poor. While uncertain, the locations of the poorest are likely to be in areas that are harder to cover by mass public transport (suburbs and outskirts).

Our **Greener Communities** scenario highlights a world with lower productivity, but where sharing is more common and socially acceptable. This means that technology inception is slower, but sharing is more widespread and technologies that deliver social and environmental goals have more traction with the public.

Our **Individual Freedoms** scenario highlights a world where people value their personal freedom and their personal data, and are not prepared to have unfettered sharing. In this scenario, the higher value placed on liberty means that citizens are not driven towards new technologies which are dependent on data. This constrains the uptake of automation and Mobility-as-a-Service, and limits the efficiency of some new technologies.

Policy perspectives

Based on our analysis in this report, we identify the following important considerations. Across all our considerations, data and its use, if appropriately shared, will be critical in transforming social practices, enabling new technology, allowing better modal integration and improving planning.

1. **Consider transport as a system, rather than loosely connected modes.** This will maximise the delivery of government goals and aligns with the Department for Transport's Investment Strategy (Department for Transport, 2017f) to support the achievement of integrated outcomes;

it will also bring wider social benefits (e.g. employment, health, access to services). Aligning policy levers for intervention can improve outcomes, deliver value for money and minimise the burden of a complex governance landscape. The recent emergence of more powerful data tools creates an opportunity to examine the system as a whole.[13] Tools such as System Dynamics have helped to understand the complex dynamics of road use in US cities (Sterman, 2000). Building on this, Boston is combining systems tools and powerful system data to shape its transport system (McCloskey, 2017).

2. **Consider the wider objectives that the transport system can help to achieve.** The transport system is greater than the sum of its parts; it is not just a means of travel, but a critical enabler for the economy and society. Health and well-being, social inclusion, job opportunities, trade, access to services, sustainable places can all be harnessed and achieved through careful design and planning of the transport system. Trade-offs will need to be addressed and this requires broad collaboration across government. It also requires value judgements as to which outcomes are more desirable and, as such, should receive greater weight.
3. **Outline a clear long-term national vision and goals that are mindful of diverse local priorities.** This will allow coming trends and modes to be shaped rather than responded to. Infrastructure decisions have long-lasting effects and there are choices to be made now; these should focus on how best to optimise the whole system. One way that government could set out such a vision is by responding to the first National Infrastructure Assessment. This would help planners, operators and the private sector, and enable more integrated outcomes.
4. **Understand that geography is key to ensuring outcomes are practical at local and regional levels.** Different places exhibit vastly different travel behaviour; even similar-sized towns can have highly contrasting travel behaviours and needs. There is no one-size-fits-all approach to transport planning; each place needs a tailored approach to ensure its challenges are adequately addressed. Decentralised decision-making should enable opportunities that exist across our towns, cities and rural areas to be seized, provided that layers of funding, operation and strategies are fully integrated. The different approaches in each region could be facilitated by simplification of a historically complex governance system.
5. **Examine the challenges and opportunities presented by rural areas.** Given the low population density (and hence low profitability) of rural areas, it is a challenge for the market to supply practical transport solutions. The ageing of rural populations poses further difficulties, and the lack of infrastructure in many rural regions reduces the opportunities to switch modes. However, new developments create an opportunity to provide healthy, sustainable transport to elderly and isolated groups. New technologies can improve accessibility and mobility for less mobile

13. There are many new systems tools being used in the transport sector. Examples include the work of de Weck et al. (2011), El-Akruti and Dwight (2013) and Petchrompo and Parlikad (2019, forthcoming).

and disabled users (e.g. autonomous vehicles), raising the question: how can government respond to these challenges equitably?

6. **Integrate passenger transport with freight, alongside housing priorities, when making planning decisions.** Policy-makers can minimise future uncertainties by planning for the impacts of policies designed to meet multiple objectives for the transport system, working in partnership with the privately-owned freight sector. There are opportunities for freight, be they around partnerships for efficiency or options for greater decarbonisation. Central and local authorities can lead by example, by: requiring their procurement and deliveries to use freight consolidation facilities; supporting the roll-out of connected infrastructure; and connecting infrastructure between modes. Reconfiguring the ways in which space is used is also important: new transport planning must be integrated with decisions about wider urban infrastructure.
7. **Use a scenarios approach to explore different futures, identify opportunities, and help mitigate the unintended consequences of new transport modes, technologies and/or trends.** This can be used to find opportunities, define future visions or make policies more resilient and help to facilitate decisions about long term transport infrastructure, for example by avoiding stranded assets (investments that become obsolete). Solutions must be increasingly flexible, and policies may be tested against several alternative future scenarios. Sufficiently robust data will also be needed to aid decision-making – users' behaviour and responses to coming technology must be well understood.
8. **Use both hard and soft measures to achieve the scale of change needed.** As most travel behaviour is habitual, understanding what users want, and how they make decisions when faced with incentives, is critical. Powerful visualisation tools and social technologies could be used to understand the impact of, and to shape behaviour. Further research and regional data collection to understand travel behaviour at local scales should be used to inform local policies.
9. **Consider the impacts of future technologies on revenues and costs.** This is important, given the likely scale and pace of change. With current policies, the shift to electric vehicles will decrease revenue from fuel duty, and uptake of automation may decrease parking charges. Policy choices such as road pricing may, therefore, need to be considered among other demand-side interventions. Technology can also significantly reduce operational and infrastructure costs.
10. **Consider prioritising walking and cycling when allocating land use for transport, to promote wider social benefits.** This can change transport behaviours for the better: it can improve health, increase physical activity and reduce sedentary behaviour, and reduce air pollution and congestion. Methods to increase walking and cycling are well known internationally (see Chapter 4) but require investments in hard infrastructure (e.g. dedicated cycle networks) and softer factors. New infrastruc-

ture can provide the stimulus needed to reset habitual travel behaviour. The recent funding increase for walking and cycling, and the Department for Transport's Cycling and Walking Strategy (Department for Transport, 2017g) are welcome moves in this space that could be built on. For example, government should consider the design and use of all space from a health perspective, and evaluate how it can cater for healthy choices. Public Health England (2018) provides helpful guidance on how decision-makers can design and use space to create better health outcomes for citizens.

The evidence presented in this report, and the scenarios presented for the future, show that this is an exciting time to be involved in transport. Government has played a powerful role in the past, and has the chance to positively shape the future. Now is the time to grasp the opportunity for a systems approach to transport, which will lead to a better connected, healthier population and a more productive economy.

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