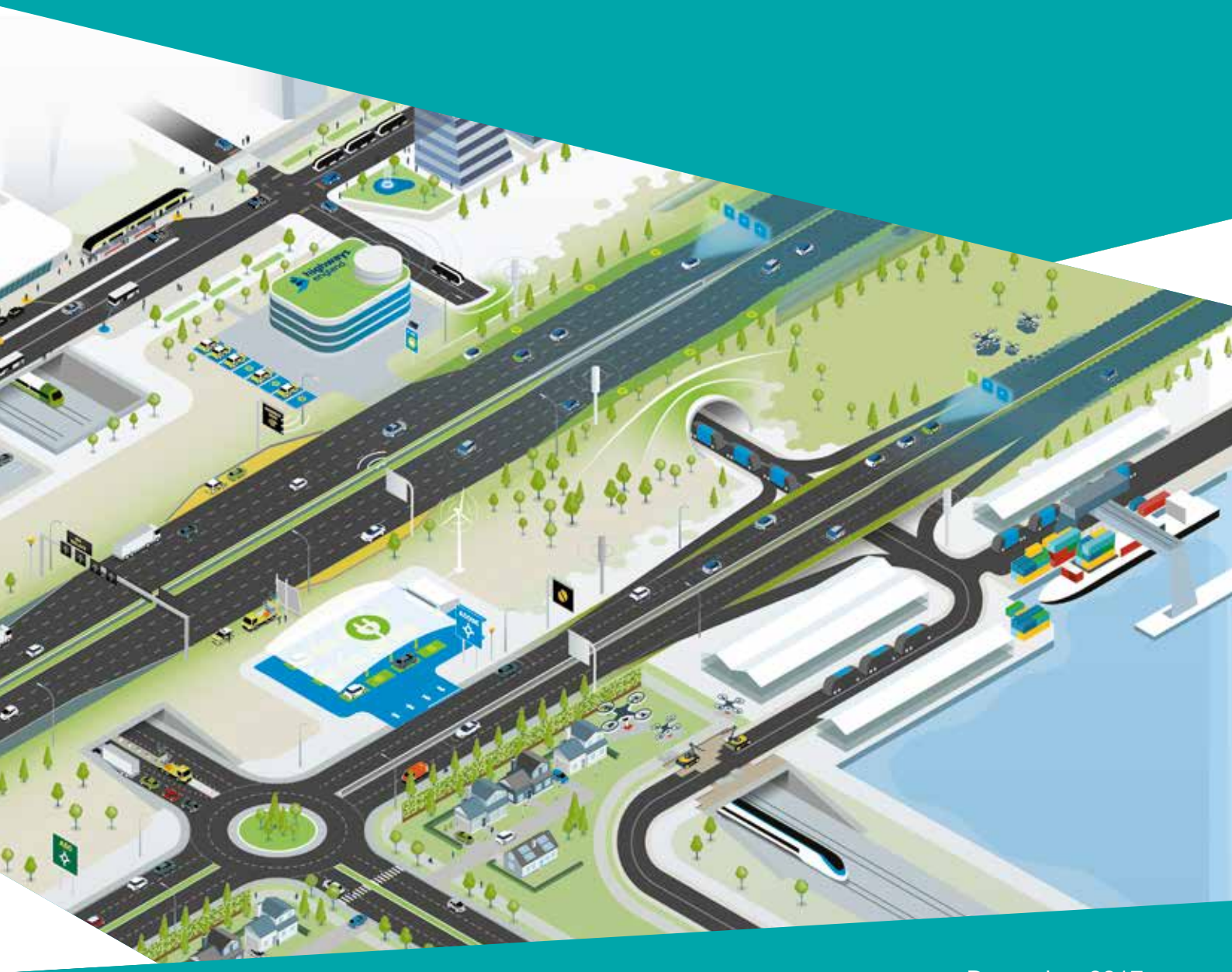
highways england

Connecting the Country
Planning for the long term



December 2017

Introduction

We believe that future investment in the Strategic Road Network (SRN) should be shaped by:

- Listening to our customers and stakeholders
- Understanding our assets and performance
- Considering our shareholders' priorities
- Planning for the long term

In this document, we discuss what we believe the future could hold. It supports the Strategic Road Network Initial Report, which sets our our views and advice to government on the key challenges and investment priorities for the SRN in Road Period 2: 2020-25.

In planning for the long term, we give as clear a view as possible of not only how the SRN might evolve, but also what this could mean for our customers and for our country's economy.

From widespread research and consultation, we have identified the trends which will shape the SRN and influence our operations over the next 30 years and beyond. Using these trends we have explored the potential future worlds that might occur, and developed a core narrative about what we believe is most likely to happen.

Looking to our network, we have sought to understand how it may need to change to reflect this potential future. Building on the planned and committed schemes for Road Period 1 (2015-2020), we have indicated how the SRN may need to be upgraded to meet future challenges.

We have also worked through the practical next steps that we expect to undertake over the short, medium, and long term, identifying the potential capital interventions as well as changes to operation and practice. 'Safety', 'customer' and 'delivery' remain our three company imperatives, and these have been our guiding principles.

We expect our plan for the SRN to evolve as time progresses. Accepting such uncertainty, we believe this represents a starting point for the future development of our network and provides a framework against which we can gauge our future activities. We hope it shows that, while there are many challenges ahead, there are also great opportunities.

We are potentially entering the "era of roads revolution" – a time when technological changes could drastically alter not only our country's transport network and roads, but even our concept of mobility.

Our network has been developing organically, evolving as required to support our customers and the economy. However, it is only recently that we have started to take a long term view of how the SRN might – or perhaps should – adapt and respond to the predicted needs of our customers and our country.

Now is the time for us to look to the future and consider what it might mean. What will be the impact of the forecast increase in demand on the SRN? How will our infrastructure cope? How quickly will technological advancements be adopted by society? What do these changes mean for us as an organisation, and our role?

While we don't have all the answers, I believe that, as we start planning for the next Road Period, we need the best possible understanding of what the future challenges and opportunities may be for our network.

The Department for Transport's (DfT) Road Investment Strategy for 2015-20 states: "Our ambition for the next 25 years is to revolutionise our strategic roads to create a modern SRN that supports a modern Britain."

I believe that planning for the long term is a vital step to making this vision a reality.

Jim O'Sullivan
Chief Executive – Highways England

Contents

1. The trends of the future

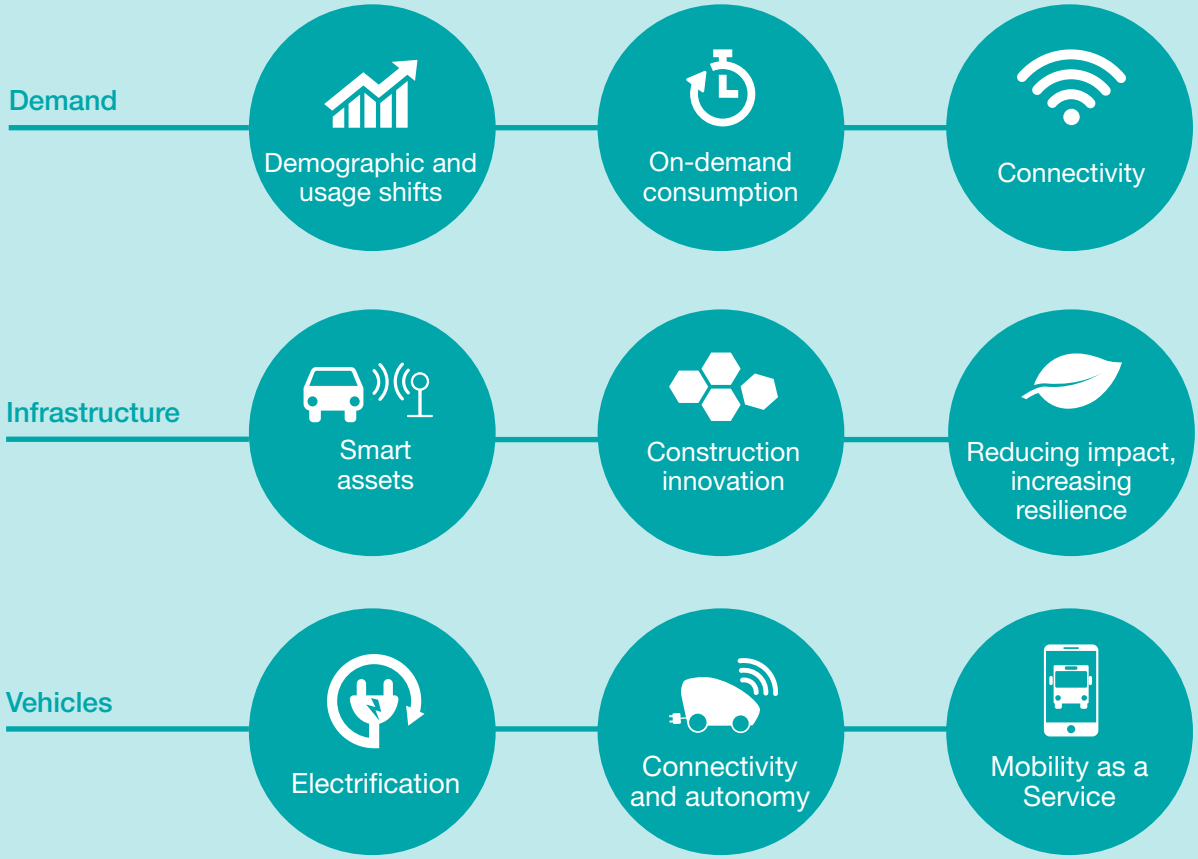
Identifying the trends

Mapping the future over the next 30 years and beyond is a difficult task – both due to the known uncertainties, such as population and economic growth, and the 'disruptors' which may occur due to technological advancement or societal change. Handling this level of uncertainty is a common problem when forecasting over the longer term in any industry or development area. Accordingly, we have sought to analyse the available evidence and extract broad trends to guide us.

Gathering evidence

Our evidence has been drawn from an extensive cross-industry research review, which included over 200 relevant and contemporary sources. We consulted extensively during the research process to test, improve, and refine our conclusions. This consultation has included experts within our organisation, technology companies, car manufacturers, sub-national transport bodies, academics, consultants, and contractors. We recognise, however, that research and evidence are always evolving so the trends we have extracted represent the best view based on the information currently available. They will be re-worked as required over forthcoming road periods.

From our research, we have identified nine trends across three core areas: demand; infrastructure; and vehicles. Whilst no-one can predict with certainty what the future will hold, we believe that these trends will shape the SRN and influence our future operations. Each trend is introduced and summarised over the following pages.



Demand trend 1: Demographic and usage shifts

Over the coming decades, the UK population will experience a shift in demographic, size, habits, and geographical location. These changes will undeniably have an impact on demand on the SRN, especially against the backdrop of the predicted population growth.

Population growth and changing driver habits

There is some uncertainty around future population projections, however government mid-point estimates suggest that the population of the UK will increase 15% from 2014 to 2039[1]. In general, population increase is heavily dependent on net migration figures, with around half of population growth resulting from migration. If increasing population projections are realised, an increase in personal, business, and freight traffic on the SRN is highly likely.

There are observed demand differences within various age groups, with the older population driving more now than in the past. The UK's aging population (65+ years) is growing and is predicted to form 24.6% of the overall population by 2045[2]. When we look to the future, autonomous vehicles or other solutions may support further increases in mobility for this age group, which in turn could impact on SRN demand.

In contrast, the younger, and possibly more urban-based, population, are driving less and have lower car licence levels. A recent Department for Transport's (DfT) study[3] found that the proportion of 21–29 year olds holding a full licence in England fell from 75% in 1994 to 64% in 2015. The trend was particularly pronounced for men in this age bracket, where the number of licence holders fell from 83% to 67%.

On balance, we believe that the predicted population growth will create further demand on our already heavily-used SRN. To put this into context, motor vehicle traffic across the UK was at a record high at the end of 2016: 1.6% above the 2007 pre-recession peak. The SRN has been the main contributor to the increase in this traffic, with motorways showing a 42.8% growth in overall vehicle usage over the past 20 years[3].

Own or share?

Traditional models of vehicle ownership are showing signs of changing, enabled by connected technologies.

There is a small but growing trend towards a shared economy of service provision, rather than ownership. Ride sharing platforms allow a community marketplace for shared mobility, connecting drivers and riders across major cities. This use of the 'sharing economy' has become more prevalent, especially in our growing cities. On-demand ride-hailing platforms provide highly efficient services based on algorithms and live GPS, paving the way for future automated on-demand vehicles for customers.

Urban migration and mobility

Urbanisation is forecasted to become increasingly prevalent across the globe. The 'mega trend' of urban migration means that approximately three-quarters of the world's population will live in cities by 2050[4]. Urban residents only travel 40% as much as those living in rural villages, while London drivers travel only 25% as far[5]. Studies in London and Berlin have concluded that urban living has lowered car dependency, although there are variations in attitudes and usages across the population (particularly by age)[6].

Overall, the exact impact of urbanisation on SRN demand remains unclear. Whilst car ownership may decrease in high density urban populations, it is expected that demand for personal journeys will not diminish for a significant proportion of the population.

Disruptive technologies, such as on-demand ride hailing or autonomous vehicles, may in fact increase demand and annual mileage as travel becomes more convenient or affordable. These technologies could even have the potential to reverse the trend of greater urbanisation in developed nations such as the UK.

More accessible and eco-friendly mobility options are also being pursued to improve our urban and inter-urban environments. Initiatives such as 'road dieting' (where roads are reconfigured to improve safety or create space for other travel modes), transport integration, and urban greenways can help to improve wellbeing, social cohesion, and overall transport efficiency.

Demand trend 2: On-demand consumption

The level of freight on the SRN is dependent on the volume of goods consumed and their source of origin. This is driven by wealth, industry, societal demand, and logistics. Overall, global and regional forecasts indicate continued growth in economic outputs, which will in turn fuel continued consumerism, trade, transportation and, we believe, demand on the SRN.

National and personal economics

Historically, growth in income and GDP is strongly linked to growth in motor vehicle use. Between 2016 and 2045, real incomes are expected to rise by 56% in the UK[7], increasing total travel and demand for highways. GDP is estimated to grow by 2% per year for advanced economies, though there remain high levels of uncertainty in long-run GDP forecasts. To put this in context, this is approximately the level of GDP growth seen by the UK since 2010.

One potential SRN demand suppressor is affordability, and government data shows that the lowest income quartile have relatively low levels of car ownership. To compound this, it is possible that the increasing application of technology to road vehicles will result in higher costs of ownership.

However, easier access to car leasing, the creation of car-sharing schemes, and the growth in ride-hailing could increase the demand on the network by making car use more economical for less frequent drivers. Other fixed costs, such as insurance, may also see changes in the future, with the advent of increasingly safe automated vehicles. The cost of fuel is also subject to potential reductions in the future as more fuel-efficient vehicles are driven and electric vehicles become more prevalent.

Technology-enabled efficient logistics

Business-to-business logistics are changing. Freight consolidation centres at accessible locations, supported by connected systems, can group deliveries from multiple destinations into one consignment. Delivery is then arranged at pre-defined times using the most efficient transportation option. 'Virtual consolidation' is also growing, where multiple businesses join together in co-ordinated procurement to reduce costs and the impact on the local area. However, it is not yet clear when these efficiencies will take off, or what the corresponding impact will be on demand on our network.

International trade and industry

Economic and industrial activity are expected to remain as primary drivers for continued traffic growth on our network into the future, with the SRN already responsible for carrying two-thirds of the nation's freight movements. Economic activity in the developing world is expected to increase quicker than in Western Europe. This may lead to greater imports from these parts of the world, and so an increase in travel between ports and urban centres.

Increasing levels of domestic manufacturing are also expected. This manufacturing activity would increase SRN freight volumes, although the travel patterns could be different to those created from imported goods, with journeys starting at the manufacturing centres.

The digital economy and logistics

The boom in e-commerce and advances in digital technology will continue to increase on-demand consumer services and delivery. Online retail in the UK grew by 10.1% from January 2016 to January 2017[8], and is expected to continue to grow. Customers increasingly expect door-to-door delivery within shorter timescales, which is one of the reasons for the increase in light goods vehicles on the SRN over recent years – and this trend looks set to continue.

Mobile platforms will be at the heart of e-commerce as customers use mobile devices to browse, compare, and pay for goods and services. It is expected that contactless and automatic payment applications will be increasingly used in the transportation sector, and one transaction will cover multiple modes within a journey.

To satisfy increased demand, logistics operators will continue to streamline and optimise their supply chains. Interestingly this may reduce the relative demand on global trade as businesses seek to use new technologies to produce items or services closer to their customers.

Demand trend 3: Connectivity

Improving connectivity between, and within, regions is vital for driving economic growth and supporting social mobility. Connectivity, however, is also about linking and integrating the different forms of transport: in today's society, and as we look to the future, nobody is simply a car driver, a train traveller, or a pedestrian.

Connecting the country

The SRN is an economic enabler[9], and our network will continue to play an important role in supporting growth and regeneration across the country.

The potential of city-regions, for example, will only be realised with efficient transportation networks which create the required national and international connections, release the potential for growth, and provide enhanced resilience for local economies. Equally, improving links between the UK's largest cities can help drive productivity through agglomeration, enabling businesses to have access to a broader labour market pool, a wider range of markets, and better-connected supply chains. Analysis has found that, for every 1 million increase in the population within 60 minutes of a city, there is a corresponding additional £0.50 in Gross Value Added (GVA) per hour per person[10]. This indicates that reducing travel times between and within regions could be key to increasing national productivity.

Importantly, the SRN will continue to play a crucial role within an integrated transport network for the movement of goods to international gateways. Ensuring all regional business have access to international supply chains and markets will be a vital economic enabler for UK companies.

Cross-sector interdependency

Co-operation will also be required across seemingly more separate sectors, including between transport and energy.

Modelling has shown UK energy consumption is likely to increase by 2050 due to the potential growth in electrification of heat and transport, driven by the need to reduce associated carbon emissions for domestic heating, and the predicted increase in electric vehicles[11]. However, the rise in energy demand will need to be satisfied whilst simultaneously making a shift towards renewable energy generation. As a result, government, infrastructure owners, operators, and energy suppliers will need to align and plan together to meet future challenges[11].

Connecting with transport providers

We are all multi-modal travellers. Our network already links to, and connects with, wider transport options, helping to support our customers' journeys. As we look to the future, we will need to continue to explore the potential for greater joint planning with other modes of transport, regional transport bodies, and associated industries. This will include continuing to work with the rail industry to coordinate upgrades, including around High Speed 2, and other engineering work and expansion projects, such as London Heathrow.

Although full integration will take time, increasing collaboration between transport providers will help to realise the vision of a truly multi-modal transport service: fit-for-purpose, sustainable, safe, resilient, and seamless.

Integration will be especially important when disruptive technology begins to enter the transport market. Some organisations, for example, are seeking to implement new high speed transport concepts, exploring the opportunity of using pods that would allow for seamless transfers between modes of transport. The aviation industry is also investigating similar technologies. These may be a long way off from materialising but, over the long term, they may provide exciting opportunities.

Infrastructure trend 1:
Smart assets

It has been proposed that the world is on the brink of a revolution, characterised by the fusion of technologies across the physical, digital and biological spheres, data processing, and artificial intelligence (AI)[12]. This fusion will not only offer huge opportunities to the SRN, but also to the wider infrastructure sector. The improved use of 'smart' technology, data, and analytics offers a potential way to improve the performance of the UK's infrastructure and support improved productivity[13].

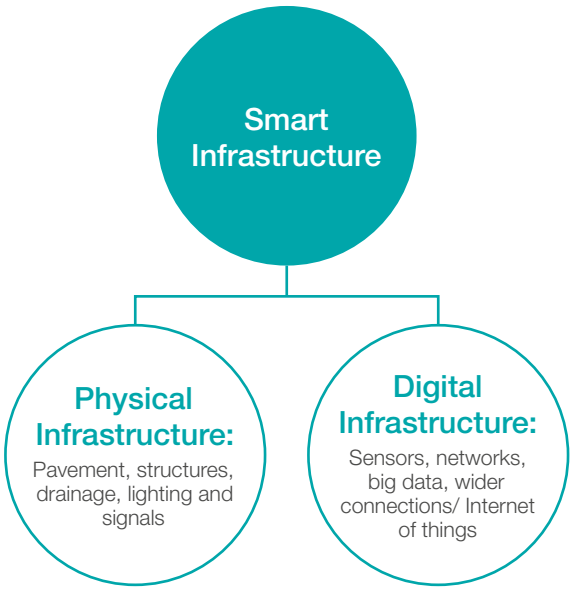
Smart infrastructure

Smart infrastructure is already beginning to play a crucial role across many sectors[14]. It uses data captured from sensors to monitor, analyse, and communicate information about the condition of assets and their environment, enabling faster response times and proactive asset management. Smart infrastructure even offers the potential to gather a better understanding of future needs and connect with contracts and procurement for stock management. Advances in AI and predictive analytics will serve to accelerate capabilities in this area[15].

Smart infrastructure offers three opportunities[14]:

- Increased efficiency, capacity, and resilience from existing and new assets
- Enhanced service provision, even if finance or resources are constrained
- Better understanding of asset performance, allowing new investments to be optimised and delivered for the best value

While smart infrastructure has had reasonably limited usage in the road sector to date, its usage is likely to increase across all of our major infrastructure assets.



The future of data

Technological advances will transform our experience of collecting, sharing, and using data.

Mobile data use has grown exponentially in recent years. Next generation mobile internet, called 5G, is expected to handle much more data, connect more devices, reduce latency, and provide increased network reliability.

It is also envisaged that wireless, real-time collection of data via miniaturised low-power sensors will transform our understanding of structures, systems, and the environment.

Open data and big data

We already generate and analyse vast amounts of data. The 'opening up' of both existing and new data assets will enable us to use the information at our disposal more efficiently, and help to drive the development of analytics and software for personal travel information, asset inquiry, and transport planning.

In-car or personal device applications, for example, will allow for the collation and potential use of vast amounts of data via open access agreements. These opportunities should not only enable us to be a more effective infrastructure operator, but also enable our customers to become more informed. Technological advances around data will also be a key enabler for the 'Internet of Things', connected vehicles, smart infrastructure, and the development of AI. Big data pools are also generated during the construction and operation of major assets, such as motorways. Continued improvements in intelligence via big data analysis, analytics, and modelling should help us to become faster and more effective in decision making.

Security

As systems evolve so do the vulnerabilities. The number of targeted attacks on industrial control systems has seen a sharp increase in recent years and, in some cases, these have resulted in significant physical and environmental damage. It is therefore important that we continue to develop our security in line with our operations. Targeted investment to increase security awareness is likely to be required, not only by us and our suppliers, but across the transport industry as a whole. There are parallels between security concerns now and health and safety concerns in the construction industry over the past two decades[13].

Infrastructure trend 2:
Construction innovation

There is a significant opportunity across the transportation industry as a whole in enabling innovations in construction. ‘Smart construction’ is rapidly emerging, bringing clear potential benefits to designers, contractors, and asset owners.

Construction components

The introduction of standardised, modularised, and pre-fabricated components through off-site or near-site construction is expected to grow. Standardisation will reduce construction costs, maintenance costs, and tolerance problems, whilst also improving end-of-life recycling planning. Modularisation will allow for greater customisation and flexibility. Pre-fabrication will increase efficiencies, enabling better construction sequencing, reduced delivery timescales and costs, and safer working environments[16].

Digital technologies

The construction of road infrastructure using digital technologies is likely to undergo a sustained period of evolution. Initially, automated additive techniques will be used to support the pre-fabrication and modular construction of components. Over time, and for larger infrastructure projects, on-site bespoke component manufacturing using printers may become economically viable. Automated construction is already part of many of our projects and, as the versatility of machinery improves, it is likely to offer further benefits to the SRN. Complementing this, and offering benefits of its own, is the automation of design. Uptake will be gradual but, over the long term, we hope to see smarter designs which will consume fewer materials whilst being quicker to construct and maintain.

Together, these developments provide great opportunities for our network. It is thought that the uptake of digital technologies will significantly reduce construction time and customer disruption, as well as reducing the total life-cycle costs of constructing and operating major infrastructure assets, such as motorways.

Emerging construction techniques

Innovative construction techniques are being developed and used across the manufacturing and built environment sectors. We – along with the transport sector as a whole – have the potential to benefit from these precedents.

Self-healing materials for road surfaces, for example, are currently being trialled which could repair cracks in the pavement. 3D metal printing facilities, producing on-demand replacement components, are now in use by infrastructure operators to reduce asset interruption. Augmented intelligence is being developed which can generate design options to set criteria, speeding up design processes and helping engineers, designers, and clients make better informed decisions.

Smarter and lightweight materials

Materials science has underpinned many of the technological leaps in the last 50 years and this shows no sign of abating. The future raises the prospect of new advances in electronics, bio-materials, energy storage, and structural properties. There are two key trends in this area which could have an impact on the SRN over the next 35 years:

1. Smart materials - which are reactive to external stimuli and provide enhanced resilience and new capabilities

2. Lightweight composite materials - which exhibit improved strength to weight ratio and are likely to be commonplace across a range of industries.

New materials are being researched and tested. Energy-generating pavements, using solar or kinetic energy, are also being investigated. These pavements could help to create roads which can self-power their associated assets. Self-repairing materials are also now under trial and could provide us with great opportunities. Self-healing concrete or asphalt, for example, could have mass relevance in reducing the expenditure on the renewal and maintenance of our assets.

Infrastructure trend 3:
Reducing impact, increasing resilience

Construction and operation of the built environment consumes 60% of all materials in the UK, and 60 million tonnes of ordered materials go to landfill[17]. As we look to the future, the construction and transport sectors must prepare to manage, rationalise, and conserve the resources they consume.

Infrastructure system design, operation, and risk management face a challenge to keep pace with emerging trends and ensure that transport systems can adapt and transform their performance. The resilience of the network will become more critical as the volume of traffic increases in parallel with increased risk of extreme weather events.

Decarbonisation and emissions

The decarbonisation of the UK economy involves the process of de-coupling energy supply and economic growth from greenhouse gas emissions (GHG). Transport as a whole is the UK's second largest emitting sector of GHG, two thirds of which are related to road transport[18].

The transition to an increasingly low emission fleet for cars and freight vehicles is anticipated to reduce significantly the current issues surrounding roadside nitrogen oxide emissions, carbon, and some of the other pollutants. These technological advances will, therefore, support progress towards the UK's decarbonisation targets. Clearly, as part of this transition, the associated interdependencies between transport, national energy production, and carbon need to be considered and fully understood.

Whilst technology is likely to offer vast improvements in emissions, we will not rely solely on this as there is likely to be more we can do beyond technology – for example by way of wider operational strategies – that will also support our targets. Furthermore, a wider approach will help mitigate any impact, should the technology-led solutions fail or stall.

Biodiversity and land-use

The loss of biodiversity is a widespread national issue. Transport corridors can be designed and managed not only to meet their functional objectives, but also to protect and nurture the natural biodiversity that the landscape supports. Additionally, the careful incorporation of green infrastructure can even have a positive impact on asset performance, resilience, and efficiency. A long-understood example of this is for embankments populated with trees, or more specifically reinforced by the roots of trees, to be more resilient to flooding and associated landslips.

Reducing waste and material consumption

New technologies and techniques continue be trialled, delivering our construction and maintenance activities in a more sustainable manner. Pioneering resurfacing, for example, allows the underlying layers of the road to be recycled and reintegrated immediately back into the new road surface. Approaches such as this greatly reduce our levels of waste and resource consumption.

Recovering and recycling materials can also cut costs, produce new revenue streams for stakeholders, and improve construction productivity. As we look to the future, the construction sector is expected to increasingly recapture materials and components for reuse instead of consuming new resources. Equally we anticipate and support the reduction and transformation of waste into useful by-products.

Circular economy and waste

The built environment – of which the transport industry is a large part – is a major consumer of natural resources, and there is a need to evolve the processes, components, and systems we use to reduce waste and increase efficiency.

The ‘circular economy’ concept offers a chance to make the step change needed, decoupling economic growth from resource consumption. We cannot do this alone; it will require a holistic view and a shared industry effort to enact any significant change in the highways sector. The circular economy concept can, and is, being aligned to the design and operation of major infrastructure assets. This includes new models for operation, asset utilisation, and maintenance strategies, focusing on minimising environmental damage, increasing longevity, and integrating network systems to enable circular resource flows.

Resilience

Transport networks are – and will continue to be – reliant on each other, and on infrastructure networks, including water, power, and communications. A system-of-systems approach is required to assess and understand these interdependencies, which are expected to gain importance over the long term.

We will also have to deploy new asset-led strategies to manage potential forthcoming challenges from severe weather events, technological change, and increasing demand. Possible solutions include improved asset design, increased customer communication opportunities, greater use of modelling, and creation of integrated strategies to improve both the SRN’s and the wider transport network’s resilience.

Vehicle trend 1:
Electrification

Fossil fuels have dominated the transportation sector for the last century. However, advances in battery, fuel cell, and other energy storage technologies, accompanied by the forecasted continual reductions in costs[19], will mean that electricity and alternative fuel sources will play an increasingly important role in personal, public, and freight transport on our network.

Electric vehicles

There are clear signs that sales of ULEV-compliant electric vehicles will increase. If they reach price and performance parity with traditional internal combustion vehicles in the 2020s as predicted, it is thought that electric vehicles will form 20% of the UK fleet by 2030[20]. This excludes internal combustion hybrids, which are also expected to form a significant proportion of the vehicle fleet. National Grid have forecasted that between 6 to 16 million battery electric vehicles (BEVs) will be on the road by 2040[21]. By 2050, there will be certainly very few, if any, purely petrol and diesel cars on our roads; BEVs have been forecasted to become the prevailing vehicle type, alongside hydrogen.

This increase in electric vehicles is supported by bold stances by governments and industry leaders. In the UK, the shift to ultra-low and zero emission vehicles is well under way. It will continue to gather pace over the coming years as we move towards 2040, by which point the government will end the sale of all new conventional petrol and diesel cars and vans with the intention that almost every car and van on the road will be a zero emission vehicle by 2050. France has also announced it will end sales of all petrol and diesel vehicles by 2040. Norway has set a target of only allowing electric or plug-in hybrid cars by 2025. In parallel, many of the car manufacturers are making similar commitments. Jaguar Land Rover, for example, plan to launch only electric or hybrid lines from 2020, and Volvo has declared that all new cars launched from 2019 will be partially or completely battery-powered. There is similarly a push to electric from mobility providers.

Powering the future

The recent upsurge in announced 'battery megafactories' demonstrates the future need for batteries to fuel the new vehicle demand.

There has been huge improvements in batteries in recent years which is set to continue globally. It is forecast that, by 2021, battery production capacity is likely to double. Developments like this should result in batteries which cost significantly less using economies of scale, innovative manufacturing techniques, technological improvements, and efficiency savings.

E-trucks

It is less clear how electrification will impact heavy goods vehicles (HGV), with the battery requirements of HGVs proving more demanding than with light-weight vehicles.

However, the issues are not insurmountable – as evidenced by the expertise in both the rail and aviation sector in new e-driven transportation. It therefore remains possible that e-trucks will appear on our network. Some manufacturers, such as Daimler and Tesla, have demonstrated or announced e-truck applications, and batteries could suit HGV applications due to their wide frame and torque requirements.

Yet, even with very large battery packs, estimated mileage would be reduced unless fuel cell generators or on-road charging are used. Charging large quantities of e-trucks would need careful consideration due to the potential energy demands.

When looking to the future of HGV electrification, it could pay to think differently. While battery-powered e-trucks are one way forward, there are other e-truck models which can be explored. Both Siemens and Volvo, for example, are testing the feasibility of overhead wires for power[22], much like trams, whilst dynamic wireless power solutions may also become viable in the future.

Vehicle trend 2:
Connectivity and autonomy

The rise of connected and autonomous vehicles (CAVs) is expected to be one of the most significant and potentially disruptive changes in future personal mobility. Connected systems promise integrated, reliable, and safer travel, whilst autonomy could increase mobility, reduce incidents, and increase national productivity. Both technologies will have implications on current infrastructure and could provide us with many exciting opportunities, as well as a number of challenges.

Technological progression

Modern vehicles already contain considerable levels of digital technology and connectivity which, traditionally, have focused upon optimising internal functions and diagnostics. Attention is now turning to developing the ability of vehicles to connect with the outside world and enhance the customer experience via sensors and connectivity.

The potential benefits of connected vehicles are likely to be realised as part of a co-operative-intelligent transport system (C-ITS), where real-time communication data is exchanged between connected vehicles, control centres, infrastructure, personal devices, and cloud-based storage[23]. Such data sharing could lead to increased safety, more efficient transportation, and better inter-modal transport links.

Driven by advances in processing power and sensor technologies, autonomous vehicles with limited functionality are becoming increasingly available to our customers. Autonomous vehicles can control some or all of their functions, such as steering, braking, and acceleration, without direct driver input through the use of on-board sensors. They could lead to increased safety, as well as improved mobility, greater road capacity, reduced environmental impact, and increased productivity

So, what are ‘connected’ and ‘autonomous’ vehicles?

A broad definition of a connected vehicle can mean any vehicle capable of wireless connectivity to: the internet, LAN or the cloud (V2N); other vehicles (V2V); infrastructure or control centres (V2I); and personal devices, such as those carried by pedestrians (V2P).

In general, the term tends to apply towards connectivity to the internet or local wireless networks. When used in this context, the term relates principally to driver information services, such as navigational support, infotainment, or driver aids. It is these V2N systems that are most commonly supported by current vehicles. C-ITS enabled vehicles in the future, however, provide a much wider opportunity. They will focus much more on V2V, V2I and V2P technologies, using wireless communication to provide real-time information on road hazards, potential incidents, traffic movement, and the wider local environment.

Autonomous vehicles are the result of combining this connected technology with AI and the software and hardware necessary to take control of the vehicle away from a human and into the hands of the vehicle itself. The degree to which autonomous vehicles are adopted will depend on the pace of technology change, how the complexities of a mixed fleet are dealt with, and the pace at which the UK is able to move towards full autonomy.

Customer uptake

Estimates for the adoption of connected vehicles which can communicate with other vehicles, infrastructure, or surrounding devices vary depending on public sector support and customers’ willingness to purchase. Most modern vehicles are already connected in the sense that they have a SIM card, or several SIM cards, and can access software and navigation updates. During the 2020s, the vast majority of the new vehicles will have considerable connected capabilities. By the 2040s, most vehicles will be connected to both infrastructure and other vehicles[24].

Such a development will not only bring improvements in safety and the flow of traffic, but it will also change the communication mechanism: from on-road signage to in-vehicle intelligent messaging and possibly control.

Forecasts for AVs indicate that vehicles with intermediary assistance technology for certain situations will become prevalent. They will most likely appear over the coming decade, followed by a move towards higher levels of automation during the 2030s[25]. It is currently thought that the vast majority of the SRN fleet will be fully autonomous by 2050[25].

Vehicle trend 3: Mobility as a Service

The changing nature of mobility services, and the possibilities enabled by digital technologies, offer the potential for road transport to become a seamless part of users end-to-end journeys. It is predicted that new business models, commonly termed ‘Mobility as a Service’ (MaaS), present the next revolution in mobility.

What is MaaS?

MaaS seeks to offer better journeys by making it easier for users to combine modes of transport. It is predicted that, over the long term, mobility payment mechanisms and inter-modal connectivity will make journeys fluid and convenient[15], while intelligent transport systems and other communication technologies will allow different transport systems to integrate and share data. Over the long term, rather than having to find, book, and pay for each mode of transportation separately, MaaS platforms will allow customers to plan and book end-to-end trips using a single interface.

MaaS is at an early stage in its development, though over the next few years the number of pilot programs is expected to rise. The future for MaaS is not limited to individual mobility – the approach can also be applied to the business world and the movement of consumer goods.

Rethinking urban mobility

Helsinki is attempting to rethink urban mobility by transforming its transport network into a door-to-door mobility on demand system. A commercial app called 'Whim', heralded as the world's first MaaS offering, is now available in the city and offers personalised travel plans based on pay-as-you-go or monthly subscription tariffs. These travel plans are designed to be flexible for the individual and to integrate the city's public transport and private options - whether train, taxi, bus, carshare, or bikeshare.

The aim is to make it unnecessary for any city resident to own a private car by 2025. The key success will be making this MaaS offering competitive with traditional ownership - not only on price, but on convenience and simplicity for the customer.

While Helsinki is a front-runner, many other cities have piloted embryonic versions, ranging from modest peer-to-peer offerings and integrated public transportation, to combined mobility services which include private sector players.

Key enablers

MaaS is enabled by a modally connected transport system. However, appropriate digital platforms – both at the front end and the back end – and a sharing economy are also essential to creating seamless mobility.

Digital platforms:

At its core, MaaS relies on digital platforms that integrate end-to-end trip planning, booking, electronic ticketing, and payment services across public and private transport. MaaS is also powered by the growth of mobile personal devices and live data, which are increasingly at the centre of our digital lifestyles. Wide connectivity across multiple platforms has already created easier, quicker, and more convenient ways for customers to interact with their environments and mobility services.

Sharing economy:

Over the last decade, customers have increasingly embraced new mobility options and apps. Traditional concepts of ownership are changing and the general adoption of connected systems is rapidly growing. Platform-based P2P services are disrupting a range of industry sectors, including personal and public transportation. This trend towards a shared economy of service provision rather than product ownership could have fundamental impacts on the current transportation market.

2. Potential future scenarios

Scenario planning

While the trends show us the areas that we believe will have a significant impact on SRN demand, usage, and operations, they do not combine to give us a definite future. Instead they give us a series of uncertainties which we need to reflect in our planning.

Given the extent of the uncertainties, especially as we look over the long term, it is necessary, and common practice, to explore the potential future states that might occur through a scenario planning process.

As part of scenario planning, we created four extreme worlds, plotted against axes which represent two key questions – two critical uncertainties – that will be pivotal for our future.

Critical Uncertainty 1. How fast will technology be developed and taken up?

There is always great uncertainty about the timing of future technology change and we must recognise this when making predictions about technology uptake in road transport. Not only is there uncertainty around the pace of change, but there are also variations in the solutions which will be explored by different suppliers and users, both at home and abroad.

So a question we must answer is how quickly should we respond to emerging trends? Should we be strategically patient and see what the future holds? Or should we seek to predict what may happen?

We believe that our role is to enable and support, rather than to drive vehicle technology change. So this requires us to take a watching brief, be prepared to change course as technology evolves, and identify where our playing an enabling role can help catalyse wider change.

Critical Uncertainty 2. How will transport and mobility be experienced and managed?

As shown in our trends, a number of drivers will influence our customers' future mobility expectations and potentially shape our role in supporting travel across the country.

Our envisaged future scenarios outline how our role as the network operator could potentially evolve. With an increasingly technology enabled vehicle fleet, the network operator may need to become an increasingly intelligent service provider, managing and optimising traffic flows, ensuring safety, and directly supporting and managing travel via connected technologies and integrated networks.

Alternatively, it may be that sufficient 'intelligence' is contained within future vehicles that there is a comparatively limited need for an intelligent network operator, with greatly reduced operational needs being placed on us.

However, we most likely see ourselves positioned in a middle ground – the majority of 'intelligence' will be in vehicles, but there will also need to be enhanced 'intelligence' in the infrastructure as well. So the requirements for the network operator are likely to increase, particularly over the period when we would be managing 'mixed fleet' of CAV and non-CAV vehicles. Our organisational emphasis is likely to shift and evolve over time in response to these changes, but this is again dependent on how the identified trends play out, and we recognise the inherent uncertainty around this.

While we do not see any of our organisational objectives disappearing over the long term, we recognise the potential for a changing emphasis:

- **Safety** for those travelling or working on the SRN will remain our first priority. However, how we deliver improved safety may change in the future through the use of new technologies or techniques.
- We aspire to deliver significant **capital improvements** to our network throughout the coming road periods. However, capital investments may reduce over the longer term as past investments ensure we have adequate capacity to support the needs of the country.
- Our obligations for the **maintenance and renewal** of our assets may gradually increase across the medium term as our network ages and new developments are completed. We expect that our relative maintenance and renewal costs could stabilise in the long term as highly efficient maintenance methods emerge with progressive approaches and technology.
- With the onset of new technologies over the coming decades, our **operational** obligations could evolve. CAVs, in particular, could bring the potential for a move towards becoming an active operator, ensuring safety and efficient traffic flows. It is unclear at this stage as to whether these changing technologies and mobility trends will increase or decrease our responsibilities as the network operator.

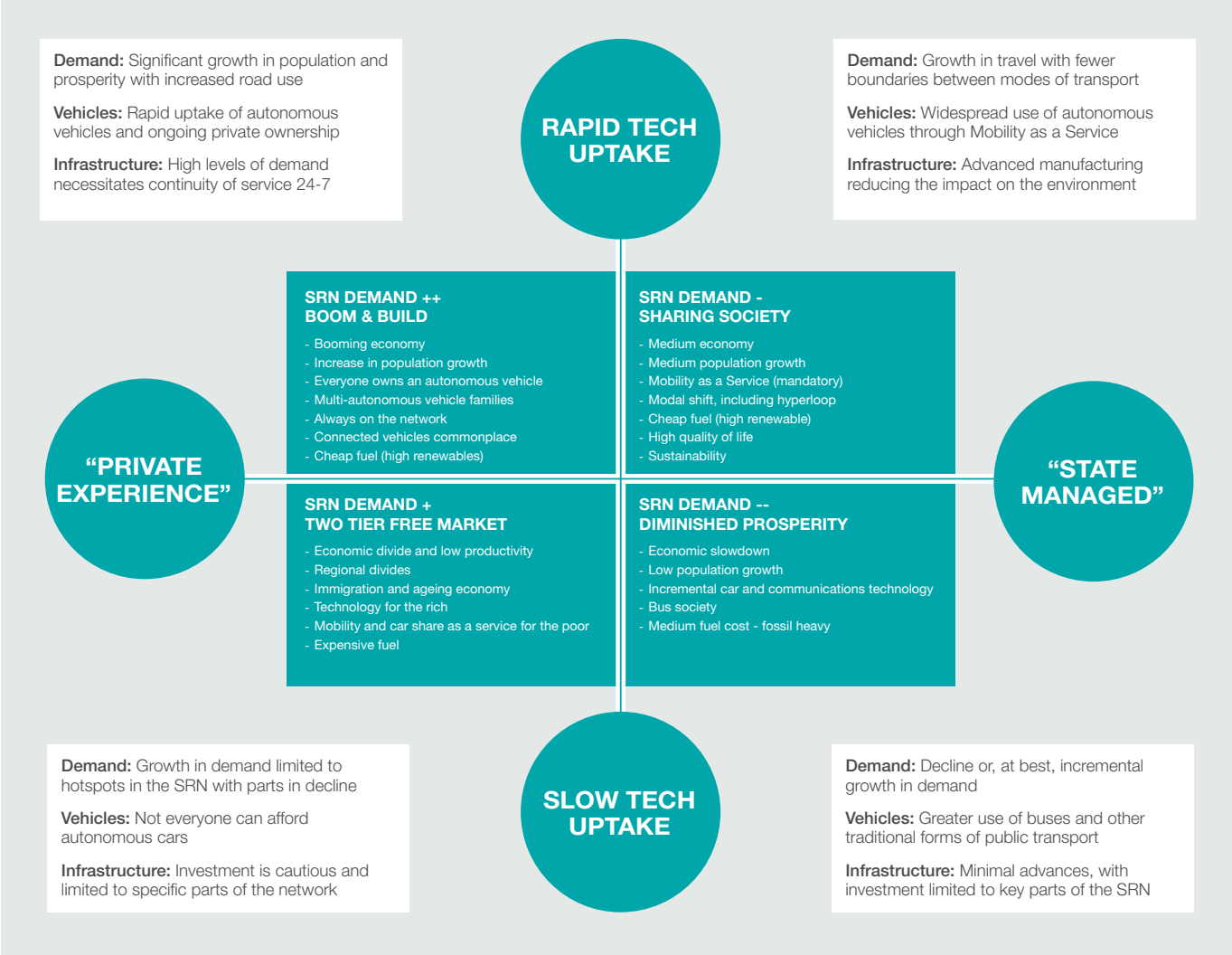
Understanding the future states

Our four scenarios consider the full range of trends, but the key themes - demand, infrastructure, vehicles - are strong defining features. The scenarios show a wide range of potential impacts. Two of them, for example, show an increase in demand on the SRN and two a decrease in demand – which is not equivalent to the probability of either occurring. The scenarios also highlight the range of factors that could affect the uptake of cleaner and autonomous cars and the potential for different priorities.

We used the scenarios to model different SRN demand levels at a network level, pivoting from central government growth forecasts. For example, a future with rapid technological uptake can be expected to yield greater network capacity through improved flow due to the benefits of connected and autonomous systems. Conversely, a future with a leaning towards the 'private experience' can be expected to have more vehicles on the network than in a 'state managed' world, and so congestion may increase. To help inform our thinking and subsequent planning, we developed high level traffic congestion maps and analysis for each of the scenarios.

The extremities of these scenarios describe quite distinct worlds. However, based on our research, we expect reality to fall somewhere between the boundaries. There are some common themes across the scenarios and strong research to support our bolder, more binary predictions. In this way, we are able to say with some confidence that, regardless of which future state comes to pass, there are a number of challenges and opportunities for the SRN which need to be addressed.

Scenario planning: four extreme worlds



An ambitious view of the future

As part of scenario planning, and to help us to develop the next steps for Road Period 2 and beyond, we have created a stretching and ambitious depiction of what we believe travel on the SRN could look like by 2050. However, through the scenario planning process, we are aware of the frailties of any scenario, and we fully expect our view of the SRN to evolve.

Overall

England's roads are now recognised as amongst the best designed and aesthetically pleasing in the world. Travel on the SRN in 2050 is safe, fast, reliable, and sustainable. Our network has reached a stable state of development, with England's key cities, gateways, and industries completely connected.

Journey times across our network are markedly reduced, with daytime roadworks a thing of the past and 100% autonomy enabling fast and reliable journeys. Our network has become smart, with maintenance driven by the data-rich detection of emerging issues before they would normally have been identified. This is achieved through a mixture of advanced analytics, based on better asset data, and smart infrastructure which can even make decisions for itself. All of this means that using our network is an enjoyable experience for passengers and one that freight users can rely on.

The fleet has reached zero emissions through the mass switch over to electric vehicles and some switching to hydrogen and fuel cell powered vehicles. Air quality is still an area of focus because of the fine particulates caused by tyres on asphalt, albeit we hit the old EU targets for nitrogen oxide reduction in the mid-2020s and had made substantial progress on decarbonising the fleet by 2035.

Delivery of our three imperatives has helped to transform the SRN.

Imperative 1: Safety

Driver-fault accidents and injury to our workers on site have been virtually eliminated. Our autonomous-only network has meant that the biggest safety concerns are now cyber security and vehicle maintenance, although the high levels of connectivity mean that the number of poorly maintained vehicles has drastically declined since the 2010s. This is an age far beyond warning lights popping up on a dashboard – when a vehicle detects a fault, it can book itself in for maintenance and drive itself there at a time it isn't needed. Diagnostics have also been improved by connectivity, with the combined performance of the vehicle being monitored, not just the individual parts in isolation.

Connected vehicles and the rich data they provide have also changed the way safety-related road maintenance is tasked. Asset degradation is now monitored in close to real time across the network, often based on vehicle feedback, and remedial work takes place before either the surface or the infrastructure is weakened to the point of failure or reduced performance.

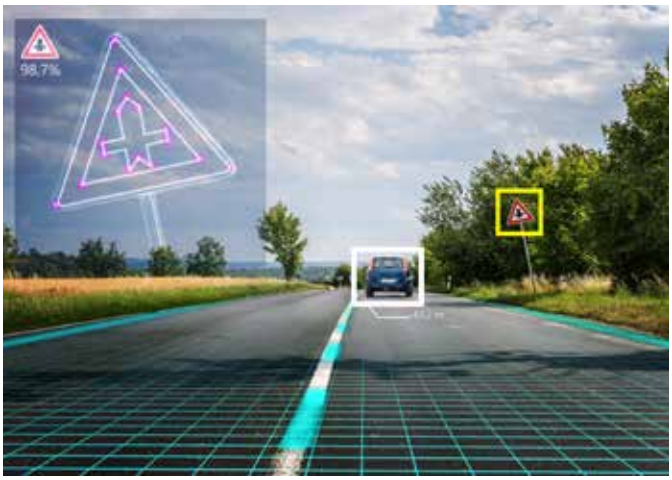
Imperative 2: Customer

The customer of the future has changed. While overall demand for travel has continued to rise, individuals have reduced car ownership and look to network operators to provide the infrastructure that guarantees a high level of service. This switch has placed new demands on the operators and also introduced a new group of customers. We are working with a range of MaaS providers to deliver high quality customer experiences across the network. These requirements are now focused on a smooth journey with uninterrupted access to digital and augmented reality services. Freight is no longer the challenge to peak capacity that it once was, with almost all freight now sent in driverless overnight platoons.

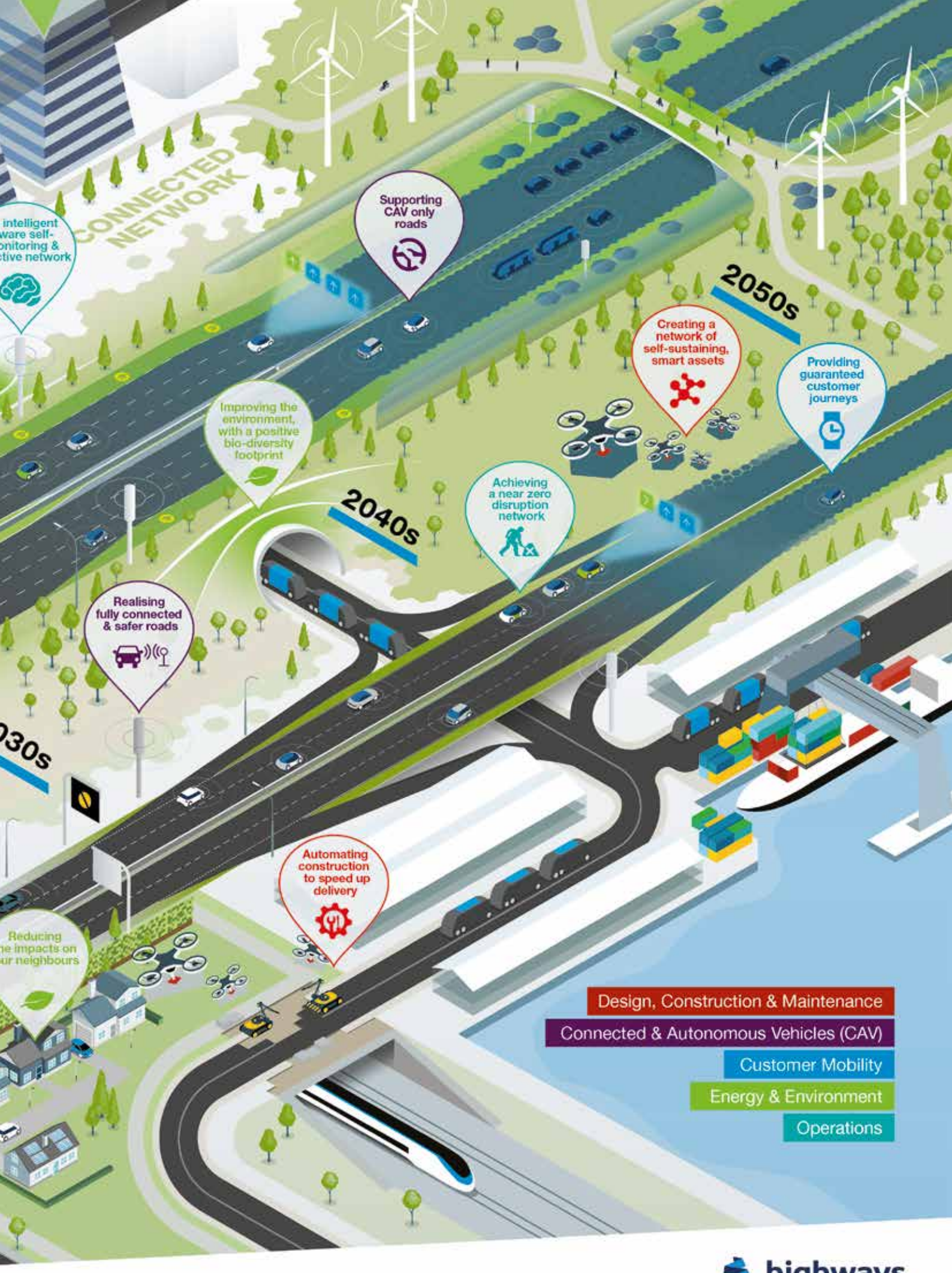
Imperative 3: Delivery

A large amount of major infrastructure delivery is now focused on keeping pace with technology changes, such as the introduction of hydrogen cell powered HGVs. The era of road improvements from 2010s to the 2050s has moved the network to a simpler, more uniform model of technology-enabled motorways and expressways to support the fully autonomous fleet. The delivery of large schemes is now largely complete.

Work on enhancement, capacity improvement, and technology renewal is now undertaken with little disruption to flow and almost completely overnight, with minimum human presence on site. Our network has become smart, with maintenance driven by the detection of emerging issues. This is achieved through a mixture of advanced analytics, based on better asset data, and smart infrastructure which can make decisions for itself. Our on-road service has changed, with the introduction of recoveries by autonomous vehicles. When this is coupled with the National Traffic Operations Centre's ability to communicate with all vehicles on the network, helping them to optimise routes and speeds, the smooth flow of our high capacity network is rarely interrupted.



The Future of the Strategic Road Network



highways england

3. What could our network be like?

Looking to the future

It is important to understand what form the SRN could take, and how it will need to change to reflect this potential future.

Building on the planned and committed schemes for Road Period 1, it is important to consider how the network may need to be upgraded to meet future challenges, whether through interventions such as outer city links or through strategic links between cities, transport hubs, and nationally significant infrastructure developments.

A range of factors inform this thinking, demand, resilience, and connectivity.

Demand

Our thinking has been informed by forecasts of the traffic congestion and stress on the SRN in 2050, based on DfT's growth forecasts, current traffic levels, and current road capacity. It forms a view of what and where future demand could be, and what an appropriate response could be, based on what we know now. We will continue to develop our view based upon the impact of key demand drivers including population, regional economics, housing, employment, freight traffic, rail and light rail, ports, and airports.

Resilience

Resilience has been central to our thinking. The future SRN needs to continue to withstand shocks and stresses – whether through incidents, weather, or security-related issues. We will consider the ability to re-route traffic if key points 'fail', such as river crossings, critical junctions, or key corridors.

Economy

The future SRN will need to continue to enable the economy. Our initial thinking has considered the possibilities for industrial, productivity, business, and freight growth, focusing on areas that are forecast to grow significantly and drawing on the insight in our Strategic Economic Growth Plan[26]. The reliance of freight on the network, for example, is particularly significant, with around 60% of freight movements occurring on the SRN[27].

Connectivity

Our future view will be developed to recognise the SRN's connectivity, whether urban, regional, or inter-modal. We will consider the interaction of the SRN with the major cities and where links could improve, for example through orbitals and facilitating inter-modal trips. We will also look at how we could enable growth in some of the more remote areas. Our future view shall also recognise the need to increase connectivity to other modes of transport, including high speed and light rail in particular. Providing high quality and reliable links to ports and airports is a clear requirement for our country, allowing smooth interface points and connectivity with the 'last mile'. The importance of achieving good multimodal connectivity is set to increase as autonomous and connected technologies start integrating across transport modes.

The evolution of our network

In the first Road Investment Strategy, government stated that its ambition for the next 25 years is "to revolutionise our strategic roads to create a modern SRN that supports a modern Britain".

We believe that achieving this will require some element of harmonisation, with road standards converging to provide a common, high quality experience for our customers. Over this period our network will reflect 'four levels' of road:

- Smart motorways – which will service our highest demand areas and will continue to evolve, taking advantage of new technologies
- Motorways – which will continue to function in their current form, providing resilience and capacity to our network and customers
- Expressways – which will bring the safety and congestion advantages of our motorways to trunk roads
- All Purpose Trunk Roads (APTR) – which will continue to provide a vital service and connectivity to significant parts of the country, particularly more remote areas.

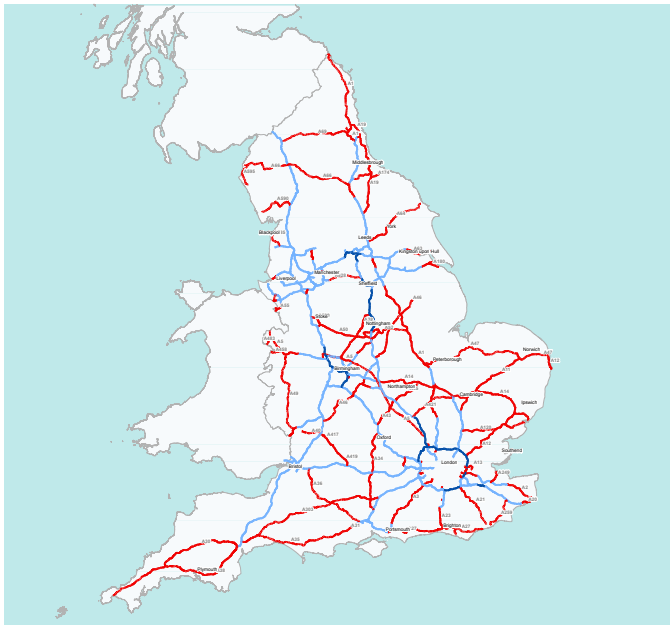
The network over the medium term

The three maps on the following pages depict the SRN, graphically, showing the possible upgrades and new corridors in a chronology leading from current day to the end of the first Road Investment Strategy and across the medium term. These maps are line with government's ambition, which was set out in the Road Investment Strategy for 2015-2020. While they form our initial estimate at this stage, we will seek to further investigate and define these possibilities over the coming months, with further engagement with our stakeholders and customers.

The network over the longer term

Changes to our network over the longer term will be driven by technology, including the roll-out of autonomous technologies. We will continue to plan and update our views as technology develops. We will consider moving to a 3-tier motorway system, with the differentiation shown to the customer through the capacity of the roads.

The current network, by road classification

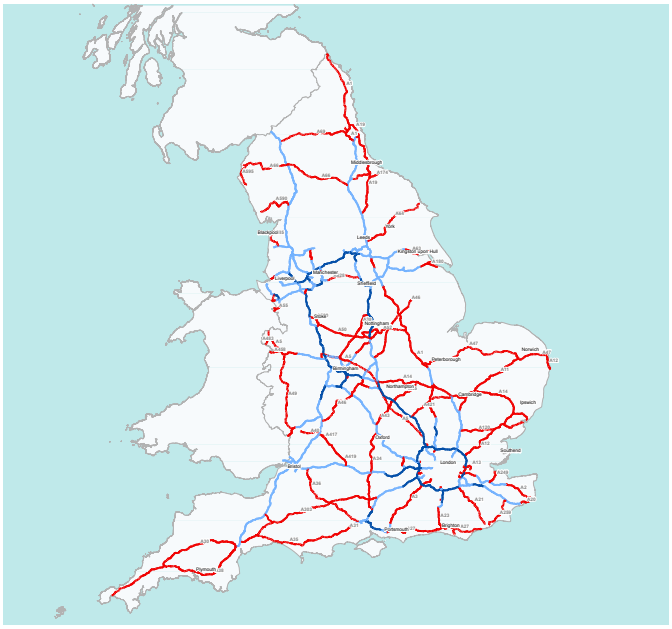


Classification

- Smart motorway
- Motorway
- APTR

- The country is connected through an established network of motorways
- The APTRs stretch across the length and breadth of the country, with widespread use of dual carriageways to provide capacity and connectivity
- There is an emerging presence of smart motorways, but they currently only count for a small amount of the overall network

The network at the end of the first Road Investment Strategy, by road classification

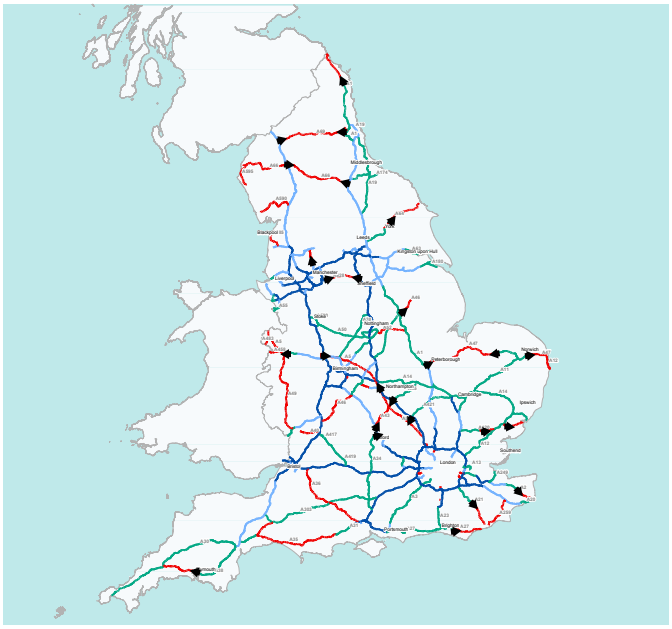


Classification

- Smart motorway
- Motorway
- APTR

- Our programme of upgrades will begin to yield benefits, with the improvement of free-flow, particularly on the A-roads
- The smart motorway network will continue to expand to support the areas where demand is the highest, as per the commitments in the first Road Investment Strategy
- The APTRs will continue to play a vital role in connecting the country
- While not yet present on the network, the end of this period will see ‘expressway-ready’ stretches of the network

The network over the medium term, by road classification



Classification

- Smart motorway
- Motorway
- Current, planned, and potential expressways
- APTR
- Options for further expressways

These maps do not constitute a plan, but provide an indication of how the network could develop. The medium term view of the network was outlined by DfT in the first Road Investment Strategy, and we aim to review and develop this in consultation with customers and stakeholders over the coming months.

- The major development will be the presence of the expressway network across the length and breadth of the country – these will start their role from Road Period 2
- Expressways will 'feel' more like motorways, with comparable levels of information, monitoring, and response
- Possible new corridors will be investigated and potentially built to relieve congestion and improve connectivity
- There will be further extension and evolution of smart motorways, creating a smart motorway spine to the network that connects our largest cities, in line with the ambition outlined in the first Road Investment Strategy
- The APTRs still provide connectivity to more remote areas

4. How could we operate and deliver?

Identifying the themes

We have looked at the practical steps we may need to take over coming decades, including the changes to operation and practice which could be required.

Many of the changes will be strongly linked and we have identified five change themes. These build on the trends and have been considered based on our core scenario. As safety and environmental issues and actions are cross-cutting, we have embedded elements of these into all five themes. The activities and steps described are separated into different time periods, giving an indication of how our ambitions may evolve. We recognise that those associated with the short term have greater certainty than those placed further into the future.

The five themes

The five themes are detailed over the coming pages, illustrated in the summary diagram below.

Steps to the future SRN

Design, construction, and maintenance	Deploying new materials and construction techniques	Increasing asset connectivity and digitisation	Automating construction to speed up delivery	Creating a network of self-sustaining, smart assets
Connected and autonomous vehicles	Providing network connectivity	Realising fully connected and safer roads	Preparing for a driverless network	Supporting CAV-only roads
Customer mobility	Providing for new mobility choices	Creating high quality connections for our customers	Enabling seamless journeys across integrated transport modes	Providing guaranteed customer journeys
Energy and the environment	Providing clean energy infrastructure Reducing impacts on our neighbours	Progress reduce, reuse & recycle	Phasing out internal combustion	Improving the environment, with a positive bio-diversity footprint
Operations	Maximising data to inform operations	Integrating networks between the road, operators, and customers	Creating an intelligent, self monitoring, and reactive network	Achieving a near zero disruption network

Next steps → Future ambition

Theme 1:
Design, construction, and maintenance

While recent advances, such as the use of smart motorways, have brought improvements, some elements of road building have not evolved substantially since the 1960s. As new technologies emerge and become mainstream, we expect there will be opportunities to modernise the design and construction methods used on our network, and we will aim to apply the principles of automation and repeatable digital techniques to the complex external environment of road design, construction, and maintenance.

Areas of focus

Over the next 30 years and beyond, we believe that our assets should become resilient, easy to maintain, and easy to build. To do this, we expect to focus on six areas:

1. Automated designs – where we will seek to automate our design process to make schemes even more efficient and reduce the potential for human error, seeking to gradually increase the level and complexity of automation

2. Data improvements – where we will increase both the number of sensors embedded in our assets and the level of data collection both from ourselves and other sources, such as vehicles

3. Asset management maturity – where we will create an increasingly sophisticated unified asset management system and move towards analytics of real time data to optimise our decision making and improve the efficiency of expenditure across all assets

4. Automated construction, maintenance, and inspections – where we will explore a range of options to make our construction work even safer and more efficient, including opportunities for incorporating robotic construction and using drones to help inspect and manage our assets

5. Modular construction – where we will adopt modular construction techniques, reducing the level of roadside working required, increasing the pace of construction, and reducing the cost and time taken to renew components

6. Smart materials – where we will reduce the amount of reactive work required to maintain the network, using advances in materials to create to a self-maintaining, better co-ordinated network capable of extending asset lives and using assets that either self-heal or do not fail

Progress over the short term

Some of this technology is already available now and, in the short term, we will continue to modularise and automate our approach to design and construction, as we have done for gantries and roadside technology. We will also give particular focus to our most frequently occurring maintenance activities. We have already applied this principle to how we maintain the road surface, where new machinery enables in-situ recycling, providing cost and time benefits.

We expect to review how asset designs could be improved to make it easier for automated construction, inspection, and maintenance. We expect to see the first designs specifically supporting remote and robotic monitoring of structures, such as barriers, and the introduction of assets which have been designed with consideration made to automated construction. We will also initiate thinking on the next generation of design standards to support CAVs, considering new junction designs, safety features, and traffic control centre communication protocols. We will start working on trials and consider where we should support the development of enabling technologies.

Progress over the medium term

In the medium term, we are planning for a new age of greater automation. We hope that all critical assets will be subject to smart monitoring. Robotic inspection of structures is likely to be supported by asset design improvements and technology enablers. Maintenance will gradually evolve, moving to automation being extensively used across routine maintenance activities. We also expect to see an increasing level of technology in construction – working towards automated construction of structures. This will help ensure that we are benefiting from many of the automated processes already seen in other industries.

Progress over the long term

In the longer term, we hope to have deployed genuinely smart assets across our network, capable of making decisions based on analysis of their own performance. Automation and drone technology, combined with the ability to take control of the fleet through connected autonomous vehicles, is likely to have a significant impact. With 3D printing, components may be better manufactured on site rather than requiring excessive inventories or over-standardisation of our assets.

Theme 2:
Connected and autonomous vehicles

Highways England is responsible for traffic management and the safe operation of the network. As the operational nature of the network changes, new capabilities may be required. We will need to facilitate a staged transition as technology and associated infrastructure evolves. This transition will effectively take us from current day, when vehicles are only capable of limited connected or autonomous functions, through to when our network is made up of fully connected and autonomous vehicles. The communication of instructions could shift away from being given to the driver, and instead to being directed to the vehicles occupying our network.

CAV uptake will be sensitive to the level of customer pull and the policy backing from government. We will have an opportunity to support certain elements of this within our remit, such as through technological trials, the funding of infrastructure, or other customer provisions. Given the high level of uncertainty about how quickly CAVs will be adopted, we will need to evolve our approach as the technology develops.

Areas of focus

We expect to focus on three areas:

1. Supporting connected cars – where we will focus on maximising the benefits of the increase in connectivity of the fleet, given the projected rates of uptake of connected technology

2. Preparing for the operation of a mixed fleet – where we will seek to understand and address the challenges around safe operation and communications that come through the presence of early adopters of CAV technology on the network, likely to be from Road Period 2 onwards

3. Developing our role in supporting and enabling CAVs – where we will develop our approach to ensure that we maximise the capacity and safety benefits that CAVs offer, using the volume of data available to us as a network operator and the intelligence and sophistication of the fleet

Progress over the short term

Over the short term, we will continue to roll out and enhance the current capital investments determined through the Road Investment Strategy process, such as smart motorways. Aside from the direct short term benefits, this will help road users to adjust to a dynamic and communicative road infrastructure. In addition, we will focus on how data is captured, supporting the creation of standardised specifications for our suppliers to allow the development of integrated network solutions.

Vehicle manufacturers expect initial deployments of CAVs in significant numbers to start in the coming years. As the fleet becomes increasingly mixed in its technological capabilities in the next road periods, we will need to address how best to communicate and interact with vehicles on our network. This work will build on the current progress with CHARM, our traffic management system, as a new traffic management capability is created to start bringing new C-ITS applications to drivers in the next decade.

In the short term, we will have three focus areas:

1. Developing future operating procedures, including operational procedures for CAVs on the SRN

2. Undertaking strategic pilot schemes to keep testing and developing our network during this transition period, including vehicle to infrastructure communication (V2I), dynamic lane management, and the next steps on platooning vehicles

3. Working with government to determine our role in enabling the roll-out of digital communications across the SRN, including Wifi and 5G

We will work with wider industry and government stakeholders to inform the debate on what the role of the network operator should be, and what level of intelligence and control over the network this requires once a critical mass of CAVs is reached.

Progress over the medium term

As the design of connected highway corridors matures, and the construction of necessary infrastructure nears completion, we anticipate that the vehicle fleet could become nearly fully connected. This would enable us to start to change the design of roads and the way we interact with customers. For example, gantries and VMS signs may no longer be required, as we may be able to inform and engage with our customers directly through the vehicle.

Automation is also likely to be highly developed, with a considerable percentage of traffic mileage being completed by vehicles capable of full autonomy. It is during this period, as fully autonomous vehicles start to become mainstream, that we expect significant benefits in capacity to be realised for the SRN, with other benefits, such as safety and flow, becoming more established. During this period we will start preparing for how we can transition some, or even the majority, of the network to a driverless environment over the long term.

Progress over the long term

There is still a high level of uncertainty about what travel could look and feel like in this period. However, based on current predictions, by 2050 we expect to run a network of connected, fully autonomous vehicles. This period is therefore likely to see the end of investment in obsolete assets and the introduction of a redefined form of road transport, including dynamic lanes, AI operations, and driverless travel. We will also assess and develop our role to ensure that the infrastructure and the way we operate it supports and enables the significant benefits that can be gained from CAV technology.

Theme 3:
Customer mobility

We believe that the way in which our customers travel, both on and off our network, will transform over the coming years. The level of forecast change also indicates that we are likely to see a real shift in the way that transport systems interact and provide for their users. We, too, expect to adapt to meet these evolving mobility demands, enabling seamless journeys for our customers.

Areas of focus

We expect to focus on three areas:

1. Customer experience – where we will work to ensure that road users, whether for personal travel or freight, will enjoy a positive experience with MSAs and other key supporting infrastructure

2. Connecting hubs – where we will support connectivity across the length and breadth of the country, seeking to tackle and improve boundaries between different modes of transport and enabling smooth onward journeys

3. New customer relationships – where we are expecting to see an increasing variety of ownership models, and potentially moving to deal with a smaller number of customers – the main service providers – about most traffic

Progress over the short term

We will explore the potential for further joint planning with other modes of transport and regional transport bodies. This will include continuing our work with the rail industry to coordinate upgrades, not least around HS2, and with other engineering work and expansion projects, such as London Heathrow. We may look to place greater emphasis on strategic park and ride schemes to improve urban mobility solutions. In some cases, we may invest off-network, where it has benefits for the SRN, such as supporting cycling and walking, or investing in local roads which improve SRN resilience.

Over the short term, we expect to see MaaS starting to be provided by multi-modal operators, though initially this will be an evolution of existing and emerging models. In this period, our primarily aim in relation to MaaS will be to seek to understand the changing nature of car use and its potential impact on the SRN. We will incorporate this knowledge into future planning, paying particular attention to the information requirements of our customers.

Progress over the medium term

Technological change is likely to start to enable tangible differences in how transport is used. We envisage that a number of fleet operators could begin to emerge, potentially mirroring a ride-hailing type model but including some multi-modal elements. The rise of CAVs would support even greater shifts to these models and, as costs reduce and convenience increases, there could be rapid growth within the market. As commercial services begin to play a more active role in road transport, this could further support multi-modal approaches. How applicable this will be to the SRN, as opposed to city regions, is less clear. However, we are interested in the opportunity that these platforms could offer to the efficient movement of freight across our network.

We will work increasingly closely with partners to manage strategic transport hubs and explore the potential for switching freight to autonomous night time operation. We expect to develop operating protocols for the network to improve how the SRN interacts with other modes of transport. We will aim to provide high quality connections – not only physically, but also in terms of information provision and accuracy.

Progress over the long term

Over the long term, we expect to see autonomous vehicles, and more innovative car ownership schemes, make road transport more accessible to the entire population. Our customers are likely to expect an increasingly integrated transport network, potentially increasing demand. Depending on the evolution of MaaS, a significant proportion of SRN traffic could be through service providers far closer to what we would today call public transport, as opposed to private transport. Private vehicle ownership for commuting could become a rare occurrence. In this scenario, our core focus would likely be to provide the infrastructure from which mobility service providers could reliably meet consumer demand for road transportation.

To cater for increasing demand for the network itself and for transferring between modes (in terms of both volume and speed, or seamlessness), we may need to become better at managing greater demand for our network. This could raise technological questions, such as how the position and speed of every vehicle on the network can be known and appropriately managed.

Theme 4:
Energy and the environment

Government has committed to achieving both reductions in the UK's greenhouse gas emissions and also improvements in air quality. As an organisation, we have made a strong commitment to an ongoing improvement in environmental outcomes through the operation, maintenance, and modernisation of the SRN. We will work with the Department for Transport (DfT), the Department for Environment, Food and Rural Affairs (Defra), Office for Low Emission Vehicles, and others to help improve air quality, lower carbon emissions, and reduce the impacts our network has on the natural environment.

A key part of our role will be supporting a transition from conventional petrol and diesel vehicles on our roads to a zero emission fleet, whilst also providing efficient and less polluting journeys for our customers by reducing congestion on the SRN.

Areas of focus

We expect to focus on three areas:

1. Clean vehicle energy – where we will support government's commitment to be a world leader in electric vehicles, supporting the roll out of the right facilities to meet demand. We will continue to track and enable the development and roll out of the next generation of electric charging technology and further long term clean energy sources, such as hydrogen

2. Reducing our impacts – where we will reduce the negative impacts the SRN has upon its neighbours and the wider environment. We aspire to a network which minimises its impact upon natural environments and protects our heritage, whilst actively tackling air, noise, and severance issues for our neighbours

3. Sustainable operations – where we will deliver enhancements and renewals to our network in an increasingly sustainable manner. Our future investments will seek to be more efficient and resilient, reducing waste during the lifetime of our assets

Progress over the short term

ULEVs are showing promising signs of significant uptake. We will aim to ensure that our on-road service has the tools and capabilities to support customers in an increasingly varied and electrified fleet.

We will identify opportunities to work with others to ensure that we are supporting the clean air agenda in line with government requirements, including exploring innovation calls, to support new research and technologies. This includes working in partnership with our existing service providers and local authorities to explore potential ideas across the SRN and wider networks. Working with Defra, we will explore ways to enhance our real-time monitoring of air quality and emissions on our network, whilst reviewing and refining our key traffic and air quality models.

As we move into forthcoming road periods, we will aim to deliver our capital improvements in a more sustainable manner. This will include being increasingly efficient in our resource use, reducing our primary resource demands, and maximising re-use where possible. We shall also seek to reduce the negative impacts the SRN can bring to its neighbours. We will seek to use barriers, including vegetation and other methods, to mitigate against noise pollution beyond network boundaries, and reduce light pollution and energy use by adopting modern lighting technologies and eliminating unnecessary lighting, where safe to do so. We will strive to ensure new capital improvements are well-designed to account for environmental, aesthetical, and local planning considerations alongside engineering requirements. As a result we expect to reduce impacts on the prevailing natural, built, and historic landscapes, whilst preserving biodiversity and community connections.

Progress over the medium term

Over the medium term, it is expected that low emission vehicles will continue to gain popularity, depending upon convenience and pricing developments. During this period, we will seek to work with DfT, Defra, and wider government to help enable access to power sources in line with current policy and addressing any barriers on our network to final mass market uptake of low emission vehicles.

We will consider how best to support cities and local authorities as they explore options for their local air quality plans, potentially considering strategic park, charge, and ride schemes.

We may also explore with government other methods to dynamically manage traffic on our network to improve traffic flows and subsequently help to improve air quality. We may examine the use of technology to switch low emission vehicles to zero emission mode in areas of poor air quality to help our neighbours.

We anticipate that improvements to clean freight power sources will progress in the future - a range of on-road HGV charging solutions (such as catenary wires), hybrid electric drive, and hydrogen cell solutions are currently being developed. We may seek to enable early uptake of these technologies once a viable option has been decided.

The delivery of our capital projects is likely to be accomplished in a sustainable manner, with working practices, such as the responsible sourcing and recycling of resources, becoming routine. Our new physical assets could become more resilient and require less renewal, and we will continue to seek to reduce our operational carbon footprint.

We hope that our investment will produce a network which is well-designed and less impactful on the surrounding environment, supporting local communities and reducing severance. This could be achieved by making use of new materials and designs for barriers, vegetation, and landscaping, as well the use of low noise road surfaces in sensitive areas.

Progress over the long term

In line with government's air quality strategy, we expect to see no sales of new petrol and diesel cars by 2040. The subsequent market shift may require a marked increase in convenient, fast-charging solutions and hydrogen facilities for our customers across our entire network. As such, the SRN is predicted to progress towards zero tailpipe emissions, greatly reducing the negative air quality and emission issues we currently experience.

We hope that our network will work harmoniously with its surroundings to produce a greatly improved wider environment and a net gain in biodiversity. When required, we expect that our capital works will embrace recycled materials and that our net resource consumption will be minimal. We will seek to ensure that the SRN is a greatly improved neighbour, with air and light pollution greatly mitigated and severance issues resolved.

Theme 5:
Operations

Our operations will evolve as the road network becomes increasingly linked through telecoms networks and connected assets. This will be supported by the enhancement and simplification of the network – removing the complexities that disrupt flow and inhibit user experiences. Furthermore, we expect to see traffic management and customer service respond to the changing business models and patterns of use on the network, and a significant reduction in the disruption caused by roadworks, extreme weather, and serious incidents.

Areas of focus

We will focus on six areas:

1. Customer service – where we will continue the emphasis on our 'customer' imperative, improving our understanding of the customer, providing better information, maximising the benefits of connected cars, and preparing for the changes in customer behaviour

2. Data-driven operations – where we expect to collect better data on our assets and how our network is performing in real time. We aim to use this data to inform our asset management operations as we aspire to move towards predictive condition monitoring and maintenance

3. Traffic management – where we expect to increasingly be able to manage the network in real time and to high levels of safety, through state of the art control centres, our on-road service, and traffic analytics. A more free-flowing network and greater operational resilience could significantly improve the experience of using the SRN

4. Network classification – where we will initially work to transform the network in line with our four classifications of smart motorways, motorways, expressways and APTR, and, in the longer term, investigate how the network should develop to reflect a largely or fully autonomous fleet

5. Roadworks – where we will continually drive for predictable and efficiently-delivered works, with the disruption they cause being understood and mitigated through better planning, co-ordination, and new technology

6. Incident and severe weather response – where we will seek to adopt a modern, technologically-enabled response to incidents to keep the SRN open

Progress over the short term

In this period, our operational focus on our customers will continue to sharpen as we deliver a larger and more ambitious programme of work, and as road users become familiar with more dynamic highways that respond to weather and congestion. We will seek to increase our insight and responsiveness to our customers, potentially setting out customer standards to explain what they can expect from us.

Since the smart motorway scheme was extended in 2010, we have continued to invest in this programme. In the short term, smart motorways will provide critical capacity to a crowded network. We will use and develop the smart motorway infrastructure to engage with connected vehicles, and communicate in an even more useful way with those driving on our roads. This will assist with the longer term transition to an entirely connected fleet, contributing to the shift in driver attitudes and behaviours.

Technology will enable improved response times, potentially including the use of drones – if only at first for assessing incidents as opposed to direct interventions. Improved use of data will create a stronger link between our operations and our asset management, as our operations become data-driven.

Progress over the medium term

Over the medium term, as we prepare for the digital switch-over, we expect to focus on the continued delivery of our upgrade programmes. We may also review the categories of roads we have. We want smart motorways to have defined specifications for technology and service, and for expressways to be aligned with a standard set of user requirements. During this period, we expect the majority of expressway conversions from the existing network to be completed.

At the same time, we also envisage this period marking the last standard motorway being converted to a smart motorway, potentially enabling us to consider whether to mandate connectivity on the SRN. Prior to this, we expect to focus on effectively managing a mixed fleet through, for example, dedicated lanes and potentially managing connected platoons.

Progress over the long term

Over the longer term, we expect to introduce real time models and use mass simulation of our entire network to transform our operational decision making. As CAV roll-out picks up pace, we may introduce routine digital communications directly to vehicles, allowing us to pass safety-critical and routing information directly to the fleet. These factors should combine to provide much greater journey reliability and safety.

We expect to see MaaS in widespread operation. There may be a potential change in the relationship between large MaaS companies and ourselves as we look to provide “timetabled” operation of the network, should this align with the emerging market’s needs.

A natural evolution for the network could be for AI operations, creating a learning environment where network performance is constantly under review. It may be the network itself making the minute-to-minute decisions on how to manage traffic flow and recover service during periods of disruption.

5. What's next?

Our long-term plan

We think advances over the next 30 years or more are likely to revolutionise transportation, road travel, and personal and commercial mobility. In this document, we have set out how we believe we can make the SRN work for the people who use it and the wider economy over the long term.

Based on our research, we have set out how we can harness the power of the existing network – building on the planned and committed programme of schemes for the current road period – whilst developing and improving for the future.

We have worked through the practical next steps we expect to undertake over the short, medium, and long term, including likely planning decisions and changes to operations and practice. Safety, customer and delivery remain our strategic imperatives, and these have been our guiding principles.

We have consulted extensively to test, improve, and refine our conclusions. Consultation has included experts within our organisation, industry societies, technology companies, car manufacturers, sub-national transport bodies, academics, consultants, and contractors. However, we recognise the inherent uncertainty in long term planning and we look forward to continuing to engage widely to evolve our analysis and plans over coming years.

Planning for the next road period

Having looked to the future, it is now time for us to return to the present and bring the insights to bear.

Our immediate focus will be on working closely with government to support the development of the next Road Investment Strategy. We will also incorporate insights and practical next steps into planning for the Road Period 2. We will continue to work closely with our wider partners and those who have informed this work to date.

We recognise, however, that research and evidence are always evolving. We fully accept, and anticipate, our view of the SRN will need to be updated over forthcoming road periods. We believe that review and testing of the key trends and long term planning will become an integral part of the research stage in developing further Road Investment Strategies.

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