Report
April 2021

Infrastructure Demand Quantitative Analysis for Scenarios of Behaviour Change

National Infrastructure Commission
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steer

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Overview

The National Infrastructure Commission (NIC) wishes to understand how any long-lasting changes in behaviour due to the COVID-19 pandemic may affect long-term infrastructure demand. In this context, the long term is defined as the period from 2025 to 2055. It is assumed that by 2025 any short-term impacts of the pandemic due to restrictions of the nation's social and economic life and the consequent short-run impacts on the national economy will have fully dissipated and the economy will be following a 'new normal' trajectory.

To help its consideration, the NIC has developed several scenarios for possible behaviour change, each with a long-term outlook. These have been informed by the NIC's own research on the behavioural impacts of the COVID-19 crisis, its theoretical understanding of how behaviour change occurs, and examples of how historical shocks have affected behaviour over the longer term.

Taking the NIC's scenarios, the purpose of the work described in this report is two-fold:

- To gain an understanding of the order of magnitude of the effects that different scenarios of behaviour change may have on the demand for different types of infrastructure in different sectors of the economy.
- To develop quantitative representations of the five NIC scenarios to support more detailed demand modelling across the sectors of interest in the future.

The infrastructure sectors that have been considered are:

- Transport
- Digital
- Energy
- Water & Wastewater
- Waste

The NIC's Scenarios

Focussing on behavioural responses to the pandemic, the NIC has identified four 'meta-trends':

- **Working from Home**: where people and businesses adopt more homeworking.
- **Social Wariness**: where people are cautious in participating in social gatherings.
- **Dispersal from Cities**: which includes suburbanisation (where people and businesses move out of the centre of cities to their suburbs and more rural areas), regionalisation (reduced population density and access to open spaces e.g. natural beauty), and/or a combination of these trends.
- **Use of Virtual Tools**: where there is a significant uptake in online and virtual activities in social, leisure, learning and consuming (including public services).

To help define its scenarios, the NIC has defined three levels of potential response to each of these meta-trends. These are:

- **Low**: where the meta-trend has a relatively small impact on the demand for infrastructure in any particular scenario.

- **Medium:** where the meta-trend has a moderate impact on the demand for infrastructure in any particular scenario.
- **High:** where the meta-trend has a large impact on the demand for infrastructure in any particular scenario.

The NIC has used these meta-trends to define five scenarios. These are:

- Scenario 1: Reversion and Reaction
  - Behaviours are broadly similar to 2019
  - The adoption of flexible working and working from home returns to pre-pandemic levels (noting there was a gradual trend in increasing home working prior to 2020)
- Scenario 2: A More Flexible Future
  - Flexible working is adopted within a sub-group of employers and employees where it is practical and feasible to do so
  - People adopt flexible lifestyles with a significant amount of social engagement
  - City centres continue to be important hubs for people to work and socialise
  - Urban and suburban areas continue to be key areas for living.
- Scenario 3: Low Social Contact Urban Living
  - Office-based working returns, with a modest increase in flexible working
  - Social wariness is permanently higher with certain habits formed during the pandemic sticking
  - There is a greater uptake of virtual activities across all domains
- Scenario 4: Social Cities
  - Homeworking is adopted at a high level among employers and employees where it is practical and feasible to do so
  - Demand to change household location is constrained by price/availability
  - People prefer to be socially active and are not anxious about large gatherings
  - A decline in permanent town/city centre office space is somewhat offset by growth in other amenities/uses.
- Scenario 5: Virtual Local Reality
  - Homeworking is adopted at a high level among employers and employees who are practically able to do so
  - Social wariness is permanently higher with certain habits formed during the pandemic sticking.
  - People radically alter how (and to a smaller extent where) they live and reduce travel as a result.

Approach to Quantitative Analysis

A series of segmented ‘consumption rate’ models were developed to produce a quantified assessment of the potential impact of each scenario on demand in the five sectors listed above. The impact of the scenarios on demand was assessed by altering variables that describe the consuming population and/or variables that give the rate of consumption. The alterations to the variables were informed by pre-pandemic trends, what has happened during the pandemic, and the experience and expertise of the project team. As such, the quantified impacts of the five scenarios are plausible potential impacts, but they are not forecasts and should not be treated as such.

Extensive use was made of Office for National Statistics (ONS) datasets, the Department for Transport’s (DfT’s) National Travel Survey, as well as administrative datasets for other sectors.

When considering the results of this work and thinking about subsequent analysis, it is important to understand and consider the limitations of the adopted approach. In particular, it should be noted that the models only seek to quantify changes in consumption rates arising from the meta trends listed above. They do not attempt to model changes arising from other external drivers, such as wider macro-economic influences. This is deliberate as this enables the analysis to focus on behavioural changes that underpin the NIC's scenarios. That said, it is likely that consumption rates would be affected by other factors, including inter-related influences such as economic growth leading to greater disposable household income, societal changes (e.g. make-up of households), and technological developments. Modelling the interaction of these additional factors with the potential post-pandemic behavioural impacts is out of the scope of this work, but it is intended that this work lays the foundation for subsequent more detailed modelling should the NIC wish to do so.

Findings

Transport

The analysis presented in this report suggests the most significant post-pandemic behavioural response is the number of people who chose to undertake activities at home, be this work or other activities such as shopping (online rather than at shops) or social activities (e.g. virtual rather than face-to-face). The Working from Home and Use of Virtual Tools meta-trends are potentially more significant than Dispersal from the Cities. This is simply because of the scale of the population that they apply to.

Considering the Working from Home meta-trend, this changes the number of people who choose to work from home, whether that be permanently or on a more flexible basis. For the purposes of this work, it has been defined that Standard Occupational Classification (SOC) Groups 1 to 4 (principally managerial and professional workers) are those who have the potential to work from home. Together, these SOC Groups account for 57% of the working population, which is 18.5 million people. The Use of Virtual Tools meta-trend affects the entire population.

In contrast, the Dispersal from Cities meta-trend has been found to have a lesser impact. This is because the number of people who could feasibly move to the suburbs ('surburbanisation') or move out of towns and cities ('regionalisation') is small compared with the population who would potentially be affected by the Working for Home and Use of Virtual Tools meta-trends. Even if the people who do move then have a significant change of travel behaviour, the scale of the population affected is such that the effect is not as great as those that could arise from the Working for Home and Use of Virtual Tools meta-trends.

The Social Wariness effect is also significant as this has the potential to materially affect future public transport patronage. As well as affecting the strategic and economic case for future public transport capital investment, such a decline could have immediate impact on the finances of public transport. Should this lead to a service reduction, this would make public transport less attractive, which in turn would have a further downward impact on patronage.

Digital

The defining feature of the digital sector is the rate of change of both network capacity and its use that has occurred in recent years. The projected future rate of change is such that there is no merit in looking at demand beyond 2025 as beyond this even modest upward or downward change to annual growth rates will lead to very different outcomes.

Pre-pandemic peaks in digital demand were leisure driven and occurred in the evenings and at weekends. While digital demand appears to have increased during the pandemic, available data suggests that the increase in weekday daytime demand did not exceed pre-pandemic evening use. Also, throughout the pandemic, digital networks have had sufficient capacity and capability to cater for the increase in leisure-driven digital demand.

Digital capacity is provided in a dynamic and commercial market. Looking to 2025, the conclusion of this work is that any behaviourally driven changes of demand can be accommodated. Before and after that, the commercial providers will both respond to market pressures and create digital markets through the products they offer.

Pre-pandemic, the challenge for digital was extending the high capacity network to 'hard to reach' places. This remains the case post-pandemic. If anything, should the NIC scenarios lead to an increase in digital demand, then this could shift the balance towards further commercially-driven roll out of enhanced network capacity across the country.

Other Sectors

This work has found that the most significant influence on modelled future demand for the other sectors in the scope of this study (Energy, Water & Wastewater and Waste) is how much time people spend at home doing activities that, pre-pandemic, would have been done elsewhere. Working from Home and Use of Virtual Tools both suggest that more time will be spent at home and this leads to greater domestic energy and water use and, potentially, greater domestic waste (for example, due to more packaging from internet shopping deliveries). To a degree, there would be a concomitant reduction in commercial consumption. However, it would not be a one-to-one reduction – a shop doesn't use less energy because it has lower footfall. Structural adjustments would be needed to realise material reductions in commercial consumption, e.g. smaller shops and/or fewer shops.

While Dispersal from the Cities would change where individual households use energy and water and generate waste, the scale of the population who might be part of this meta-trend is small. In contrast, the Working from Home and Use of Virtual Tools have the potential to affect a much larger share of the population. Without a shift in land-use policy, those who move as part of a Dispersal from the Cities meta-trend will move to extant properties or new properties that would be built in any event. While the movers may consume more per household, this will be a marginal increase on the previous occupants of the property.

Future Modelling

Informed by a review of a representative set of transport models, it is clear that such models could be used to explore in more detail the potential transport implications of the NIC's scenarios. However, what is also clear from the review is that while it is possible to establish a set of general principles that can be used to reflect the NIC's scenarios, it is not possible to pre-define a set of changes to model inputs or model parameters. These would need to be derived on a case-by-case basis, taking into account the particulars of model structure, as well as how they have been developed and calibrated.

1 Introduction

1.1 The National Infrastructure Commission (NIC) wishes to understand how any long-lasting changes in behaviour due to the COVID-19 pandemic may affect long-term infrastructure demand. In this context, the long term is defined as the period from 2025 to 2055, with the assumption that by 2025 any short-term impacts of the pandemic due to restrictions of the nation's social and economic life and the consequent short-run impacts on the national economy will have fully dissipated and the economy will be following a 'new normal' trajectory.

1.2 To help its consideration, the NIC has developed five scenarios for possible behaviour change, each with a long-term outlook. These have been informed by the NIC's own research on the behavioural impacts of the COVID-19 crisis, its theoretical understanding of how behaviour change occurs and examples of how historical shocks have affected behaviour over the longer term.

1.3 Taking the NIC five scenarios, the purpose of the work described in this report is two-fold:

- To gain an understanding of the order of magnitude of the effects that different scenarios of behaviour change may have on the demand for different types of infrastructure in different sectors of the economy.
- To develop quantitative representations of the five NIC scenarios to support more detailed demand modelling across the sectors of interest in the future.

1.4 This work has been undertaken over a ten week period, commencing at the beginning of February 2021 and concluding in mid-April. It has considered five sectors of the economy, namely:

- Transport
- Digital
- Energy
- Water & Wastewater
- Waste

1.5 The approach has been to develop a series of segmented 'consumption rate' models for each of the five sectors. The impact of the scenarios on demand has been assessed by altering variables that describe the consuming population and/or variables that give the rate of consumption. The alterations to the variables have been informed by pre-pandemic trends, what has happened during the pandemic and the experience of the project team. As such, the quantified impacts of the five scenarios are plausible potential impacts, but they are not forecasts and should not be treated as such.

1.6 This work has been undertaken by Steer with support from DMS Research & Consulting (Digital) and SPR Energy Consulting (other non-transport sectors). Throughout the work the Steer-led team has engaged closely with the NIC's project team.

Report Structure

1.7 This Final Report is structured as follows:

- **Chapter 2** gives a high level overview of recent pre-pandemic demand trends for each of the sectors considered by this work. More detail is provided in Appendices A to E inclusive.
- **Chapter 3** summarises the NIC's five scenarios. This summary provides context for what follows. It introduces the 'meta-trends' that have been defined by the NIC. More detail on the scenarios is provided in the NIC's own reporting.
- **Chapter 4** sets out the approach to quantitative analysis for the transport sector.
- **Chapter 5** goes on to set the approach to quantitative analysis for the other sectors that have been considered.
- **Chapter 6** sets out the transport impacts that have been associated with the NIC's meta-trends, how these have been translated into quantified changes in drivers of transport demand and then what that means for transport demand for each of the NIC's scenarios.
- **Chapter 7** focusses on the non-transport sectors and sets out how quantified estimates of demand for each of the scenarios have been developed, as well as summarising the results of the assessment.
- **Chapter 8** summarises how more detailed transport models could be used in the future to explore the NIC's scenarios. More detail is provided in Appendix F.
- **Chapter 9** offers some concluding remarks

1.8 The report has the following appendices:

- **Appendix A**: a review of recent pre-pandemic trends and the impacts of pandemic on personal travel.
- **Appendix B**: a review of recent pre-pandemic trends and the impacts of pandemic on the demand for light freight, along with a consideration of how e-commerce and technological changes may affect the small package market.
- **Appendix C**: consideration of pre-pandemic trends in digital demand, the impacts of the pandemic and future trends.
- **Appendix D**: an overview of pre-pandemic trends in the energy sector, what has happened during the pandemic and consideration of future trends.
- **Appendix E:** a look at the water and wastewater sectors, again considering pre-pandemic trends, what has happened during the pandemic and future trends.
- **Appendix F:** more details of the review of transport models that underpins Chapter 8.
- **Appendix G:** describes uncertainties that may influence the future demand for infrastructure previously identified by the NIC as part of the first National Infrastructure Assessment (NIA).

2 Demand During the Pandemic

Introduction

2.1 In this Chapter we briefly review demand trends both pre-pandemic and during the pandemic with a view to seeing if there are any lessons that can be drawn for quantifying post pandemic scenarios. A more detailed consideration of the key sectors is provided in Appendices A to E.

Transport

2.2 Measured by passenger kilometres, in the decade before the pandemic:

- Travel by car, van and taxi increased by 11%. This is a continuation of the long term trend of sustained growth in traffic, albeit at rates slower than observed in previous decades;
- Travel by rail grew by 37%. Trip making by train and travel on the national rail network has experienced strong growth over the last quarter of a century, although much of the growth in the last decade was in its first five years;
- Travel by bus and coach has fallen by 26%, a continuation of a long term decline in bus travel since the 1950s. However, within this overall trend travel by bus in London increased whilst outside London it fell.

2.3 Throughout the pandemic the Department for Transport (DfT) has been publishing statistics showing the use of different transport modes. This includes:

- Car traffic on the Strategic Road Network (SRN) – this is the network owned and managed by Highways England and includes all motorways as well as some A roads;
- Light Commercial Vehicle (LCV) and Heavy Goods Vehicle (HGV) traffic on the Strategic Road Network;
- Passenger numbers on the
  - National Rail network
  - London Underground
  - Bus outside London
  - Bus within London.

2.4 The DfT data is benchmarked against early February 2020, that is just before the pandemic took hold within the UK. Because of this, a degree of caution needs to be applied when looking at the data as February 2020 may not necessarily be a typical or average period for travel by the modes for which data is provided. Also, the data on car, LGV and HGV traffic is for the Strategic Road Network. The experiences on local roads may well be different. With these caveats in mind:

- Before the introduction of lockdown restrictions on 23rd March, public transport demand was already falling as travellers heeded the advice to work from home if possible and avoid non-essential journeys.
- The March lockdown led to an immediate and precipitous fall in public transport patronage. As well as businesses being closed, travellers were advised by Government

not to use public transport unless the journey was essential. In mid-April, national rail and London Underground patronage was less than 5% of its pre-pandemic levels, patronage for local bus services outside London was around a tenth of pre-pandemic levels and in London bus patronage was less than a fifth of that before the pandemic

- As lockdown eased, public transport patronage recovered and then declined as restrictions were reimposed. By September national rail patronage recovered to around 40% of its pre-pandemic levels, but declined as restrictions were tightened. London Underground patronage followed a similar pattern. Bus services in London and elsewhere had reached a peak around 60% of their pre-pandemic levels and were less affected by tightened restrictions. Pre-pandemic, bus users typically had less access to a car than rail travellers and a greater proportion of their journeys would fit the pandemic's 'essential' category. In contrast, many rail journeys and especially those into London and other town and city centres were made by people who were able to work from home. Together these facets help explain why by Autumn 2020 bus patronage recovered to a greater extent than rail.
- The continuing operation of public transport has required substantial and on-going financial support from the Government.
- Social distancing measures remain on public transport, which places a practical limit on capacity which is below pre-pandemic levels of demand.
- On the Strategic Road Network, on the whole car and van traffic has remained below its pre-pandemic levels. While van traffic for deliveries has increased, it is important to note that pre-pandemic a greater share of van traffic was associated with trades going about their business. Any increase in delivery traffic has not offset the fall in other van traffic. HGV traffic recovered to above February 2020 levels, although it is noted that in terms of road traffic February is a below average month.

2.5 While the pandemic has had significant impacts on transport use it is difficult to draw any lasting lessons from this. Restrictions on social and economic activity all have had a direct and immediate impact on transport demand. It is not yet possible to isolate any longer lasting impacts from these shorter-term ones.

Digital

2.6 In the five years preceding the pandemic, monthly data usage over fixed broadband grew at greater than 35% per annum. Market driven technology developments are considered to be the most important factors that have driven growth. These have been in telecoms technology, customer equipment, and new or enhanced applications that use greater quantities of data. A strong provider market has driven capacity expansion while also offering price competition.

2.7 During the early stages of the pandemic:

- There was a large increase in daytime traffic during weekdays. This will have been driven by the traffic demands of people working or studying from home (and using video conferencing tools, such as Zoom and Microsoft Teams, heavily), and also by the traffic generated by millions of people put on furlough, many of whom will have turned to online entertainment during the lockdown, including video-streaming applications such as Netflix, and online gaming.
- As with pre-pandemic, the peak period for traffic was in the evenings, both at weekends and weekdays. This is considered to be driven by leisure not business/work related use. Operators of mass market broadband services dimension their networks to handle this peak, with headroom, and the anticipated growth in that peak.

- The increase in typical traffic during the peak period was significant but relatively modest, both for weekdays and weekends.
- The increase in daytime traffic did not exceed pre-pandemic evening peaks.

2.8 Overall, the UK's internet infrastructure has coped very well with the step-changes in behaviours enforced by the pandemic lockdowns. As restrictions on economic and social life are eased it is anticipated that demand will fall back to below the pandemic peaks.

Energy

2.9 Energy has various end uses which drives demand:

- In the domestic sector, it is used for space and water heating, cooking and lighting, as well as by various household appliances and consumer electronics.
- In industry, it is used for operating machinery, production chains, etc.
- In the service sector, it is used, for example, by hospitals, schools, etc for heating purposes and power electronic equipment, etc.
- In the transport sector, it is used in the different modes i.e. road, air, rail, maritime.

2.10 While year-on-year national energy usage fluctuates (with the weather being a key factor), the trend since 2001 has been a decline of around 0.8% per year on average. Much of this has been driven by a fall in industrial use. Over the same period, the UK energy sector has undergone significant change as it decarbonises with the phasing out of coal generation and the increase in renewables being notable features. Further change is expected as the UK moves to net zero, which will have an effect both on the way energy is provided and the way it is consumed.

2.11 Energy consumption in the UK has been affected by the impacts of pandemic restrictions on economic output, leisure activities and travel. Total final energy consumption fell by 18% between Q3 2019 and Q3 2020, though there were notable differences by sector:

- Domestic sector consumption increased by 2.5%, as more people were home working or were furloughed or laid off.
- Transport sector consumption fell by 30%, as lockdown restrictions affected both domestic and international travel.
- Service sector consumption fell by 7.8% as many shops and offices were closed.
- Industrial sector consumption fell by 8.4%.

2.12 As restrictions are lifted it is anticipated that service and industrial sector consumption will return towards pre-pandemic norms, albeit with a potential downward impact due to the longer-lasting economic consequences of the pandemic.

Water & Wastewater

2.13 Data is available on the public water supply between 2000 and 2017. What this shows is that abstraction levels in 2017 were below those in 2000. Although abstractions increased in 2016 and 2017 from the low seen in 2015, they were still some 16% below the peak seen in 2005. These figures exclude agricultural uses, private supplies and the electricity supply industry amongst other exceptions.

2.14 There have been various studies into changes in water demand as a result of the lockdowns imposed in response to the pandemic. UK data, based on consumption from about 200,000 households and some 1,000 non-households found:

- the morning peak started later in the day for households;
- household peak daily consumption at the end of May 2020 was about 35% higher than it was pre-lockdown, and the evening peak was often higher than the morning peak, but this may be more attributable to the warm weather at the time; and
- non-household consumption reduced significantly during the first lockdown.

2.15 The changes were attributed to a number of factors, notably:

- the changes in behaviour from working at home and not needing to get children up and ready for school in the mornings;
- increased occupancy during the day (for example, older children returning home when colleges and universities closed);
- less movement of people between areas (people not going to work and not going away on holiday);
- changes in water use, such as more handwashing; and
- the huge reduction in consumption from the hospitality, entertainment and retail sectors.

2.16 A comparison of water use before lockdown (February to early-March) and at the beginning of lockdown (late-March to early-April) found:

- most water companies saw an increase in average water consumption during lockdown;
- companies covering predominantly suburban areas saw the most noticeable increase, while companies operating in city areas saw a reduction in water use; and
- differences between weekday and weekend water consumption largely disappeared.

2.17 As restrictions are lifted it is likely that commercial consumption will return towards pre-pandemic levels, but with a negative downward impact due to the pandemic's lasting economic consequences. Greater numbers spending more of the working day at home will act to increase domestic water consumption, as well as potentially change the pattern of consumption across the day and between weekdays and weekends.

Domestic Waste

2.18 In 2018 UK households produced 26.4 million tonnes of household waste. In the four years to 2018 there had been little change in the quantity of waste from households. Similarly, there has been very little change in the recycling rate at around 45%. In Wales a greater proportion of domestic waste is recycled than in the other home nations, which may be taken as an indication that there is scope to increase the total share of domestic waste that is recycled.

2.19 It is difficult to discern trends in household waste during the pandemic. People were at home because they were working from home or had been furloughed/laid off. More home deliveries led to more packaging and there were potentially one-off effects (e.g. increase in DIY, 'life laundries') that increased domestic waste. Confusing the picture is that many councils adjusted their waste collection schedules and many municipal collection sites had reduced hours or were closed.

2.20 It has been estimated that during Q2 2020, kerbside collected household waste rose by around 10%. However, this was offset by a significant reduction in tonnages of household waste accepted at Household Waste Recycling Centres. The net result was a modest fall in overall household waste.

2.21 Available data suggests that the make-up of household waste changed during the pandemic, with an increase in dry recyclables (e.g. packaging) and a drop in collected garden waste, the latter potentially a result of changed collection practices.

2.22 In the absence of any specific data on the impact of working from home during the pandemic on waste, it would seem reasonable that greater working from home will lead to a modest increase in the volumes of household waste.

3 The NIC's Post COVID-19 Scenarios

3.1 The NIC has developed a qualitative description of five post pandemic scenarios. The scenarios have been developed such that the scenarios:

- cover a plausible range of outcomes;
- are based on a range of different behavioural responses;
- form coherent packages of futures, based on underlying interactions between behavioural trends; and
- should help deliver useable outputs and enable more detailed demand sector modelling.

3.2 Focussing on behavioural responses to the pandemic, the NIC has identified 25 trends which in turn have been grouped into four 'meta-trends' as summarised below:

- **Working from Home**: people & businesses to adopt more homeworking.
- **Social Wariness**: people cautious to participate in social gatherings.
- **Dispersal from Cities** (people and businesses): suburbanisation (desire to move out of cities to suburbs and more rural areas), regionalisation (reduced population density and access to open spaces, e.g. natural beauty) or a combination of these.
- **Use of Virtual Tools**: uptake of online and virtual activities in social, leisure, learning and consuming (including public services).

3.3 The NIC has gone on to define five scenarios. These are:

- Scenario 1: Reversion and Reaction
  - Behaviours similar to 2019
  - Limited adoption of flexible working and working from home
- Scenario 2: A More Flexible Future
  - Flexible working is adopted within a sub-group of employers and employees where it is practical and feasible to do so
  - Flexible lifestyles with a significant amount of social engagement
  - City centres continue to be important hubs for people to work and socialise
  - Urban and suburban areas continue to be key areas for living
- Scenario 3: Low Social Contact Urban Living
  - Office-based working returns, with a modest increase in flexible working
  - Social wariness is permanently higher with certain habits formed during the pandemic sticking
  - Greater uptake of virtual activities across all domains
- Scenario 4: Social Cities
  - Homeworking is adopted at a high level among employers and employees where it is practical and feasible to do so
  - Demand to change household location is constrained by price/availability
  - People prefer to be socially active and are not anxious about large gatherings

  - Decline in permanent town/city centre office space is somewhat offset by growth in other amenities/uses
- Scenario 5: Virtual Local Reality
  - Homeworking is adopted at a high level among employers and employees who are practically able to do so
  - Social wariness is permanently higher with certain habits formed during the pandemic sticking
  - People radically alter how (and to a smaller extent where) they live and reduce travel as a result

3.4 To help define these scenarios, the NIC has defined three levels of potential response. These are:

- **low**, which means the meta-trend has a relatively small impact on the demand for infrastructure in any particular scenario
- **medium**, a moderate impact on the demand for infrastructure in any particular scenario
- **high**, which means the meta-trend has a large impact on the demand for infrastructure in any particular scenario

3.5 In Table 3.1 below we have mapped the NIC's four meta-trends onto the five scenarios.

Table 3.1: Meta-trend and Scenario Summary

Meta-trend	Sc1: Reversion and reaction	Sc2: A more flexible future	Sc3: Low social contact urban living	Sc4: Social cities	Sc5: Virtual local reality
Working from Home	Low	Medium	Low	High	High
Social Wariness	Low	Low	High	Low	High
Dispersal from Cities	Low	High	Low	Low	High
Use of Virtual Tools	Low	Medium	High	Medium	High

3.6 Early in this study it was established that for each scenario it would be assumed that:

- In each projection year, the national economy (as measured by GVA/GDP) would be constant between scenarios. However, the spatial distribution of economic activity may vary between scenarios.
- Similarly, the national population and employment would be taken as constant between scenarios, although the geographic distribution of that population and employment may differ.

3.7 Normalising the size of the economy and population and employment allows the scenarios to focus on the impact of pandemic induced behavioural change.

4 Approach to Quantitative Analysis - Transport

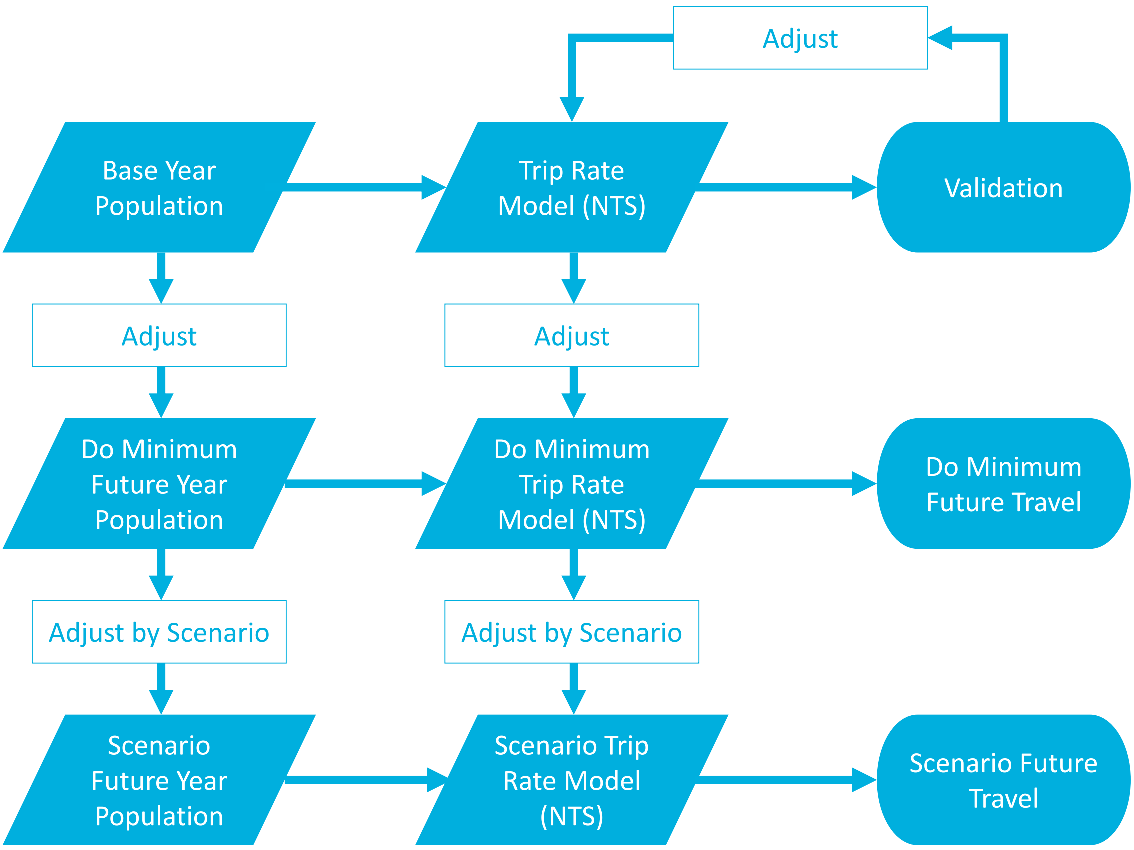
Introduction

4.1 In this section we set out our approach to developing projections of transport demand for each scenario. We first cover personal travel before moving on to consider freight.

Personal Travel

4.2 The approach to producing projections of personal trip making and travel for the NIC's scenarios is shown below in Figure 4.1. In summary, the approach is to develop a segmented trip rate model, with trip rates derived from the National Travel Survey (NTS). Future year projections are then developed by adjusting the future year population and trip rates to reflect the different facets of the NIC's scenarios.

Figure 4.1: Personal Transport – Model Structure



Base Year Population

4.3 The Office for National Statistics (ONS) publishes detailed data that has been used by this study to determine the characteristics of the baseline population. The application of this data is not restricted to the transport elements of the study and has been used for the other sector models as well (see Chapter 5) but as we cover transport first, we consider the ONS data here.

4.4 A key consideration has been the level of spatial disaggregation of the data. The finest geographic level is the Output Area, which would be the ideal 'building block', as it can be aggregated into larger areas such as Lower Layer Super Output Areas (LSOA), Middle Layer Super Output Areas (MSOA), Local Authorities or Regions.

4.5 Socio-economic data is useful to establish the current characteristics of the population in the UK. This can be disaggregated spatially, but also by other criteria such as occupation groups, and be used to produce a segmentation that allows for a more targeted analysis of different groups in each of the proposed future scenarios. However, not all socio-economic data is available at the most detailed level of spatial disaggregation.

4.6 The base year population (2019) data has been obtained from ONS at the Output Area level, the finest one available. This has been combined with the Output Area Classification (OAC), as defined in the 2011 Census, to assign each resident population in each of the Output Areas to an OAC supergroup, allowing for an aggregation of population by OAC supergroups at the local, regional and national level.

4.7 The Output Area Classification is based on the socio-economic characteristics of the population at the Output Area level, classifying each Output Area into a supergroup, group and subgroup, of which there are 8, 15 and 24 in total, respectively. This classification system is updated with the Census and therefore the 2011 Census OAC classification has been used here as this is the most recent one available.

4.8 In addition to total population figures, 2019 labour market data has been used. This details the classification of population into Standard Occupational Classification (SOC) and Socio-economic Classification (NS-SEC) groups. Correspondences between the SOC and NS-SEC classifications, as well as between SOC and OAC supergroups, have been obtained from ONS.

Trip Rate Model

Transport Data

4.9 The base year transport model has been developed using trip and distance rate data from the National Travel Survey. The NTS is a household survey designed to monitor long-term trends in personal travel and to inform the development of policy. It provides a comprehensive dataset of travel behaviour (including distance travelled and trip frequency by mode, by journey purpose, broad trends over time, etc). NTS data is collected annually and data is readily available for recent years. However, NTS data is collected only for residents of England which requires assumptions to be made on its applicability to the United Kingdom as a whole.

4.10 Other potential sources of comprehensive travel behaviour data were considered but subsequently dismissed as none had the same degree of spatial and socio-economic classification detail combined with the availability of recent data as NTS. For example, while Census data provides an even greater level of spatial disaggregation in travel to work trips, it does not have information about other trip purposes and the latest data is from 2011.

4.11 For this study, NTS data has been used to develop 'travel profiles' of different population segments, using trip and distance rates (number of trips and distance travelled by an individual per year), disaggregated by purpose and mode.

4.12 Something to note here is that the definition of transport mode is slightly different for trip rates and distance travelled. A trip can be formed by several stages on different modes (e.g. walk + bus or car + train), but it is still considered a single trip. For the transport model, the modal split of trips refers to the 'main mode', or the mode used for the longest stage of the trip, while the modal split of distance accounts for the actual distance travelled by each mode, considering all individual stages. This difference is simply due to the way that NTS collects trips and travel data.

Population Segmentation

4.13 Instead of simply presenting the transport data by area (e.g. by region or nation), population segments have been created as they can be useful to understand different travel demand patterns across different sectors of the population. These segments can be subsequently linked to the definition of both the 'broader group' and 'sub-group' with potential to realise behaviour change in the NIC scenarios. These travel profiles for population segments form the 'trip rate model' shown in Figure 4.1 above.

4.14 After the exploration and analysis of the available data from NTS (transport) and ONS (population, employment and socio-economic classifications), it was decided to base the transport model on three different population segmentations:

- Census Output Area Classification (OAC);
- Standard Occupational Classification (SOC); and
- National Statistics-Socio-economic Classification (NS-SEC).

4.15 The OAC supergroups classification was the preferred segmentation system, as it is available for most of the NTS survey responses and provides a clear classification of the population based on socio-economic factors, with also a clear spatial pattern. This is useful for our purposes, as socio-economic and spatial factors have a significant influence on travel behaviour.

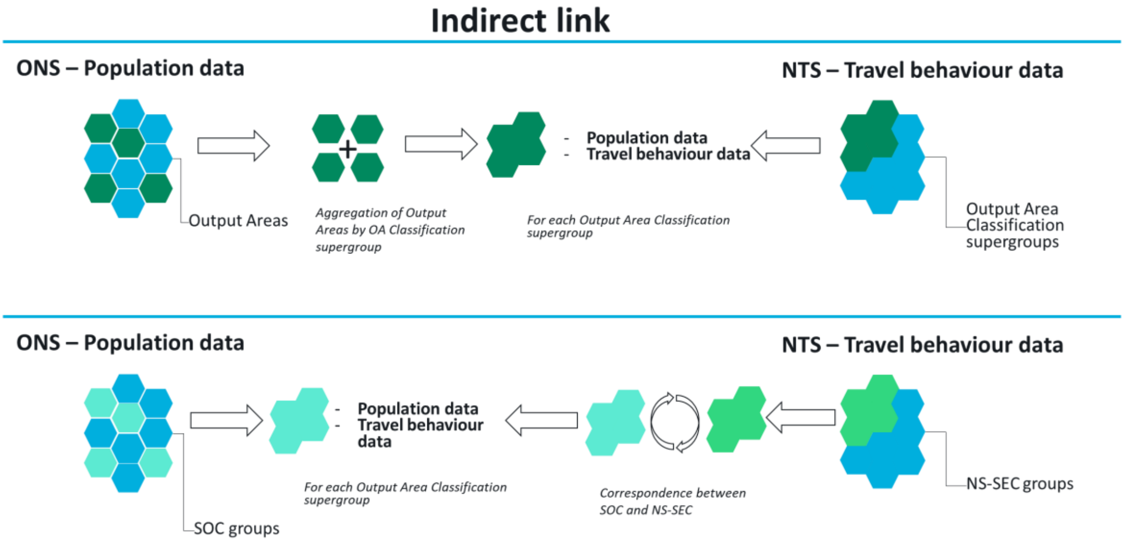
4.16 The SOC segmentation was chosen to work with the homeworking trend data published by the ONS, which was identified as a useful source of data for the development of the future year scenarios of the transport model. This homeworking data was published by different classifications (age, region, sex, industry, etc) with the SOC being identified as the most interesting one due to its compatibility with the description of the scenarios by NIC.

4.17 Using the SOC segmentation, however, created a challenge for the transport model, as this classification is not available in the NTS database and therefore a third segmentation was needed, which should comply with two requisites:

- Being available in the NTS database; and
- Having a direct correspondence with the SOC classification.

4.18 The NS-SEC classification complies with both of these requirements and was therefore selected as the third segmentation to work with in the development of the transport model. Figure 4.2 shows the links between ONS population data and NTS travel behaviour data as mentioned above, including the OAC and SOC/NS-SEC segmentations used.

Figure 4.2: Indirect link between classifications/segments in ONS population data and NTS travel behaviour data



NTS Data Extraction

4.19 After considering the above, data was extracted from the NTS database, with the following level of detail:

- Transport rates: trip rates and distance rates.
- Spatial: each region of England and England as a whole.
- Time: every year between 2015 and 2019.
- Segmentation: OAC supergroups and NS-SEC 3-group classification.
- Purpose: business, commuting, education, leisure, shopping, personal business and other.
- Mode ('main mode' for trips): bus, surface rail, other public, car, other private, walk and cycle.

4.20 There are a few caveats related to the NTS database worth mentioning here. The first one is that OAC classification information is provided for 2015-2017, but not for 2018 and 2019. Transport rates for OAC supergroups for these years were derived from the 2015-2017 rates, using a growth factor of the global (without OAC segmentation) rates between 2015-2017 and 2018-2019. A second caveat is that the NTS only has travel behaviour data for residents in England, with no available data for those in Wales, Scotland or Northern Ireland.

4.21 As the NTS is a survey of only several thousand participants across England, extracting data in a segmented way, especially when adding different layers of segmentation (e.g. regional + OAC classification) results in reductions to the sample size that, in certain occasions, can lead to unreliable data.

4.22 To address this, a typical approach consists of using multi-year data from the database, assuming that temporal detail is lost (i.e. data not specific to a certain year) in return for having a larger sample which adds robustness to the data. As the purpose of this study is to compare transport demand in the future based on a series of assumptions regarding travel behaviour changes due to the COVID-19 pandemic, this trade-off was deemed reasonable. As a result, it was decided to use 2017-2019 NTS data to build the base year transport model.

4.23 After initially extracting the transport data for each region in England, an analysis was undertaken to identify potential similarities or differences in travel patterns between population in different regions. One of the main findings of the analysis was that the OAC segmentation played a more relevant role in terms of travel behaviour than the regional segmentation (i.e. travel behaviours are more similar for people in different regions but in the same OAC supergroup than for people in the same region and different supergroups).

4.24 This analysis also showed a difference between trip purpose and mode split. While trip purpose splits were found to be quite homogeneous across regions, this was not the case for mode splits, especially for London. Based on this analysis, and with the aim to both simplify the transport model building process and to ensure adequate sample size levels (the sample size of some OAC supergroups outside London was quite small for individual regions), it was decided to build the model with the following regional split:

- London;
- East and South East; and
- Rest of England.

4.25 After subsequent feedback received in discussions with the NIC, a series of factors were derived to be able to present the transport model outputs by individual regions and UK nations, instead of only using the London/East and South East/Rest of England split. These factors were produced using actual 2015-2017 transport rates by region and OAC classification and are therefore accurate.

4.26 The only caveat is that, when applying these factors to the model outputs for the "East and South East" or the "Rest of England" areas to obtain individual regions, there will be a degree of detail that is lost when compared to a hypothetical model in which the whole process had been done using a region-by-region approach instead of the regional split used. However, the impact on the overall trends when comparing scenarios is not expected to be significant.

Validation

4.27 After completing the base year model, a series of checks were undertaken to rule out potential errors in the calculations and to make sure the model was producing reasonable outputs.

4.28 For this purpose, NTS summary statistics were obtained from the Department for Transport and compared against the global trip and distance rates for England, by mode and purpose. Given that the base year transport model uses exclusively NTS data, the figures should match exactly, and this was found to be the case.

4.29 While the initial intention was to gather official non-NTS data about transport use, in passenger journeys and passenger kilometres (e.g. rail statistics from ORR and bus statistics from DfT) to validate and adjust the base year transport model, several difficulties were found that made the process infeasible.

4.30 These difficulties were mainly related to the fact that published rail and bus statistics from the ORR and DfT do not use the same units and counting methodology for either and/or trips and distance travelled whereas the NTS database does. For example, the NTS database assigns each trip to a 'main mode', which is the mode used by the passenger for the longest distance, while both rail and bus stats count each passenger journeys on those modes (e.g. a bus + car trip where car covers a longer distance would count as one car trip and zero bus trips in NTS, but would appear as one bus trips in the DfT bus usage statistics).

4.31 Other difficulties included the fact that ORR counts one passenger journey for each train used in the regional statistics, but one passenger journey for each trip (regardless of the number of transfers) in the national statistics. Also, the bus statistics published by the DfT include local buses only, while the bus rates in the transport model (NTS data) include all local and non-local buses.

4.32 The impossibility to produce a like for like comparison of transport usage totals between the NTS-based transport model and other official transport statistical datasets rendered the validation/adjustment process as it was initially planned infeasible.

Counterfactual

4.33 Once the base year transport model was built, using NTS trip and distance rates as well as population and employment data, a counterfactual scenario was defined, which would be considered as the 'default' position of the transport trends with no impacts from the COVID-19 pandemic.

4.34 To develop the counterfactual, the approach for the population growth has been to use the DfT's TEMPRO projections at the Local Authority District (LAD) level. With respect to the distribution of population across OAC supergroups for each LAD, the assumption has been to keep the distribution constant, applying the LAD-based TEMPRO growth factor across all OAC supergroups in each district. In the absence of any evidence to suggest otherwise, this was seen as a reasonable and easy to implement approach.

4.35 The development of the employment projections for the counterfactual model has followed the same approach as the population model, using TEMPRO growth factors by LAD and applying them to all employment in each LAD, keeping the distribution across SOC groups constant.

4.36 The counterfactual model includes seven years (2025, 2030, 2035, 2040, 2045, 2050 and 2055) as defined by the requirements set out by NIC. TEMPRO projections, however, only provide data up to 2050. To address this issue, a simple assumption has been made to use the 2045-2050 TEMPRO growth factors as a proxy for the 2050-2055 growth factors, both for population and employment.

4.37 With respect to the trip and distance rates, the main assumption built in the counterfactual model is that the individual rates for each combination of area (e.g. London) and classification group (e.g. OAC Supergroup 1. Rural Residents) stay constant, keeping the same values as those defined in the base year model.

4.38 The global rates could however change slightly, as they are obtained as a weighted average of the individual area/classification rates, using the population distribution across classifications and areas as weights. If some regions were to have significantly different projected growth rates, this would affect the weights and therefore the global rates. In reality, although some districts and regions are expected to grow more than others, the effect on the OAC supergroup and regional weights are minor and the overall rates stay broadly the same.

4.39 The total volume of trips and distance travelled, however, will not remain constant, growing in line with the expected population growth.

Scenarios

4.40 As for the counterfactual scenario, for each of the five future scenarios defined by NIC there have been two areas of work:

- Future year population and employment growth and distribution.
- Future year trip and distance rates.

4.41 For both areas of work the counterfactual has been taken as the starting point from which to develop the future scenarios. The description of the scenarios, as summarised in Chapter 3, has been translated into qualitative and then quantitative assumptions that are inputs to the transport model. These assumptions are then used to produce sets of factors for each scenario that are applied to the counterfactual figures.

4.42 These assumptions can be grouped in four blocks. The first three blocks affect the individual transport rates (trips and distances) for each area/classification pair. They are related to homeworking trends, changes to other trip purposes (e.g. leisure) and modal split. The fourth group of assumptions affects the distribution of population and employment across classification groups and regions and is related to the meta-trend 'Dispersal from Cities'.

4.43 While the distribution of population across regions and classification groups might be different between scenarios, the total population is constant and equal to the counterfactual. All scenarios are based on the same projections of population and employment growth from TEMPRO.

4.44 The outputs of the transport model are trip and distance rates for each future scenario, which differ from the counterfactual as a result of both direct changes to the individual rates (e.g. reduced commuting trips for Rural Residents in the South East) and changes to the underlying population distribution (e.g. people moving from London to the home counties).

4.45 By their nature the projections for future scenario transport demand are 'what if' scenarios, that is they are a projection of transport demand given a set of assumptions.

Freight

4.46 In January 2019, the NIC published research by MDS Transmodal which looked at the future of freight demand.[1] We have considered the published report and developed and applied an approach which is consistent with the findings of that work as well as the overall approach of this study.

4.47 The MDS report identifies four drivers of future freight demand. These are:[2]

- The state and structure of the economy, which leads to changes in the volume and mix of freight flows generated by different industrial sectors;
- Consumer behaviour, particularly in the retail sector and the penetration of e-commerce;
- Technological change, leading to changes in the relative cost effectiveness of the different types of 'vehicles' used to transport freight and therefore changes in modal share; and
- Public policy and regulation: changes in regulations, policies, taxation and land use planning.

4.48 The report goes on to define a 'business as usual' scenario.[3] In this:

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[1] MDS Transmodal (January 2019) *Future of Freight Demand*

[2] Page 48, *ibid.*

[3] Pages 63/64, *ibid.*

- The economy follows the (pre-Covid) business as usual trend, i.e. what was then the OBR central case projection.
- There are electric vehicles in the LGV sector and the sale of diesel/petrol LGVs is banned.
- By 2050 e-commerce accounts for:
  - 35% of food retail
  - 65% of general merchandise.

4.49 Importantly for this work, a finding from the MDS Transmodal work is that 'heavy' freight, that is the volume of freight (whether measured by tonnes lifted or tonne kilometres) carried by heavy goods vehicles and by rail, is principally a function of:

- The size and structure of the economy and the mix between manufacturing and the service sector;
- Technological changes which change unit costs; and
- Public policy, for example whether or not per mile pricing for HGVs is introduced.

4.50 Importantly for this work, a finding of the MDS Transmodal work is that heavy freight traffic on the roads will only be affected at the margin by change in consumer behaviour patterns (such as where and how people go shopping) and there will be no material impact on rail freight.

4.51 The principal anticipated change in consumer behaviour is growth in e-commerce. Integral to the MDS business as usual scenario is:[4]

- Continued decline in large stores in both the grocery and non-food sectors;
- Reduced store numbers for most retailers, except hard-discount stores;
- Continued increase in convenience retail for grocery ;
- Transformation of high streets and malls to retail experiences, with food, drink and entertainment being central;
- Re-purposing small stores to residential and food and beverage, and entertainment; and
- Re-purposing in high streets to provide micro-hubs and Click & Collect facilities.

4.52 For this work it is being assumed that the size of the economy is constant between scenarios (see Paragraph 3.6). It is then natural to assume that the structure of the economy is also constant, specifically the split between the service and manufacturing sectors and the make-up of the manufacturing sector. The freight modelling therefore focusses on the take up of e-commerce in the different scenarios and what this means for LGV traffic, for which retail has a growing share and for which e-commerce is associated with the growth in LGV traffic.

LGV Traffic

4.53 There are two principal drivers of the proportion of LGV traffic that relates to e-commerce:

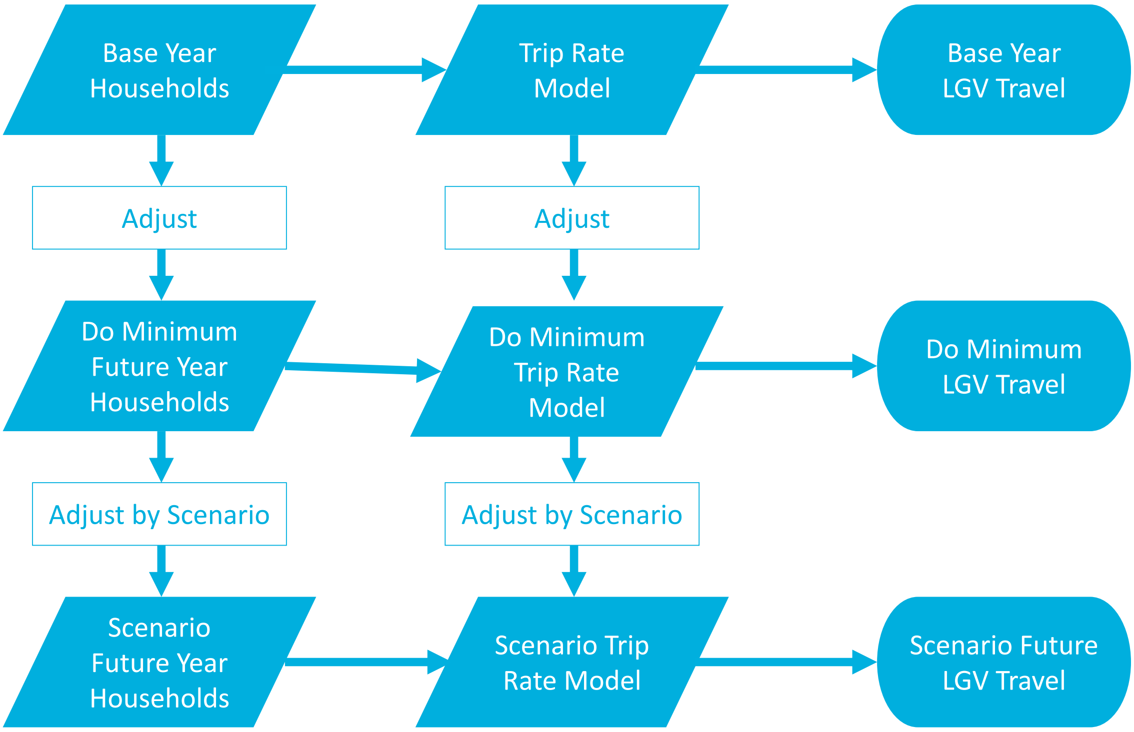
- The household take up of e-commerce – the 35% for food and 65% for general merchandise by 2050 in the MDS business as usual scenario figures are an average. For some households the take up will be high, for others it could be close to zero. The hypothesis would be that households where people can readily work from home and those that are made up of retirees would have the highest take up of e-commerce.
- Changes to the logistics chain – as e-commerce grows we can anticipate that greater volumes would support investment in initiatives to drive down unit costs, for example

[4] Page 58 *ibid.*

consolidation centres, with the result that the growth in LGV vehicle-kilometres is at a lower rate than growth in e-commerce. Public policy interventions to support the development of consolidation with a goal of reducing LGV-related traffic could have the same effect.

4.54 This means we can adopt a modelling approach similar to that for personal travel and this is illustrated in Figure 4.3.

Figure 4.3: LGVs – Model Structure



4.55 An advantage of this approach is that the household data that we will use for the base year, counterfactual and the scenarios will come from the same data sources and be consistent with the population data we use in the personal travel model.

4.56 The limitations of this approach are that the data available to develop the LGV trip rate model is much more limited than for personal travel. Data published by the DfT from its Company Van Survey is helpful, but aggregate. Road traffic statistics are also helpful, as is the MDS report.

HGV Traffic

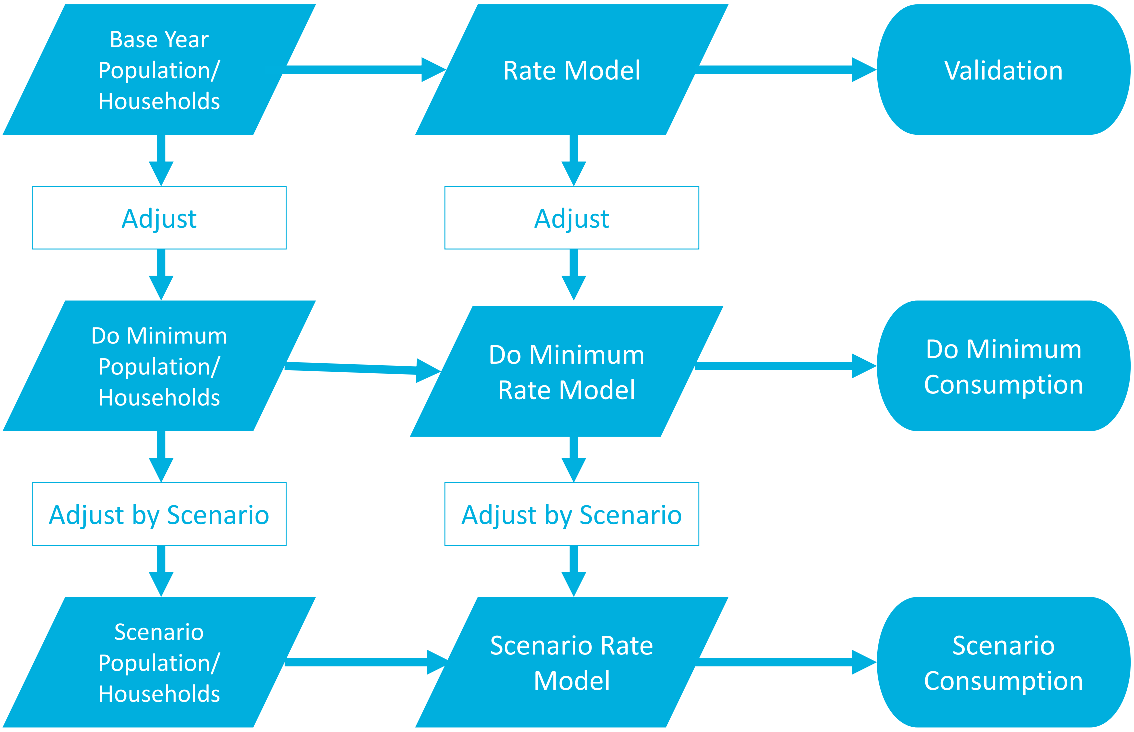
4.57 Given the MDS findings and the definition of the scenarios, there is no need for a bespoke model to look at HGVs.

5 Approach to Quantitative Analysis – Other Sectors

Introduction

5.1 The approach to projecting demand in the non-transport sectors is analogous to the approach that we have adopted for personal travel and for e-commerce related LGVs. We illustrate this in Figure 5.1 below. As a consequence, the process of building, refining and then applying the other sector models has been very similar as those for transport.

Figure 5.1: Non-transport sectors – Model Structure



Population/Households

5.2 The source of population/household data for the base year, counterfactual and scenarios is the same as for the transport sector. This is described in Chapter 4 and is not repeated here.

Rate Models

5.3 Rates of consumption were gathered from the sources set out in Table 5.1 below for the non-transport sectors that we are interested in. These were used to produce the base year rate model and also the future demand for building the counterfactual model.

5.4 The process is analogous to the transport sector:

- Use best available evidence to develop a counterfactual rate model
- Adjust the counterfactual model for each scenario

Table 5.1: Non-transport Sectors

Sector	Overall Method	Evidence & Data
Digital	Average monthly data use on fixed broadband lines by OAC supergroup multiplied by number of lines	Baseline: Ofcom Connected Nations 2019 by OAC supergroup Counterfactual: Evidence-based assessment of future digital connectivity Scenarios: Pivot counterfactual based on the impact of each meta-trend and population projections.
Energy	Domestic and non-domestic units multiplied by typical domestic and non-domestic consumption values (using the BEIS 2019 Updated Energy & Emissions Projections)	Baseline: Ofgem Typical Domestic Consumption Values (TDCVs) by region. Disaggregate by electricity and gas. Counterfactual: Evidence-based assessment of future per unit energy consumption Scenarios: Pivot counterfactual based on the impact of each meta-trend and population projections.
Water & Wastewater	Population by region multiplied by per capita demand.	Baseline: Ofwat/water companies consumption data (DEFRA Water conservation report 2018) Counterfactual: Ofwat central case consumption projections Scenarios: Pivot counterfactual based on the impact of each meta-trend and population projections.
Waste	Population by region multiplied by per capita waste production	Baseline: DEFRA statistics on household waste. Counterfactual: Based on population projections. Scenarios: Pivot counterfactual based on the impact of each meta-trend and population projections.

6 The NIC's Scenarios and the Demand for Infrastructure - Transport

Introduction

6.1 As set out in Chapter 3, the NIC has used four meta-trends to define five scenarios. The four meta-trends are:

- **Working from home**: people & businesses to adopt more homeworking.
- **Use of Virtual Tools**: uptake of online and virtual activities in social, leisure, learning and consuming (including public services).
- **Social Wariness**: people cautious to participate in social gatherings.
- **Dispersal from Cities**: people and businesses: suburbanisation (desire to move out of cities to suburbs and more rural areas), regionalisation (reduced population density and access to open spaces e.g. natural beauty) or combination of these.

6.2 To develop alternative scenarios, each of the meta-trends has three levels, which are low, medium and high. The NIC scenarios are then different combinations of meta-trends levels. These are shown in Table 3.1. The impact of the meta-trend in any particular scenario can then be assessed by adjusting transport variables to represent either a low, medium or high effect.

6.3 Each of the meta-trends has been associated with a particular transport impact that in turn has been associated with a set of transport variables. For all, other than the Dispersal from Cities meta-trend, which is covered later, these effects and variables are set out in Table 6.1.

Table 6.1: Meta-trends, Transport Impacts and Transport Variables

Meta-trend	Transport impact compared to pre-Covid trend	Transport variables
Working from Home	Fewer commuting journeys (journeys to work)	JTW trip rates by population in SOC Groups 1-4
	Fewer business trips (employer's business)	EB trip rates by population in SOC Groups 1-4
Social Wariness	Fewer trips by public transport	PT trip rates
	More trips by car	Car trip rates
	More trips by active modes	Active mode trip rates
Use of Virtual Tools	Fewer leisure trips	Leisure trip rates
	Fewer shopping trips	Shopping trip rates
	Fewer education trips	Education trip rates

Working from Home

6.4 The NIC has identified two potential behavioural responses as part of the Working from Home meta-trend. These are:

- Flexible homeworking: a worker works from home some of the time and commutes some of the time
- Permanent homeworking: home is a worker's principal place of work and the worker does not commute any of the time

6.5 Not all people can work from home. For some jobs – e.g. construction, retail, hospitality – homeworking is simply not possible. For this study, we have assumed that only people in Standard Occupational Classification (SOC) Groups 1 to 4 can work from home, either flexibly or permanently. This reflects the pre-pandemic experience that these four occupational groups account for the majority of homeworking for which commuting was a possible alternative. SOC groups 1 to 4 are:

- SOC1: Managers, Directors and Senior Officials
- SOC2: Professional Occupations
- SOC3: Associate Professional and Technical Occupations
- SOC4: Administrative and Secretarial Occupations

6.6 Data collected by the ONS (Table 6.2) allows us to compare pre-pandemic rates of working from home with those in the first lockdown in April 2020. From the table it can be seen that for each of these SOC groups, the pandemic restrictions led to a large increase in the proportion working from home. Of course, this increase is not made up of people acting under their own volition, rather they were acting under duress. And even then, there was still substantial shares of each SOC group who did not work from home, either because their job could only be undertaken from their work premises, or they couldn't work at all (e.g. they were furloughed or laid off). For this study, the April 2020 figures are considered to represent the maximum proportion of each SOC group who can work from home given the current make-up of the national economy.

Table 6.2: Pre-Pandemic and Pandemic Proportions Working from Home

	1 Managers, Directors and Senior Officials		2 Professional Occupations		3 Associate Professional and Technical Occupations		4 Administrative and Secretarial Occupations	
	Jan-Dec 2019	Covid April 2020	Jan-Dec 2019	Covid April 2020	Jan-Dec 2019	Covid April 2020	Jan-Dec 2019	Covid April 2020
Not working from home	75.7%	43.6%	79.7%	38.3%	80.7%	41.9%	89.5%	50.7%
Working from home	24.3%	56.4%	20.3%	61.7%	19.3%	58.1%	10.5%	49.3%
Of which Flexible	14.3%		14.5%		11.2%		3.7%	
Of which Permanent	10.0%		5.8%		8.1%		6.9%	

Data Source: ONS Labour Market Survey

6.7 For the purposes of modelling the NIC's scenarios, it has been assumed that:

- **Scenario 1**: a low increase in flexible homeworking, as per current pre-COVID trends with no change in permanent homeworking patterns.
- **Scenario 2**: a medium increase in flexible homeworking, with a low increase in permanent homeworking.
- **Scenario 3**: similar to Scenario 1, with no change in permanent homeworking and a low increase in flexible homeworking.
- **Scenario 4:** a high increase in permanent homeworking with a low increase in flexible homeworking arrangements, similar to Scenarios 1 and 3.
- **Scenario 5**: as Scenario 4.

6.8 For each scenario, the percentage share of each SOC group that is assumed to work from home either flexibly or permanently is shown in Table 6.3.

Table 6.3: Working from Home – Percentages Working from Home

		Scenario 1: Reversion and reaction	Scenario 2: A more flexible future	Scenario 3: Low social contact urban living	Scenario 4: Social cities	Scenario 5: Virtual local reality
1 Managers, Directors and Senior Officials	Flexible	20.0%	30.0%	20.0%	20.0%	20.0%
	Perm.	10.0%	12.5%	10.0%	22.5%	22.5%
2 Professional Occupations	Flexible	20.0%	30.0%	20.0%	20.0%	20.0%
	Perm.	5.8%	7.5%	5.8%	12.5%	12.5%
3 Associate Professional and Technical Occupations	Flexible	15.0%	22.5%	15.0%	15.0%	15.0%
	Perm.	8.1%	10.0%	8.1%	17.5%	17.5%
4 Administrative and Secretarial Occupations	Flexible	5.0%	7.5%	5.0%	5.0%	5.0%
	Perm.	6.9%	7.5%	6.9%	15.0%	15.0%

6.9 For the translation of these assumptions into transport values:

- Flexible homeworking is assumed to reduce commuting trips by 50%, compared to the default office-based pattern.
- Permanent homeworking is assumed to result in no commuting trips

Use of Virtual Tools

6.10 During the pandemic many activities have moved online. Social activities have moved online, there has been an increase in on-line shopping and for many, schooling and tertiary education has also become an online activity. For the purposes of modelling transport demand, 'Use of Virtual Tools' has been assumed to be manifested in two ways:

- Fewer trips made for leisure, shopping and education purposes
- Those trips that are made are, on average, shorter

6.11 This move could come about because post-pandemic online is seen by consumers as more convenient and/or the new norm. Businesses/providers may also see online as integral to their post-pandemic business model, building upon the increased uptake during the pandemic and potentially withdrawing non-online options. These trends could be reinforced by a long-lasting social wariness that deters people from activities that involve high inter-personal interactions. For the purposes of the transport assessment these effects are considered together in 'Use of Virtual Tools' and social wariness deterring the use of public transport is considered explicitly under the 'Social Wariness' heading.

6.12 In the years before the pandemic there had been a steady decline in 'high street' footfall, with the high street widely defined as city, town and district centres. A review by the High Streets Task Force has identified a 5% drop in high street footfall in the five years to 2019.[5] Over the same time, e-commerce has been growing. In January 2020, internet sales were 20% of all retail sales. The comparable figure in January 2015 was 13%.[6] Pre-pandemic there was a long term trend of decline in high street footfall and growth in e-commerce. Reflecting this, earlier pre-pandemic work for the NIC developed a scenario in which e-commerce's retail share in 2050 could be 50%, with food at 35% and non-food at 65% of retail sales. [7] It is felt unlikely, however, that this would translate into a commensurate fall in footfall. Over time it is expected that high street retail would become more integrated with the on-line offer, acting as 'show rooms' and providing a more experiential offer.[8] For food retail, high street basket size should be expected to fall as high street shopping complements on-line purchases.

6.13 As we set out in Appendix B, the pandemic has accelerated the take-up of e-commerce. In the short term, this has been simply due to 'bricks & mortar' shops being closed or restricted in the way they can trade, as well as people turning to e-commerce either because they were self-isolating or shielding, or to minimise their perceived risk of infection in a physical retail environment. The net result is that more people have adopted e-commerce than pre-pandemic, as well as previous e-commerce users increasing their online retail activity. In May 2020 internet sales were 33% of all sales before dropping to 26% in September, which was still 8 percentage points higher that its September 2019 or around 7 percentage points higher than pre-pandemic trends would suggest.

6.14 For some, these new habits are expected to persist post-pandemic. Furthermore, the failure of a number of high street chains (with some activity moving on-line) will reduce the short-term attractiveness of high street as a post-pandemic shopping destination. The unknown question is the degree to which the pandemic has simply brought forward trends that were happening in any event or whether it has accelerated the long-term up-take of e-commerce beyond any counterfactual scenario.

6.15 Data on trends in leisure activities is disparate and generally inconclusive, but the National Travel Survey does track how many trips per year people make for different leisure purposes.[9] Looking over the period 2002 to 2019, what the NTS shows is that (excluding short walk trips):

- There has been a long term decline in visiting friends in their homes.
- There has been a modest increase in visiting friends elsewhere.
- There has been a reduction in travel to participate in sport.

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[5] https://www.highstreetstaskforce.org.uk/media/b5dnkp4z/hstf-footfall-report-2020-for-publication.pdf

[6] https://www.ons.gov.uk/businessindustryandtrade/retailindustry/timeseries/j4mc/drsi

[7] https://nic.org.uk/app/uploads/Future-of-Freight_Future-of-Freight-Demand_MDS-Transmodal.pdf

[8] see Appendix B Paragraph B.37 *et seq.*

[9] NTS0403

- Other trip purposes such as travel to 'entertainment/public activity' and 'day trips' have increased.
- The net effect is a decline in trip making for leisure purposes – the decline in visiting friends in their homes has not been compensated for by increases in trips for other leisure purposes.

6.16 Over the same period (2002 to 2019), there has been little change in the number of journeys made to access education, although there has been a steady increase in the distance travelled making escort to education journeys, which was around 20% higher in 2019 than in 2002.

6.17 For the purposes of modelling the NIC's scenarios, it has been assumed that in some scenarios, Use of Virtual Tools is a permanent effect. Using the same six point scale (low/medium/high and decrease/increase), the following have been assumed:

- **Scenario 1**: no change to trip making rate or average distance of trips for leisure, shopping and education purposes.
- **Scenario 2**: no change to leisure trip making rate, medium reduction in shopping trip making rate and low reduction in education trip making rate, as some activities go virtual.
- **Scenario 3**: medium reduction in leisure trip making rate and a high reduction in shopping and education trip making rate, as a result of increased social wariness at the activity end of the trip.
- **Scenario 4**: as Scenario 2.
- **Scenario 5**: high reduction in leisure, shopping and education trip making rate, due to a combination of strong social wariness and strong move to virtual activities.

6.18 These assumptions are summarised in Table 6.4.

Table 6.4: Use of Virtual Tools – Changes to Trip Making

	Split category	Scenario 1: Reversion & Reaction	Scenario 2: A more flexible future	Scenario 3: Low social contact urban living	Scenario 4: Social cities	Scenario 5: Virtual local reality
Trip rate	Leisure	Similar	Similar	Decrease - medium	Similar	Decrease - high
	Shopping	Similar	Decrease - medium	Decrease - high	Decrease - medium	Decrease - high
	Education	Similar	Decrease - low	Decrease - medium	Decrease - low	Decrease - medium
Distance rate	Leisure	Similar	Similar	Decrease - medium	Similar	Decrease - high
	Shopping	Similar	Decrease - medium	Decrease - high	Decrease - medium	Decrease - high
	Education	Similar	Decrease - low	Decrease - medium	Decrease - low	Decrease - medium

6.19 How these translate to changes in trip rates and average trip length is set out in Table 6.5 below. When setting these levels consideration has been given to recent trends, but also how the nature of activities and hence trip making may change in the future. For example, when thinking about retail an e-commerce market share of 50% is unlikely to lead to a proportionate fall in shopping trips – the high street offer will evolve and basket sizes will change. To an extent, this effect has been happening already. While it is difficult to construct a time series, the available evidence suggests that online sales have been growing faster than high street footfall has been falling. To help interpret this table, the 'decrease – high' factor of 0.80 means that base year trip rates calculated for each OAC Group from the National Travel Survey are factored by 0.80.

Table 6.5: Use of Virtual Tools – Changes to Trip Rates and Average Distance

Change	Trip rate factor	Distance rate factor
Decrease – high	0.80	0.80
Decrease – medium	0.90	0.90
Decrease – low	0.95	0.95
Similar	1.00	1.00
Increase – low	1.05	1.05
Increase – medium	1.10	1.10
Increase – high	1.20	1.20

Social Wariness

6.20 The restrictions introduced during the pandemic have affected how people travel, how often that they travel and why they travel. While much of the travel behaviour change is a direct response to restrictions on people's social and economic activity, it is reasonable to assume that some of the change reflects social wariness – people were allowed to travel in a certain way but chose not to. The degree to which such social wariness will survive post pandemic and for how long can only be speculation, but it seems reasonable to assume that some social wariness will continue for some time to come.

6.21 For the purposes of modelling transport demand, 'Social Wariness' has been assumed to be manifested in three ways:

- A smaller share of all trips is made by public transport
- The share of trips made by car increases
- The share of trips made by active modes (walk/cycle) increases

6.22 Data has been collected through the pandemic on the use of different transport modes and updates have been published weekly by the Department for Transport. This data is summarised in Appendix A. The data shows that no time since March 2020 has public transport use come close to its pre-pandemic levels. There are three principal factors that have affected public transport patronage:

- To a greater or lesser extent since March 2020 there have been restrictions on the activities that generate public transport demand.
- For a period in the first lockdown people were actively discouraged from taking public transport unless the journey was essential and since then social distancing has limited public transport capacity to a fraction of its pre-pandemic levels.

- Data collected during the pandemic as part of the National Travel Attitudes Study shows that there are concerns about exposure to infection on public transport and no doubt this too has affected people's willingness to use public transport.[10]

6.23 The National Travel Attitudes Study also asked how people might use public transport once the pandemic restrictions are removed and two-thirds of respondents said it was very likely or fairly likely that they will avoid using public transport if it is crowded. Other surveys have found similar results. However, such stated intention surveys are notoriously unreliable and the extent to which such attitudes may persist once restrictions are removed is highly uncertain.

6.24 There are lessons that can be drawn from abroad,[11] although as with all such international comparisons socio-economic and cultural differences can play a part in explaining different responses. This international experience is also covered in Appendix A. What the available data does show is that even in countries that have been less affected by pandemic-related restrictions on economic and social activity, public transport demand has not returned to pre-pandemic levels. However, in none of the countries for which data is available have there been no pandemic-related restrictions and each has experienced to a greater or lesser extent an economic shock. This said, it is reasonable to hypothesise that some of the shortfall is due to an increased social wariness manifested as a reluctance to use public transport.

6.25 What the limited international evidence suggests is that in a worst case could see public transport demand returning to 85% of its pre-pandemic levels before trend growth (or decline) restarts and a best case could be 100% recovery. Some or all of the shortfall would be due to other meta-trends (which in the short term would be 'Working from Home' and 'Use of Virtual Tools'), but for the purposes of defining an upper limit to the Social Wariness meta-trend an 85% reduction in demand has been adopted.

6.26 For the purposes of modelling the NIC's scenarios, it has therefore also been assumed that in some scenarios, social wariness leads to a permanent shift in people's attitudes to use of different modes of transport. Using the same six point scale (low/medium/high and decrease/increase), the following have been assumed:

- **Scenario 1**: no change to the modal split for trips (main mode) and distance travelled.
- **Scenario 2**: a low decrease in public transport's mode share, with a commensurate increase in car (mainly) and active modes.
- **Scenario 3**: a high decrease in PT use with trips being made by car and active modes instead.
- **Scenario 4**: a medium decrease in public transport share, with trips transferring to car and active, with a higher increment on the latter.
- **Scenario 5**: as Scenario 3

6.27 These assumptions are summarised in Table 6.6.

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[10] See for example: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/956170/national-travel-attitudes-study-wave-4-final.pdf

[11] See Appendix A for further details

Table 6.6: Social Wariness – Changes in Mode Share

Mode	Scenario 1: Reversion and reaction	Scenario 2: A more flexible future	Scenario 3: Low social contact urban living	Scenario 4: Social cities	Scenario 5: Virtual local reality
PT	Similar	Decrease – low	Decrease – high	Decrease - medium	Decrease - high
Car	Similar	Increase – low	Increase - medium	Increase - low	Increase - medium
Active modes	Similar	Increase – low	Increase - medium	Increase - medium	Increase - medium

6.28 In the transport model the approach is to reduce public transport mode share and then redistribute these trips to other modes. The following assumptions are applied:

- Decrease – low: PT mode share is reduced to 95% of its pre-pandemic level
- Decrease – medium: PT mode share is reduced to 90% of its pre-pandemic level
- Decrease – high: PT mode share is reduced to 85% of its pre-pandemic level

6.29 For those trips that move away from public transport, these are allocated as follows:

- No change for Scenario 1
- 75% to car and 25% to active modes for Scenarios 2, 3 and 5
- 50% to car and 50% to active modes for Scenario 4

6.30 The mode share reductions are applied to each OAC Group, noting that each OAC Group has different initial mode shares.

6.31 While mode shares are assumed to change, it has also been assumed that there will be no changes to the average length of public transport journeys made by the different OAC groups.

Summary – Working from Home, Use of Virtual Tools, Social Wariness

6.32 Table 6.7 shows the direction that each of the transport metrics are adjusted to capture the NIC scenarios. For each scenario, each metric is allocated to one of six levels (low/medium/high and decrease/increase), although not all potential levels are used.

Table 6.7: Summary – Working from Home, Use of Virtual Tools, Social Wariness

NIC Demand Driver	Broader group	Sub-group	Variable	Split category	Spatial split	Scenario 1: Reversion and reaction	Scenario 2: A more flexible future	Scenario 3: Low social contact urban living	Scenario 4: Social cities	Scenario 5: Virtual local reality
Working from Home	Occupation group	SOC groups 1-4: Managerial, professional, associate professional and technical, admin	Trip rate	Business	All	Decrease - low	Decrease - medium	Decrease - low	Decrease - high	Decrease - high
Working from Home	Occupation group	SOC groups 1-4: Managerial, professional, associate professional and technical, admin	Trip rate	Commuting	All	Decrease - low	Decrease - medium	Decrease - low	Decrease - high	Decrease - high
Use of Virtual Tools	Population	All	Trip rate	Leisure	All	Similar	Similar	Decrease - medium	Similar	Decrease - high
Use of Virtual Tools	Population	All	Trip rate	Shopping	All	Similar	Decrease - medium	Decrease - high	Decrease - medium	Decrease - high
Use of Virtual Tools	Population	All	Trip rate	Education	All	Similar	Decrease - low	Decrease - high	Decrease - low	Decrease - high
Social Wariness	Population	All	Trip rate	PT	All	Similar	Decrease - low	Decrease - high	Decrease - medium	Decrease - high
Social Wariness	Population	All	Trip rate	Car	All	Similar	Increase - medium	Increase - medium	Increase - low	Increase - medium
Social Wariness	Population	All	Trip rate	Active modes	All	Similar	Increase - low	Increase - medium	Increase - medium	Increase - medium

Dispersal from Cities

6.33 In the NIC scenarios 'Dispersal from Cities' manifests itself in two ways:

- Suburbanisation – a move from the centre of cities to the suburbs and commuter towns
- Regionalisation – a move from established urban areas to more rural areas

6.34 To help develop assumptions on the scale of the potential suburbanisation and regionalisation effects a number of data sources have been considered:

- ONS analysis of the 2011 Census indicates in the 12 months preceding Census day, 6.8 million people moved home. Of these, 4.0 million moved within the same district.[12] Data from commercial providers of property services suggests that half of people move three miles or less. Only 7% of people move more than 50 miles.[13]
- Later ONS analysis released in 2016 states that 2.85 million people moved between local authorities in England and Wales between July 2014 and June 2015.[14] This is said to have been similar to the previous year. While the analysis of the 2011 Census is for the UK and the 2016 analysis is for England & Wales, these two pieces of analysis paint a similar picture of the number of people who move from one district to another.
- The majority (71%) of those with a different address a year prior to the 2011 Census were aged 16 to 49. In particular, people between the ages of 19 and 29 have the greatest propensity to move from one district to another. The 2016 ONS analysis identifies that 22% of 19 year olds moved district in the 12 months from July 2014 and June 2015. The propensity drops with age: 10% of 29 year olds moved between districts over the same period. The high propensity of 19 to 29 years olds to move between districts is associated with entering tertiary education and starting first jobs, as well as forming households.
- Moving home is a relatively infrequent event. In 2017, on average people moved home every 23 years. This period has been extending overtime – the housing market has become more 'sticky'. In the late 1980s people moved as often as every 9 years on average.[15]
- London has the greatest rates of inward and outward migration. Inward migration is in part accounted for by people entering tertiary education in the Capital or starting their working careers. Young families moving away from London is a feature of outward migration.

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12 https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/internationalmigration/articles/internalandinternationalmigrationfortheunitedkingdomintheyearpriortothe2011census/2014-11-25

13 https://www.savills.co.uk/blog/article/303292/residential-property/home-movers-in-england--how-far-do-they-go-to-their-new-homes-.aspx

14 https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/migrationwithintheuk/bulletins/internalmigrationbylocalauthoritiesinenglandandwales/yearendingjune2015#:~:text=There%20were%20an%20estimated%202.85,July%202014%20and%20June%202015.&text=For%20the%20total%20number%20of,million%20(52%25)%20were%20females.

15 https://www.zoopla.co.uk/discover/property-news/how-often-do-we-move-house-in-britain/

- Other than London, there is no strong pattern of migration between regions and inflows and outflows are broadly balanced.

6.35 For the purposes of assessing the potential impact of the NIC's scenarios the goal is to assess the potential differences in churn in population due to the behavioural responses that are not already captured in the national projections of population and the distribution of that population across the country. It is therefore assumed that only those in SOC Groups 1 to 4 and who can readily work from home will be able to take part in the suburbanisation and regionalisation trends as defined by the NIC. This means it in inherently assumed that the nature of employment is not changed by suburbanisation or regionalisation, rather only where people live. What is not captured by this meta-trend is people seeking a change in lifestyle by changing the nature of their employment, for example giving up the office job in a city to run a B&B in the countryside, or moving home when they retire. Pre-pandemic, such trends should be captured within national projections. Any change to these trends due to the pandemic imply structural changes to the economy, which is considered out of scope of this work.

6.36 For the transport model, suburbanisation is represented by:

- A movement of a portion of "Cosmopolitans" OAC groups to the "Urbanites" and "Suburbanites" groups
- A movement of a portion of "Ethnicity Central" OAC groups to the "Urbanites" and "Suburbanites" groups
- A movement of a portion of the "Urbanites" OAC group to the "Suburbanites" group.
- Population movement to neighbouring regions, for example from London to the South East

6.37 Regionalisation is represented as:

- A movement of a proportion of the Cosmopolitans, Urbanites and Suburbanites OAC groups to the Rural Residents group
- Inter-regional population movement, for example from London to the South West

6.38 It is assumed that those who move OAC group take up the trip making behaviour of the group that they move to. For example, a move to the Rural Group results in the person who moves having the trip making characteristics – number of trips, trip length, mode share – of the Rural group.

6.39 For each scenario it is assumed:

- **Scenario 1**: no change
- **Scenario 2**: a small suburbanisation effect.
- **Scenario 3**: no change
- **Scenario 4**: no change
- **Scenario 5**: a medium suburbanisation effect and a medium regionalisation effect

6.40 These changes are summarised in Table 6.8.

Table 6.8: Dispersal from Cities– Summary of Trends

	Scenario 1: Reversion and reaction	Scenario 2: A more flexible future	Scenario 3: Low social contact urban living	Scenario 4: Social cities	Scenario 5: Virtual local reality
Suburbanisation	No change	Low Effect	No change	No change	Medium Effect
Regionalisation	No change	No change	No change	No change	Medium Effect

6.41 Pre-pandemic data suggests that:

- For those that have been defined in scope for the suburbanisation and regionalisation trends, moving house is something that happens infrequently. While no direct data source is directly available, from the available evidence it has been assumed that pre-pandemic less than 5% of the in-scope population would move house every year.
- Pre-pandemic, the vast majority of these moves would have been within a few miles. Pre-pandemic, based on the available data less than 0.5% of the in-scope population have been assumed to move more than 50 miles, which is taken as a proxy for inter-regional movements. In the absence of data, it has also been assumed that 1.0% of the in scope might 'suburbanise' in any one year.

6.42 Noting that the trends set out immediately above are subsumed within existing population projections, for the purpose of this scenario modelling it has been assumed that:

- A high rate of change would be a doubling of the existing trend, that is an additional 1% of the in-scope population 'suburbanising' and 0.5% of the in-scope population 'regionalising' in each year.
- A medium rate of change has been assumed to be an additional 0.67% of the in-scope population 'suburbanising' and 0.34% of the in-scope population 'regionalising' in each year.
- A low rate of change has been assumed to be an additional 0.33% of the in-scope population 'suburbanising' and 0.17% of the in-scope population 'regionalising' in each year.

6.43 Furthermore, it has been assumed that these changes are time bound. This is because there is limited supply of housing and increased demand should be anticipated to lead to a price response that in turn affects demand. Any change to anticipated supply is out of scope of the scenarios. It has been assumed that the 'suburbanising' and 'regionalising' upward trend lasts for five years. With rounding this leads to the following assumptions:

- A high rate of change is 5% of the in-scope population 'suburbanising' and 2.5% of the in-scope population 'regionalising'.
- A medium rate of change is 3.4% of the in-scope population 'suburbanising' and 1.7% of the in-scope population 'regionalising'.
- A high rate of change is 1.7% of the in-scope population 'suburbanising' and 0.8% of the in-scope population 'regionalising'.

Light Freight

6.44 As set out earlier under the 'Use of Virtual Tools' heading, during the pandemic many activities have moved online. In particular, there has been an increase in on-line shopping which in turn has led to an increase in the number of deliveries.

6.45 Pre-pandemic online retail activity was steadily increasing. In October 2018, ONS data states that 18.0% of all retail sales were online.[16] By October 2019, this had increased to 19.2% and further increases would have been expected. Earlier pre-pandemic work for the NIC considered a scenario where by 2050 50.0% of all retail sales are online.

6.46 While food retail has remained open throughout the pandemic, social distancing requirements, a reluctance from some to be in retail environments even with social distancing along with people shielding and unable to visit food retail has all supported an increase in online shopping for food and other essentials. Non-essential retail shops have been closed for much of the pandemic. Together, this has led to a step-change increase in the proportion of retail activity that is online. In October 2020, 28.5% of retail sales were online. In January 2021 when non-essential retail was closed once again, the online proportion was 35.2%. The pandemic has resulted in people who have not shopped online before doing so and for those who had shopped online extending the number and range of goods that are routinely purchased online.

6.47 As set out in more detail in Appendix B, the expectation is that the pandemic will result in a lasting step-change increase in the proportion of retail sales that are online. However, it is also reasonable to expect that once pandemic restrictions on retail activity are fully lifted the online proportion will drop down from its lockdown peaks. For the purposes of this work it has been assumed that the pandemic will result in a step change in online retail activity equivalent to five years pre-pandemic trend growth.

6.48 There is only limited data on the number of deliveries of goods by light vans and the data that is available does not distinguish between goods purchased in-store and are then subsequently delivered and those that are purchased online. Nonetheless, what the Department for Transport's Van Survey shows is that in 2019:[17]

- Of the 4.1 million vans in the country, 16% were primarily used for delivery/collection;
- Of the 55.5 billion van-miles that were driven, 23% were associated with deliveries/collection; and
- The average van involved in delivery/collection makes 16 stops per day.

6.49 Assuming each van operates for 300 days a year, from this data it can be inferred that there are over 3 billion delivery/collections per year and that each delivery results in approximately 4 van-miles.

6.50 Looking ahead, for Scenario 1 'Reversion and Reaction' it has been assumed that:

- Post pandemic online retail will continue to grow at pre-pandemic rates, albeit from a higher base;

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[16] ONS retail sales data is taken from this series: https://www.ons.gov.uk/businessindustryandtrade/retailindustry/bulletins/retailsales/previousReleases

[17] https://www.gov.uk/government/collections/van-statistics

- Online retail's share will plateau at 50% in 2045, which is the scenario established by pre-pandemic work for the NIC but with the maximum penetration brought forward five years to represent the long term effects of the pandemic; and
- Deliveries will grow in proportion to online retail's overall share.

6.51 However, continued growth should be expected to promote greater efficiency within the delivery sector which will temper the growth in the number of deliveries and the aggregate van miles. This is for two principal reasons:

- greater online retail will increase the density of customers, which will allow more efficient vehicle utilisation with the effect of reducing the miles per delivery; and
- greater online retail will support the retailers/couriers developing approaches to consolidate deliveries (e.g. two orders being consolidated into one drop off, click & collect, local collection hubs) with the effect of tempering the rate of increase of deliveries.

6.52 Looking at the NIC's meta-trends, it has been assumed that:

- Working from Home: greater numbers working from home will make internet shopping more attractive, simply because recipients are more likely to be at home to receive deliveries.
- Use of Virtual Tools: inherent within this is that people will be more willing to engage in online shopping as part of their day-to-day life.
- Social Wariness: for this work social wariness has been defined as a reluctance to use public transport and a concomitant greater propensity to drive and use active modes. As such, the Social Wariness meta-trend is not expected to result in greater online shopping than Scenario 1.
- Dispersal from Cities: this meta-trend is not considered to increase the propensity to use online retail, but by dispersing parts of the population may make it more difficult for the online retailers to drive efficiency gains.

6.53 For the purposes of quantifying the NIC's scenarios, it has been assumed that:

- The peak of online market penetration (50%) will occur in 2045 and this is the low effect. The medium effect will bring forward the peak to 2040 and the high effect will bring it forward to 2035. Scenario 1 has the low effect, Scenarios 2 and 4 have been assumed to experience the medium effect and Scenarios 3 and 5 the high effect.
- Scenario 1 will have a medium efficiency gain, which is a 20% reduction in aggregate miles achieved through a combination of fewer deliveries per transaction and less vehicle miles per delivery. Because both are focussed around urban living, Scenarios 3 and 4 will have a high efficiency gain, which is taken to be a 30% reduction in aggregate miles. Scenarios 2 and 5 will have a low efficiency gain, which is taken to be a 10% reduction in aggregate miles.

6.54 These trends are summarised in Table 6.9.

Table 6.9: Light Freight – Summary of Trends

	Scenario 1: Reversion and reaction	Scenario 2: A more flexible future	Scenario 3: Low social contact urban living	Scenario 4: Social cities	Scenario 5: Virtual local reality
Peak online market penetration	Low Effect	Medium Effect	High Effect	Medium Effect	High Effect
Efficiency gains	Medium Effect	Low Effect	High Effect	High Effect	Low Effect

The NIC's Scenarios – A Quantitative Description

Population/employment

Base Year

6.55 As explained in Chapter 4, 2019 has been taken as the base year for this study, as it is the last full year with data unaffected by the COVID-19 pandemic. Population and employment figures have been obtained from official sources at the Output Area and Local Authority District levels, respectively. While the population figures at the OA level have been used to classify population in the OAC supergroups, the models have used LAD and mainly regional levels only for their spatial disaggregation.

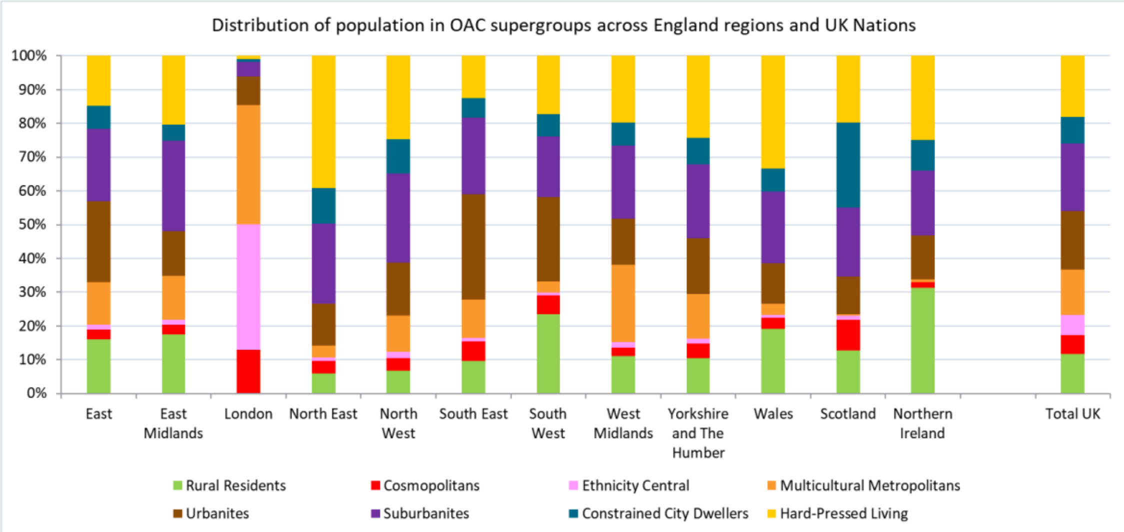
6.56 Table 6.10 shows the mid-year 2019 population estimates from ONS and the 2019 employment figures from the Annual Population Survey, at the region/nation level.

Table 6.10: 2019 population and employment, by region and nation

Region/Nation	2019 Population	2019 Employment
East	6,236,072	3,081,600
East Midlands	4,835,928	2,357,200
London	8,961,989	4,646,200
North East	2,669,941	1,193,200
North West	7,341,196	3,453,000
South East	9,180,135	4,621,300
South West	5,624,696	2,779,300
West Midlands	5,934,037	2,763,800
Yorkshire and The Humber	5,502,967	2,568,200
Wales	3,152,879	1,455,500
Scotland	5,463,300	2,658,000
Northern Ireland	1,893,691	860,800
Total UK	**66,796,831**	**32,438,100**

6.57 The Output Area Classification has been used as the main segmentation in the transport model. Population is classified in one of eight OAC supergroups according to socio-economic and demographic factors. This is shown in Figure 6.1. It can be seen that, while some supergroups have similar shares of population across most regions (e.g. Suburbanites), others show a significant degree of variability (e.g. Hard-Pressed Living). London is clearly an outlier, with more than 85% of its population belonging to the Cosmopolitans, Ethnicity Central and Multicultural Metropolitans supergroups.

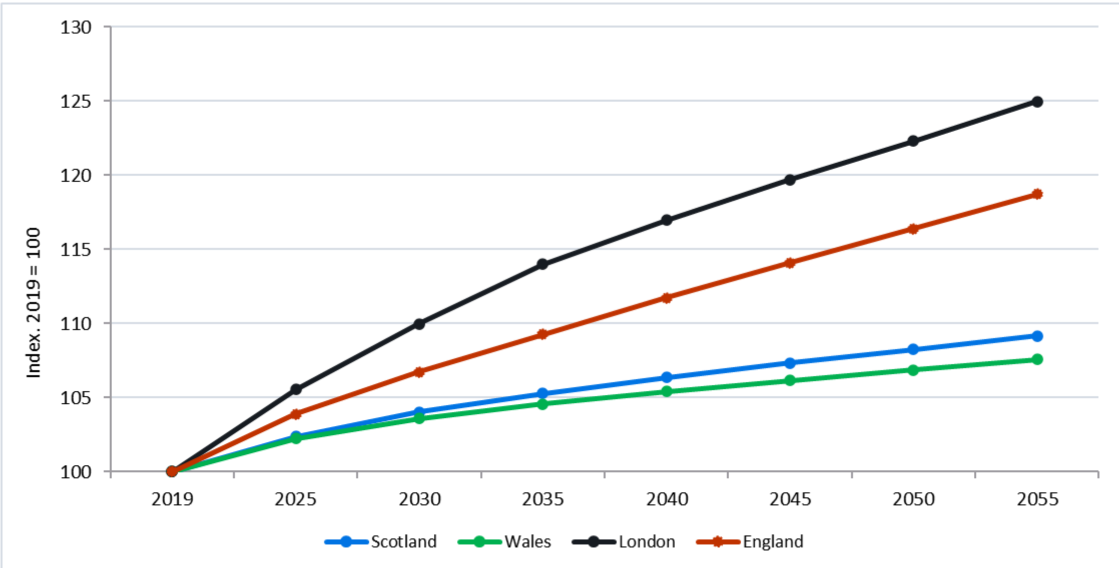
Figure 6.1: Distribution of population in OAC supergroups



Background Growth

6.58 The base year population and employment are expected to grow in the coming years, with TEMPRO forecasting continuous growth for the whole study period to 2050. Growth rates between 2050 and 2055 have been assumed to be the same as the preceding five years. This is shown in Figure 6.2 and Figure 6.3. TEMPRO only provides data for areas in Great Britain.

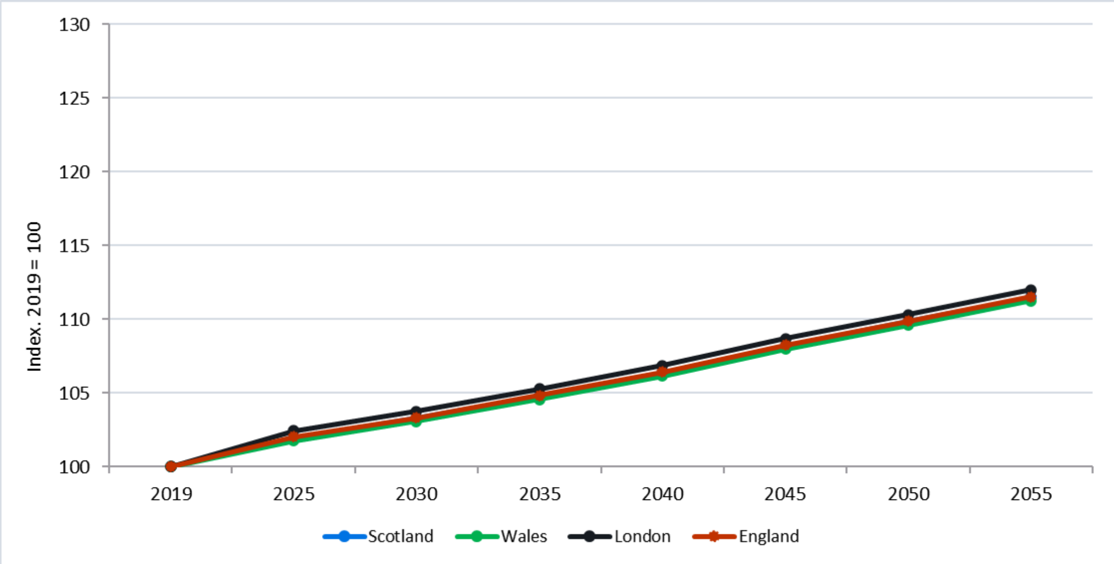
Figure 6.2: Projected population growth (NTEM/TEMPRO), indexed to 2019



6.59 There are clear differences in the projected growth by nation, with England expected to grow at more than double the growth rate of Scotland or Wales (+19% compared to +9% and +8% in the 2019-2055 period, respectively). There are also differences between regions in England, with London included in the chart as the one with the highest projected growth (+25% by 2055).

6.60 On the other hand, the employment growth projections from TEMPRO are almost identical for all regions and nations, and mostly linear in time, with a projected increase of 11-12% by 2055 from base year 2019.

Figure 6.3: Projected employment growth (NTEM/TEMPRO), indexed to 2019



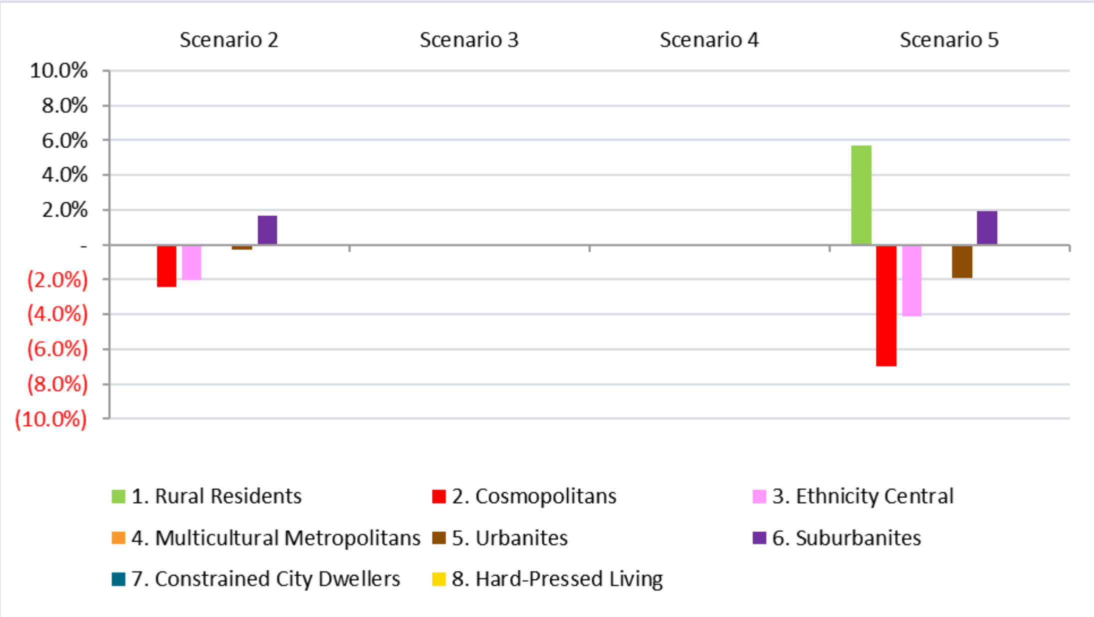
Scenarios

6.61 The background population and employment growth obtained from TEMPRO is included in all future year scenarios so that, for each modelled year, all scenarios have the same total population and employment in each nation. There is, however, variation in terms of the distribution of population across regions and especially across supergroups in the OAC segmentation. The assumptions for these movements are explained earlier in this chapter.

6.62 While the assumed movements of population between regions are limited in volume, with no region assumed to change its population by 1% or more, movements between OAC supergroups are stronger.

6.63 This is shown in Figure 6.4, with population in OAC supergroups in Scenarios 2 to 5 represented as relative changes to the population distribution of Scenario 1, which is used as the reference.

Figure 6.4: Change in population distribution by OAC supergroup and scenario (2055) vs Scenario 1



6.64 It can be seen that only Scenario 2 and Scenario 5 assume movements of population between OAC supergroups as a result of the 'Dispersal from Cities' meta-trend, with Scenario 2 including Suburbanisation effects only and Scenario 5 including both Suburbanisation and Regionalisation effects.

6.65 OAC supergroups with a stronger urban character and a higher proportion of managerial, professional, technical and administrative occupations, (those more likely to adopt homeworking behaviours) see decreases in population, which move to suburban and rural locations.

Results

Transport

Total Trips and Distance Travelled

6.66 Trip and distance rates are produced in the transport model for every combination of regional split, OAC supergroup, year and scenario. These can be subsequently disaggregated by both mode and purpose, as explained in Chapter 4. Combining the individual rates with the projected population for each combination of area and OAC supergroup produces the total figures of trips and distance travelled.

6.67 Figure 6.5 and Figure 6.6 show the total trips and distance travelled by region and nation in the base year model. As mentioned in Chapter 4, the NTS only provides data for England, therefore figures for Wales and Scotland here have been estimated using the 'Rest of England' regional split rates as a proxy, and the actual populations of Scotland and Wales, from ONS.

Figure 6.5: Total trips by region and nation in the base year transport model

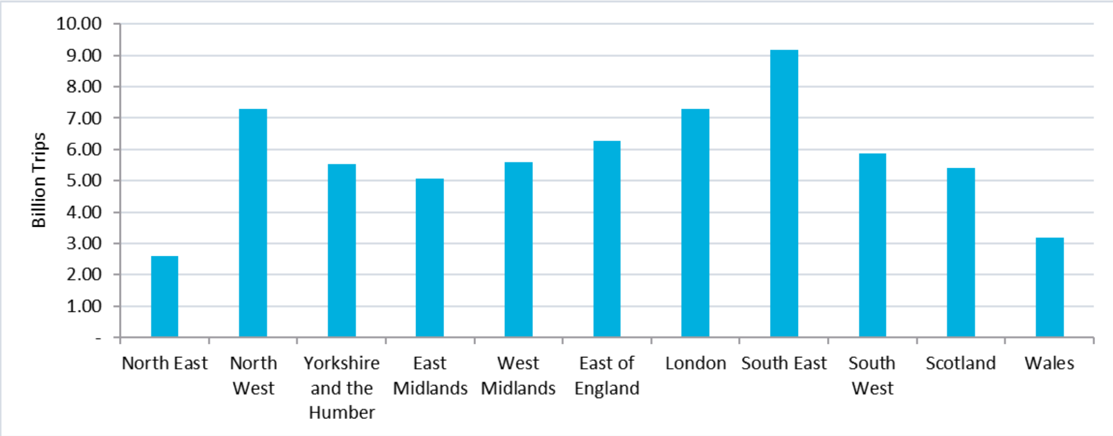
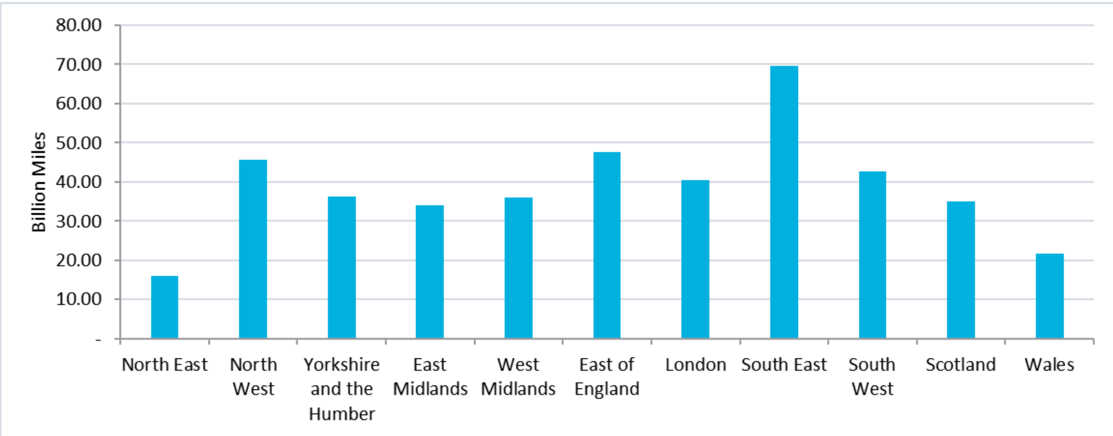


Figure 6.6: Total distance travelled by region and nation in the base year transport model



6.68 Scenario 1 shows a steady increase of both total trips and distance, driven by minimal change to the base year and counterfactual trip rates combined with forecast population growth. Scenarios 2 and 4, after consideration of all the assumptions, would have similar volumes of travel, in terms of trips and total distance, with Scenario 3 and especially Scenario 5 being somewhat lower.

Trips and Distance Travelled: By Purpose

6.69 Changes to the trips and distances travelled by purpose are dependent on the assumptions made with regards to the 'Working from home', 'Social Wariness' and 'Use of Virtual Tools' meta-trends. While the first one directly affects the business and commuting purposes, the other two are translated into reductions to the trip and distance rates for other purposes, such as leisure or education.

6.70 In addition to the direct changes to rates based on the trends listed above, total volumes of trips and distances are affected by the Suburbanisation and Regionalisation effects. As people move away from city centres to suburban or rural areas, changing their OAC classification, they are assumed to adopt the travel behaviours of residents in the areas they move to, which has an impact on the number of trips and the distance they travel, with differences by purpose.

6.71 Figure 6.7 and Figure 6.8 show the changes in total trips and distance travelled, respectively, by purpose and scenario. Scenario 1 ("Reversion and Reaction") has been taken as the reference for comparison here, with the change in trips and distance travelled for each scenario expressed as a percentage increase or decrease with respect to the Scenario 1 results.

Figure 6.7: Change in total trips by purpose vs Scenario 1 (2055)

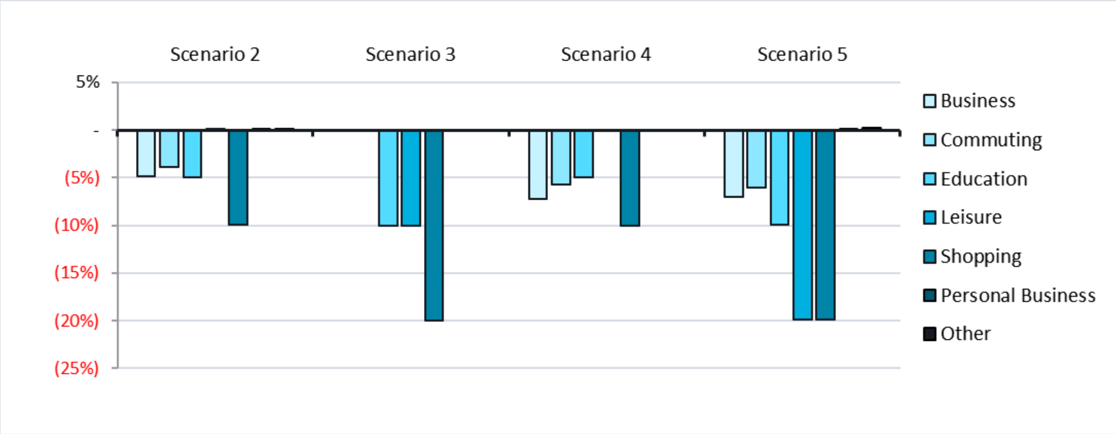
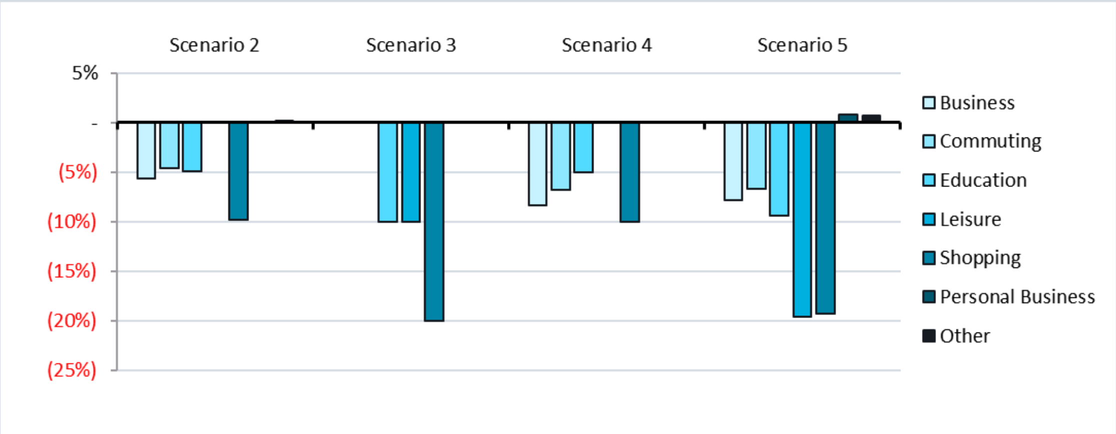


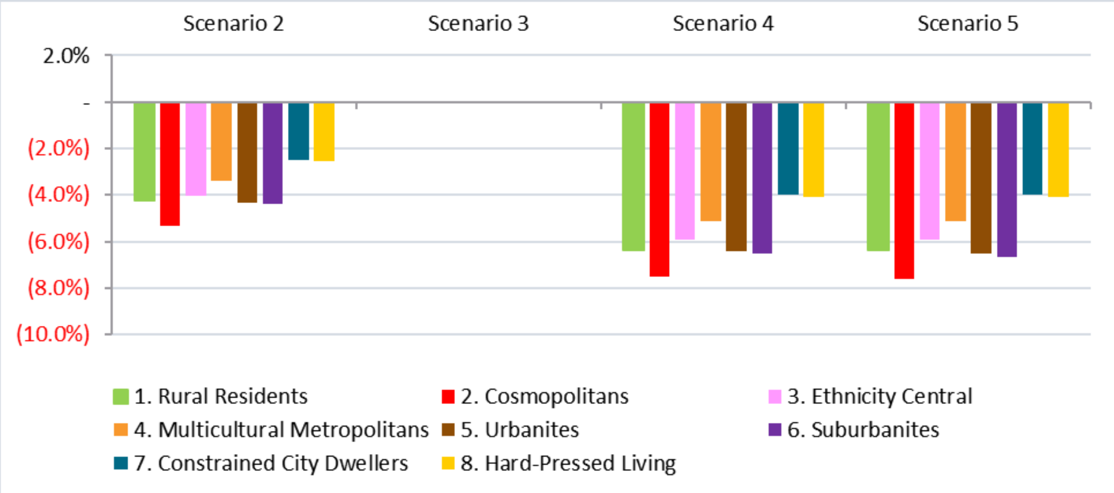
Figure 6.8: Change in total distance travelled by purpose vs Scenario 1 (2055)



6.72 While changes to leisure, shopping and education trips, informed by the 'Social Wariness' and 'Use of Virtual Tools' meta-trends have been assumed equal for all regions and population groups, this is not the case for business and commuting. As discussed earlier in this chapter, SOC groups 1-4 have been defined as the sub-group of population that is more likely to adopt and maintain a relevant change in homeworking patterns, in turn impacting the frequency of both commuting and business trips.

6.73 Figure 6.9 shows the percentage change in commuting trip rates of each scenario when compared to Scenario 1, by OAC supergroup. It can be seen that those OAC supergroups known to have a larger proportion of employees in the SOC groups 1-4 see larger decreases in commuting rates than others with smaller proportions (e.g. larger reduction in commuting trips for Cosmopolitans than for Constrained City Dwellers).

Figure 6.9: Change in commuting trip rates by OAC supergroup and scenario (2055) vs Scenario 1



Trips and Distance Travelled: By Mode

6.74 With the trip and distance rates in the transport model being produced based on changes to individual trip purposes, the mode split of those transport indicators was subsequently calculated. Using the counterfactual (base year) splits as a starting point, both the 'Social Wariness' and 'Use of Virtual Tools' meta-trends were considered to estimate different mode splits for each scenario, which generally consist of different levels of reduction of public transport use and distribution of mode share loss between active and private motorised modes.

6.75 As for the trip and distance totals by purpose, the totals by mode are not only affected by the assumed changes in travel behaviour for each individual but also by the assumed population movements. The latter has a greater impact on mode split than purpose split, as the OAC supergroups have clearer differences in their patterns of travel mode use than in their patterns of trips by purpose. For example, the difference in public transport and car use between urban and rural residents is greater than the difference in their share of leisure or education trips.

6.76 Figure 6.10 and Figure 6.11 show the changes in total trips and distance travelled by mode and scenario, using Scenario 1 as the reference. A caveat to consider when interpreting these results, as already mentioned in Chapter 4, is that the mode split of trips refers to 'main mode', this is the mode used for the longest stage of a trip (e.g. if a trip involves a short bus stage and a long rail stage, the trip is assigned to rail only). On the other hand, distance travelled includes all stages of the trip, therefore accounting truly for all distance travelled on each mode.

Figure 6.10: Change in total trips by main mode vs Scenario 1 (2055)

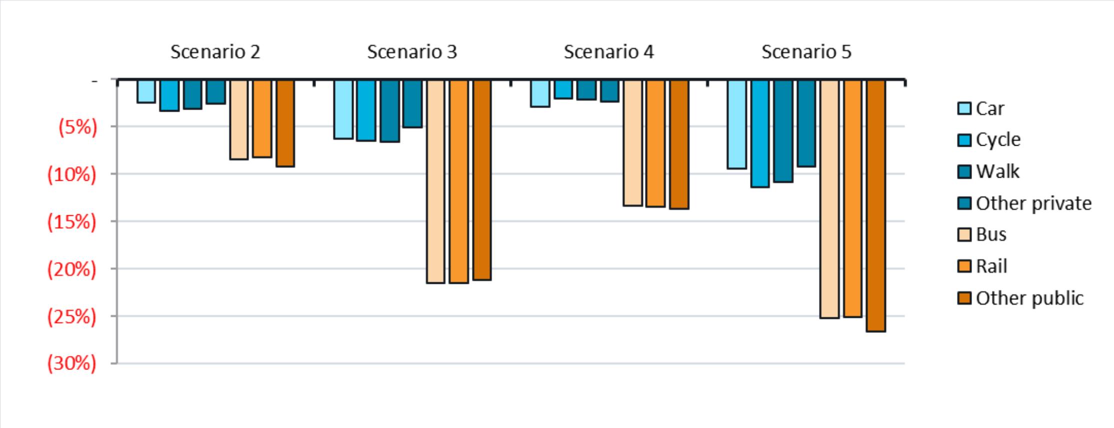
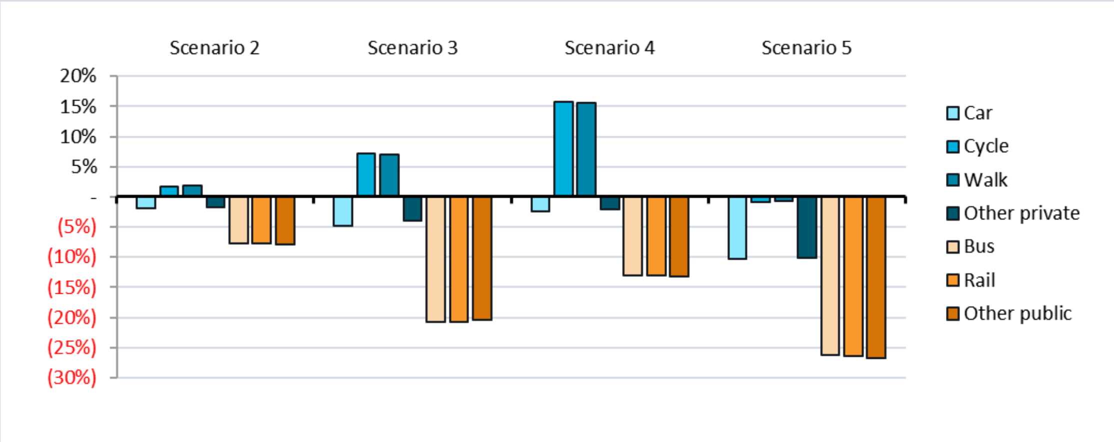


Figure 6.11: Change in total distance travelled by mode vs Scenario 1 (2055)



6.77 Figure 6.12 and Figure 6.13 show the differences in mode share of total trips by scenario in London and the rest of the country, respectively. While the assumption built into the model is that the changes to mode split as a result of change in travel behaviour are the same across the country, this would be difficult to see if only a nationwide figure were included here. This is due to public transport mode split in the UK being low and changes to a low number are more difficult to see.

6.78 For example, between Scenario 1 and Scenario 5 the public transport mode share is assumed to reduce by around 15%, from 29% to 25% in London and from 6% to 5% in the rest of the country. This reduction in public transport use results in an increase in the share of active and private motorised modes.

Figure 6.12: Mode share of total trips by scenario in London

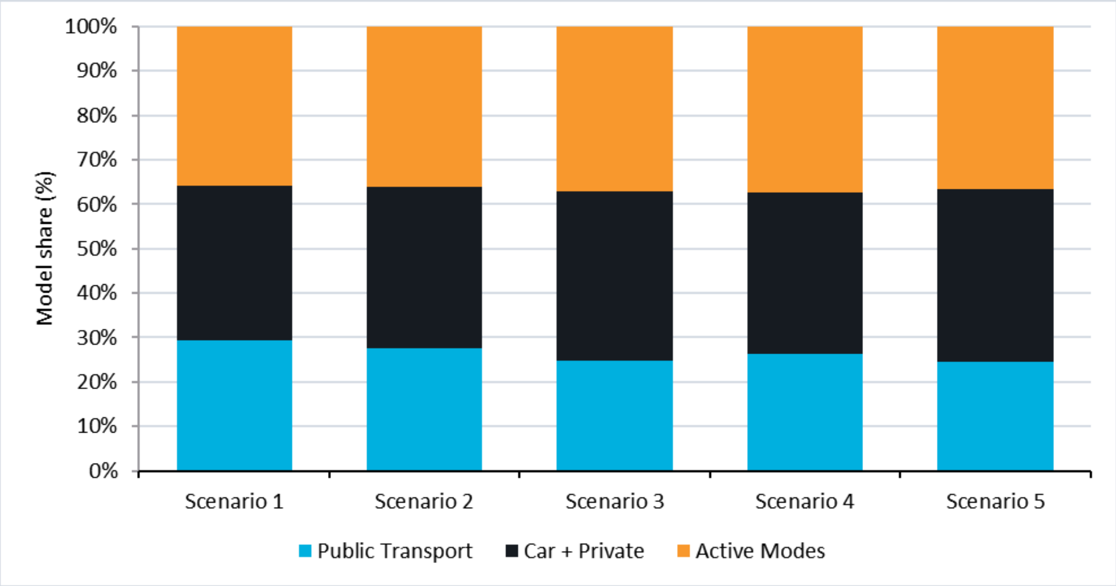
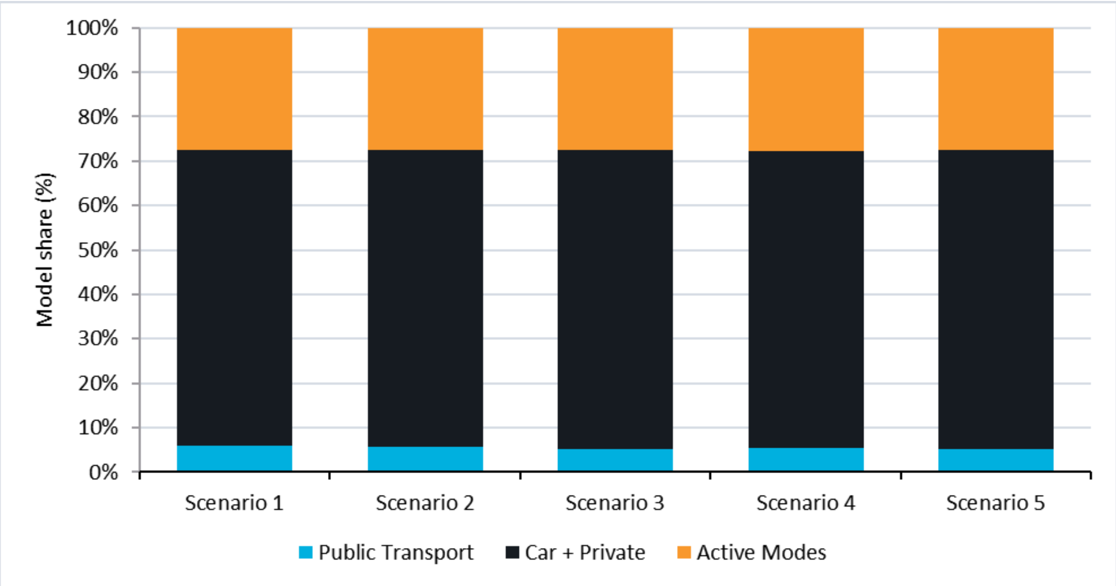


Figure 6.13: Mode share of total trips by scenario in the rest of the UK

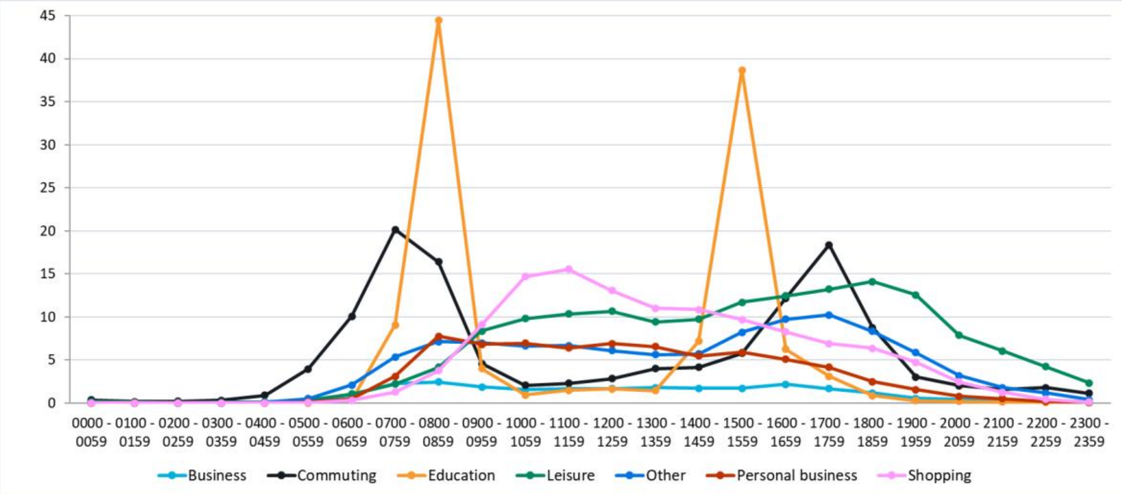


Time Profile of Travel

6.79 The figures shown above in this Chapter refer to trip and distance rates, expressed in a per person per year basis. However, trips tend to be made at certain times, with patterns that appear depending on the purpose.

6.80 Figure 6.14 shows the time profile of average trip rates, by purpose, for the average weekday. These trip rates have been extracted from NTS and correspond to the England average for the base year model, using 2017-2019 data. Trip rates are distributed through the day corresponding to the 1-hour slot (e.g. between 08.00 and 08.59) in which the trip started.

Figure 6.14: Time profile of average trip rates by purpose - base year



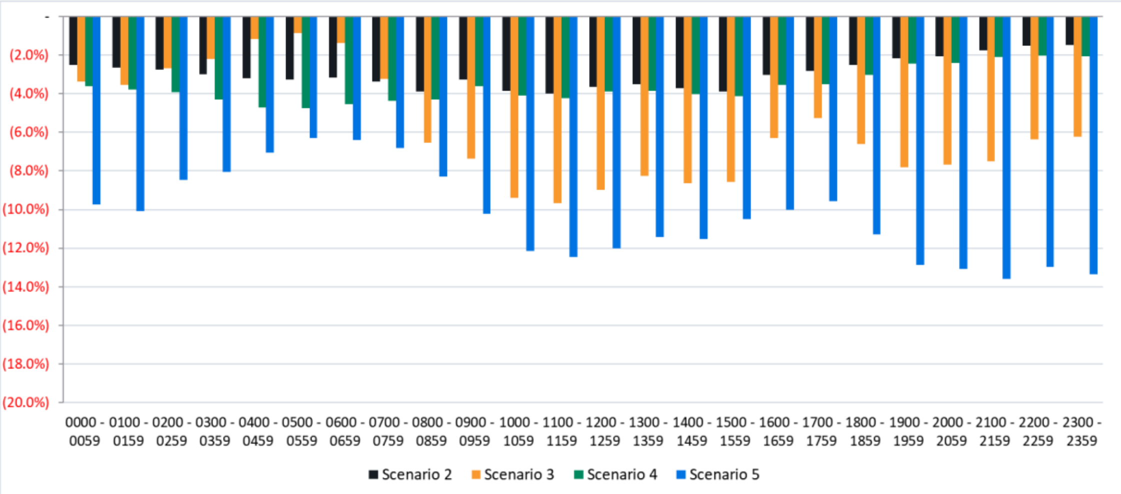
6.81 It can be seen that each purpose has a clearly defined pattern and also different average trip rates. Commuting trips are mostly concentrated around the peak hours in the morning and evening, with education (including escort education) having a similar, albeit more extreme, pattern, reflecting start and finish school times. Shopping trips are at low levels in the early morning, peaking before noon and then slowly decreasing for the remainder of the day, with leisure having almost the opposite pattern, with increasing trip rates during the day until the peak in the evening.

6.82 It is important to note that the assumptions made for the development of the transport model do not consider changes to travel patterns within the day or between different days of the week. For instance, in a scenario with greater working from home leading to fewer commuting trips the scenarios assume an equal proportionate reduction in commuting trips at all times of the day. They do not assume that people re-time their journeys or focus their working from home on particular days of the week.

6.83 Nonetheless, the daily profile of total trips does differ between scenarios. While each purpose is adjusted equally throughout the day, because different times of the day have different purpose splits this results in a differential impacts between scenarios. Although the hourly profile for each purpose will not change, the volume does as each scenario has a different impact on each purpose, the total number of trips made each hour will vary through the day, and will do so differently for each scenario.

6.84 Figure 6.15 shows the time profile of the change of total trip rates for each scenario. Scenario 1 has been used as the scenario of reference, with the change expressed as a percentage variation from Scenario 1. These are changes to total trips, combining all purposes, and are assigned the 1-hour slot during which the trip started.

Figure 6.15: Time profile of change in trips by scenario and purpose (2055)



6.85 As explained earlier, it can be seen that in each scenario the change in trip making relative to Scenario 1 varies throughout the day and the variation is different for each scenario. Overall, Scenario 5 has the greatest reduction in trips rates, which is consistent with the results shown earlier in this chapter.

6.86 The general pattern is that the change in trip rates for each scenario is greater in those periods of the day during which trip purposes that are more affected in that specific scenario have a greater share of trips. For example, between 05.00 and 08.00 commuting is the largest purpose and therefore the greatest changes for those scenarios that have the largest reduction in journey to work travel.

6.87 Another example is the pattern during the late morning and early afternoon, where leisure and shopping trips are dominant. Scenario 3 has a strong downward impact on the number of such trips and therefore has a larger reduction than Scenarios 2 and 4, which have lower impacts on shopping and none on leisure trips.

Light Freight (Deliveries)

6.88 Figure 6.16 shows changes in the number of light freight delivery trips indexed against Scenario 1, that is in each year Scenario 1 is equal to 100 and the scale of demand in the other scenarios is relative to Scenario 1 in that year. Figure 6.17 is equivalent to Figure 6.16 , except that the chart shows an index of light freight delivery-miles.

Figure 6.16: Light Freight deliveries compared to Scenario 1

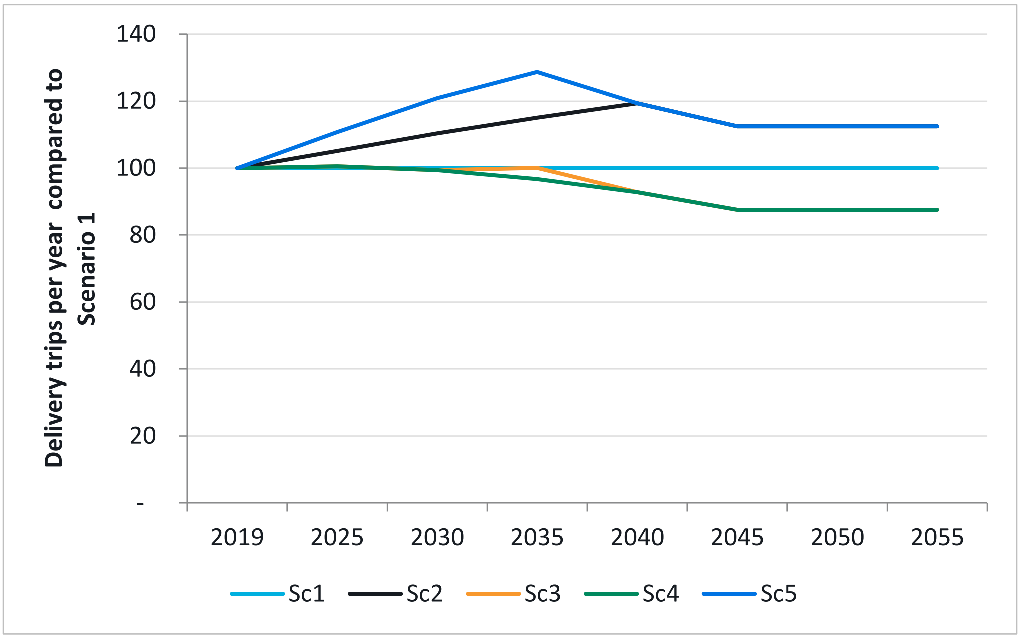
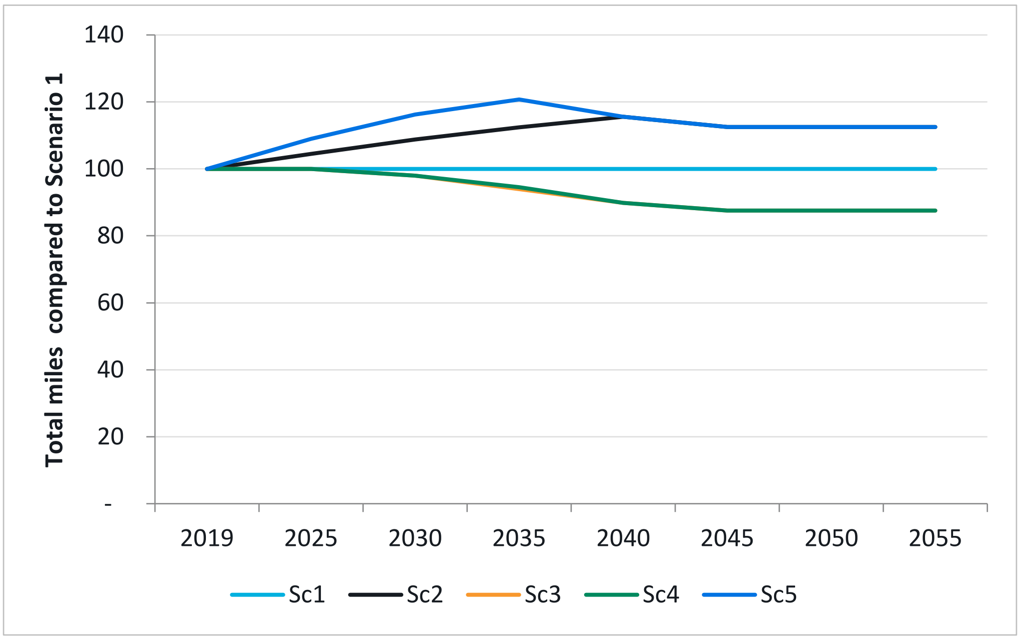


Figure 6.17: Light Freight Delivery Miles compared to Scenario 1



7 The NIC's Scenarios and the Demand for Infrastructure – Other Sectors

Introduction

7.1 As well as transport, the impact of the NIC scenarios on demand in four further sectors has been considered. These are:

- Digital
- Energy
- Water & Wastewater
- Waste

7.2 As with the transport sector, for each sector each of the NIC's meta-trends has been associated with a particular impact that in turn has been associated with a set of variables. For the other sectors, an alternative approach has been undertaken with the meta-trends considered in turn to develop a direction of change for a single variable, using the same six point scale that has been used for the transport impacts (low/medium/high and increase/decrease). This approach has been adopted because a much more limited set of demand metrics are being used for the other sectors and it is not possible to associate any particular meta-trend with the direction of change of a single metric or unique set of metrics. Rather, the impact on the chosen metrics is due to the meta-trends working in combination.

7.3 Here for each sector we set out the assumptions that have been made to define the scenarios and the rationale that underpins these.

Digital

7.4 Prior to the pandemic digital data usage was growing on average at around 35% per annum.

7.5 During the pandemic, it has been seen that:

- There was a large increase in daytime digital traffic during weekdays (08:00 to 18:00). This will have been driven by the more people working or studying from home (and using video conferencing tools such Zoom and Microsoft Teams heavily), but also by the traffic generated by people on furlough, many of whom will have turned to online entertainment during the lockdown, including video-streaming applications such as Netflix, and online gaming. During the restrictions, the traffic profile by time-of-day during weekdays became similar to that at weekends.
- The peak period for traffic is in the evenings (c. 20:00 to 22:00), both at weekends and weekdays. Telecoms operators (of mass market broadband services) dimension their networks to handle this peak, with headroom, and the anticipated growth in that peak.

- The increase in typical traffic during the peak period was significant but relatively modest, both for weekdays and weekends. It is presumed that this was driven by more people using video-streaming and gaming, etc, at home, rather than going out to socialise with friends.

7.6 Further details on digital use before and during the pandemic can be found in Appendix C.

7.7 For the purposes of modelling the NIC's scenarios, it has been assumed that:

- Given the rapid rate of digital growth the longer into the future that demand projections are made, the greater the uncertainty on digital demand. Given the compounding effect over time, modest differences in growth assumptions can lead to very different future projections. Because of this, digital demand is not projected beyond 2025.
- As seen in the pre-pandemic trend, the annual percentage growth rates are assumed to reduce gradually over time. However, it should be noted that the annual growth rates by the end of the modelling period are still very high (19% to 20% p.a.), and would lead to very large compounded changes over time..
- The Social Wariness and Dispersal from Cities meta-trends have been assumed not to effect digital demand, though the latter will have an effect on the geographic distribution of data usage.
- Both the Working from Home and Use of Virtual Tools meta-trends depend on greater on-line activity and it is assumed that each will lead to a growth in digital demand.

7.8 For digital we have considered the potential impact of the NIC's meta-trends in the round and derived estimated growth increments that encapsulate the combined effect of each trend. These are shown in Table 7.1. In this Table, the percentage figures are the growth increment versus the level of data usage which would be expected in that year at pre-pandemic growth trends. In 2020, digital demand was c.6% higher than would be expected at the estimated pre-pandemic growth trend, for reasons set out in Paragraph 7.5 above. In Scenario 1, it is assumed that data usage will be slightly lower than the levels projected at pre-pandemic growth trends. All other scenarios assume average data usage at levels higher than those projected at the estimated pre-pandemic growth trends, with Scenario 5 having the greatest increase in average data usage..

Table 7.1: Digital – Growth Increment on Pre-Pandemic Trend

	2020	2021	2022	2023	2024	2025
Sc1: Reversion and reaction	6%	-1%	-1%	-1%	-1%	-1%
Sc2: A more flexible future	6%	4%	5%	5%	5%	5%
Sc3: Low social contact urban living	6%	5%	6%	7%	8%	9%
Sc4: Social cities	6%	5%	6%	6%	6%	6%
Sc5: Virtual local reality	6%	7%	8%	9%	10%	11%

Energy

7.9 During the pandemic:

- Total energy consumption reduced by almost a fifth between Q3 2019 and Q3 2020, although the permanence of this fall is uncertain given the time of year when the weather was relatively warm.
- There has been a shift in demand from non-households to households and from urban to suburban areas, with service sector consumption falling by 7.8% and industrial sector

consumption by 8.4%, whilst domestic consumption increased by 2.5% over the same period.
- Electricity consumption by households changed due to lockdown restrictions imposing working from home and home schooling, causing morning peaks in demand to flatten as activity was spread throughout the day.

7.10 Shifts to new working patterns with a greater emphasis on working from home may result in permanent changes in household energy demand. Overall, however, the permanence of changes are uncertain. As restrictions eased during the course of 2020 aggregate demand returned to around 5% below pre-Covid levels, with some indications that demand was returning to expected levels as restrictions were further eased, highlighting that the impact of the pandemic could be temporary.

7.11 Further details on national energy consumption before and during the pandemic can be found in Appendix D.

7.12 For the purposes of modelling the NIC's scenarios, it has been assumed that for domestic energy consumption:

- The high intensity change leads to a 9% increase in domestic demand (assuming a 3% increase in domestic consumption with every 10% shift to work from home).
- The medium intensity change will have two thirds of the high intensity impact and low intensity only one third.
- For Dispersal from Cities, it is assumed that there is no effect on domestic energy consumption, although the location where energy is consumed will change.

7.13 For the non-domestic sector, it has been assumed that:

- For the Working from Home meta-trend, the high intensity change leads to a 6% reduction in non-domestic energy consumption. For Use of Virtual Tools and Social Wariness, the high intensity change is a 3% reduction in energy use.
- For Dispersal from Cities, it is assumed that the high intensity change is a 3% increase in energy use. This reflects an assumption that a more dispersed population leads to a more dispersed pattern of commercial activity, i.e. more premises catering for the same demand. If an alternative assumption is adopted of people travelling further to the current distribution of commercial premises then the appropriate assumption would be Dispersal from Cities having no impact on non-domestic energy consumption.
- As with the domestic sector, it is assumed that the medium intensity change will have two thirds of the high intensity impact and low intensity only one third.

7.14 The assumed impact of each meta-trend on domestic and non-domestic energy consumption are shown in Table 7.2 and Table 7.3. These tables define what is a low, medium and high change and then show the impact of each meta-trend in each scenario before setting out the cumulative impact.

Table 7.2: Domestic Energy – Impact of Meta Trends

Meta-trend	Low	Medium	High	Sc1: Reversion and reaction	Sc2: A more flexible future	Sc3: Low social contact urban living	Sc4: Social cities	Sc5: Virtual local reality
Working from Home	1%	2%	3%	1%	2%	1%	3%	3%
Use of Virtual Tools	1%	2%	3%	1%	2%	3%	2%	3%
Social Wariness	1%	2%	3%	1%	1%	3%	1%	3%
Dispersal from Cities	-	-	-	-	-	-	-	-
Cumulative Effect				**3%**	**5%**	**7%**	**6%**	**9%**

Table 7.3: Non Domestic Energy – Impact of Meta Trends

Meta-trend	Low	Medium	High	Sc1: Reversion and reaction	Sc2: A more flexible future	Sc3: Low social contact urban living	Sc4: Social cities	Sc5: Virtual local reality
Working from Home	(2%)	(4%)	(6%)	(2%)	(4%)	(2%)	(6%)	(6%)
Use of Virtual Tools	(1%)	(2%)	(3%)	(1%)	(2%)	(3%)	(2%)	(3%)
Social Wariness	(1%)	(2%)	(3%)	(1%)	(1%)	(3%)	(1%)	(3%)
Dispersal from Cities	1%	2%	3%	1%	3%	1%	1%	3%
Cumulative Effect				**(3%)**	**(4%)**	**(7%)**	**(8%)**	**(9%)**

Water & Wastewater

7.15 There is some uncertainty about the impacts of pandemic restrictions on water consumption. Most water companies saw an increase in average household water consumption during the first lockdown. Companies covering predominantly suburban areas saw the most noticeable increases, while companies operating in city areas saw a reduction in water use. Differences between weekday and weekend water consumption largely disappeared.

7.16 Survey data has identified that in the first lockdown:

- the morning peak started later in the day for households;
- household peak daily consumption at the end of May 2020 was about 35% higher than it was pre-lockdown, and the evening peak was often higher than the morning peak, but this may be more attributable to the warm weather at the time; and
- non-household consumption reduced very significantly during the lockdown.

7.17 These charges have been attributed to a number of factors including:

- the changes in behaviour from working at home and not needing to get children up and ready for school in the mornings;
- increased occupancy during the day (for example, older children returning home when colleges and universities closed);
- less movement of people between areas (people not going to work and not going away on holiday);
- changes in water use, such as more handwashing;
- the huge reduction in consumption from the hospitality, entertainment and retail sectors.

7.18 In considering the impact of the NIC scenarios, the working assumption is that greater numbers working from home will have an upward impact on domestic water consumption, simply because more activities are being undertaken at home. To a degree, this would be offset by lower consumption at commercial premises. However, this will not be a one-to-one offset.

7.19 For planning purposes, the proportion of water consumption that is returned to the sewer network is generally put at between 90% and 95%. For the purposes of this work, it is assumed that increments in domestic wastewater are proportionate to changes in domestic water consumption.

7.20 Further details on water use before and during the pandemic can be found in Appendix E.

7.21 Given that changes in water use during the pandemic offer limited insight on future trends, it is necessary to postulate the potential impact of the NIC meta-trends. For the purposes of modelling the NIC's scenarios, it has been assumed that:

- For the Working from Home meta-trend, the high intensity change leads to a 6% increase in domestic water consumption. For Use of Virtual Tools and Social Wariness, the high intensity change is a 3% increase.
- As with the domestic sector, it is assumed that the medium intensity change will have two thirds of the high intensity impact and low intensity only one third.
- It is considered that the Social Wariness meta-trend will not have any impact on water consumption. When considering transport impacts this meta-trend has been defined as manifesting itself as an on-going reluctance to use public transport rather than something

- that affects domestic or commercial activities. Changes to activities are captured by the Working from Home and Use of Virtual Tools meta-trends.
- Also, it is not considered that the Dispersal from Cities meta-trend is likely to have a material impact on total domestic water consumption, although it is likely to affect where in the country that consumption occurs.

7.22 For each scenario:

- the allocation of high/medium/low effects to the Working from Home meta-trend is consistent with the allocation of high/medium/low effects to the commuting trip rate in the transport model. Both reflect more people working from home.
- the allocation of high/medium/low effects to the Use of Virtual Tools meta-trend is consistent with allocation to the leisure trip rate in the transport model. Both reflect greater time being spent at home.

7.23 The assumed impacts of each meta-trend on domestic and non-domestic energy consumption are shown in Table 7.4.

Waste

7.24 It is difficult to discern trends in household waste during the pandemic. People were at home because they were working from home or had been furloughed/laid off. More home deliveries led to more packaging and there were potentially one-off effects (e.g. increase in DIY, 'life laundries') that increased domestic waste. Confusing the picture is that many councils adjusted their waste collection schedules and many municipal collection sites had reduced hours or were closed.

7.25 It has been estimated that:[18]

- During Q2 2020, kerbside collected household waste rose by around 10%
- However, this was offset by a significant reduction in tonnages of household waste accepted at Household Waste Recycling Centres
- The net result was a modest fall in overall household waste

7.26 Available data suggests that the make-up of household waste changed during the pandemic, with an increase in dry recyclables (e.g. packaging) and a drop in collected garden waste, the latter potentially a result of changed collection practices.

7.27 In the absence of any specific data on the impact of working from home during the pandemic on waste, our working assumption is that greater working from home will lead to a modest increase in the volumes of household waste.

7.28 As with water, given that data on changes in waste use during the pandemic offer limited insight on future trends, it is necessary to postulate potential impact of the NIC meta-trends. For the purposes of modelling the NIC's scenarios, it has been assumed that:

- For the Working from Home meta-trend, the high intensity change leads to a 6% increase in waste. For Use of Virtual Tools, the high intensity change is a 3% increase.
- As with the other sectors, it is assumed that the medium intensity change will have two thirds of the high intensity impact and low intensity only one third.

[18] https://www.tolvik.com/wp-content/uploads/2020/11/Covid-19-and-UK-Waste-Sector-Autumn-20_published-10-November-2020.pdf

- As with water and for the same reasons, it is considered that the Social Wariness meta-trend will not have any impact on household waste.
- Also, it is not considered that the Dispersal from Cities meta-trend is likely to have a material impact on total waste, although it is likely to affect where in the country that consumption occurs.

7.29 As with water, for each scenario:

- the allocation of high/medium/low effects to the Working from Home meta-trend is consistent with the allocation of high/medium/low effects to the commuting trip rate in the transport model. Both reflect more people working from home.
- the allocation of high/medium/low effects to the Use of Virtual Tools meta-trend is consistent with allocation to the leisure trip rate in the transport model. Both reflect greater time being spent at home.

7.30 The assumed impact of each meta-trend on waste are shown in Table 7.5

Summary

The trends for other non-transport sectors are summarised in Table 7.6.

Results

7.31 On the following pages are charts that set out the headline results for each scenario. These are for the UK. The model that has been provided to NIC allows for more detailed interrogation of the outputs from the modelling at a national and regional scale.

7.32 For each headline metric a graph is provided. that shows changes in demand indexed against Scenario 1, that is in each year Scenario 1 is equal to 100 and the scale of demand in the other scenarios is relative to Scenario 1 in that year.

7.33 The following charts are provided:

- Digital
  - Monthly Data Usage
- Energy
  - Domestic Electricity Consumption
  - Non-domestic Electricity Consumption
  - Total Electricity Consumption
  - Domestic Gas Consumption
  - Non-domestic Gas Consumption
  - Total Gas Consumption
- Water
  - Domestic Water Consumption
- Waste
  - Domestic Waste Demand

Table 7.4: Water – Impact of Meta Trends

Meta-trend	Low	Medium	High	Sc1: Reversion and reaction	Sc2: A more flexible future	Sc3: Low social contact urban living	Sc4: Social cities	Sc5: Virtual local reality
Working from Home	2%	4%	6%	2%	4%	2%	6%	6%
Use of Virtual Tools	1%	2%	3%	-	-	2%	-	3%
Social Wariness	-	-	-	-	-	-	-	-
Dispersal from Cities	-	-	-	-	-	-	-	-
Cumulative Effect				**2%**	**4%**	**4%**	**6%**	**9%**

Table 7.5: Waste – Impact of Meta Trends

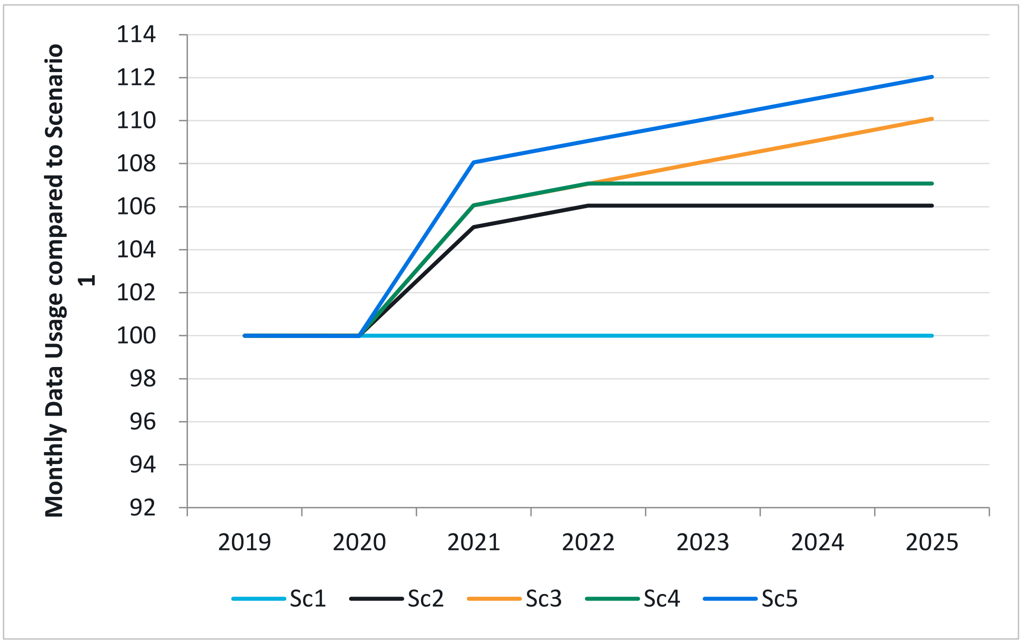
Meta-trend	Low	Medium	High	Sc1: Reversion and reaction	Sc2: A more flexible future	Sc3: Low social contact urban living	Sc4: Social cities	Sc5: Virtual local reality
Working from Home	1%	2%	3%	1%	2%	1%	3%	3%
Use of Virtual Tools	1%	1.5%	2%	-	-	1.5%	-	2%
Social Wariness	-	-	-	-	-	-	-	-
Dispersal from Cities	-	-	-	-	-	-	-	-
Cumulative Effect				**1%**	**2%**	**2.5%**	**3%**	**5%**

Table 7.6: Summary – Other Sectors and Alternative Future Scenarios

		Alternative Future Scenarios (change in trend vs Base)					
Variable	**Segmentation**	**Sc1: Reversion and reaction**	**Sc2: A more flexible future**	**Sc3: Low social contact urban living**	**Sc4: Social cities**	**Sc5: Virtual local reality**	**Comments**
Consumption rates (per person per year)							
Digital	OAC	Data demand ↓	Data demand ↑	Data demand ↑↑	Data demand ↑	Data demand ↑↑↑	Given the very high counterfactual annual growth rates in digital demand, modelling horizon restricted to 2025 for digital
Waste demand by household	NUTS 1 Region	Domestic ↑	Domestic ↑↑	Domestic ↑↑	Domestic ↑↑	Domestic ↑↑↑	"Commercial", "Construction, Demolition & Excavation" and "other" waste not modelled
Energy demand (Gas/Electricity) by household	NUTS 1 Region	Domestic ↑ Non-domestic ↓	Domestic ↑↑ Non-domestic ↓	Domestic ↑↑ Non-domestic ↓↓	Domestic ↑↑ Non-domestic ↓↓	Domestic ↑↑↑ Non-domestic ↓↓↓	
Water and wastewater demand by household	Water supplier / NUTS 1 Region	Household ↑	Household ↑↑	Household ↑↑	Household ↑↑	Household ↑↑↑	Non-household and leakage not modelled

Digital

Figure 7.1: Monthly Data Usage Compared to Scenario 1



Energy

Electricity

Figure 7.2: Domestic Electricity Consumption Compared to Scenario 1

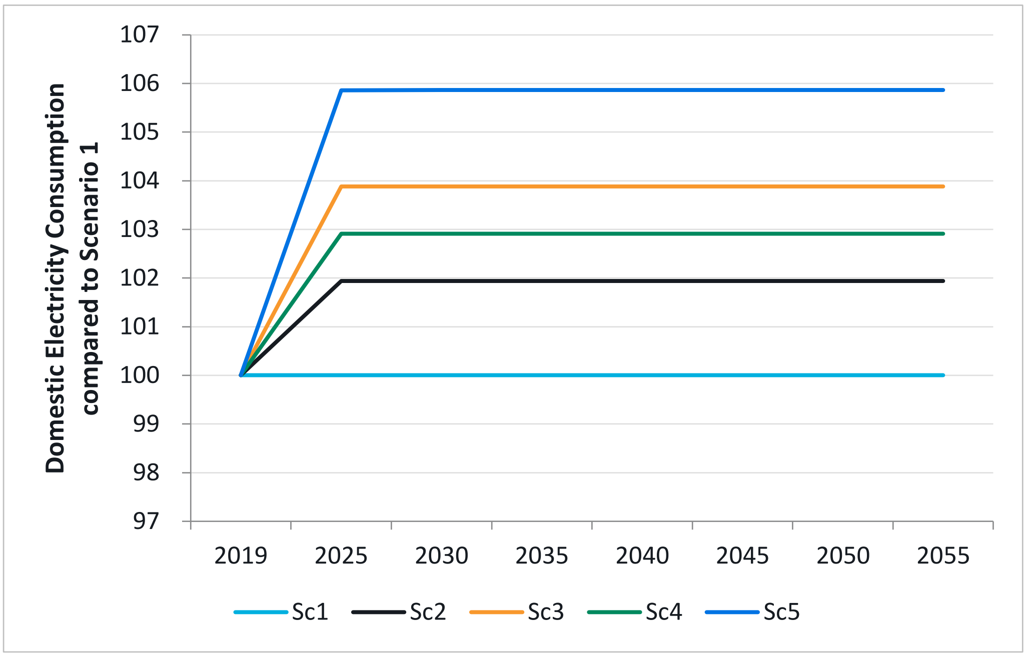


Figure 7.3: Non-domestic Electricity Consumption compared to Scenario 1

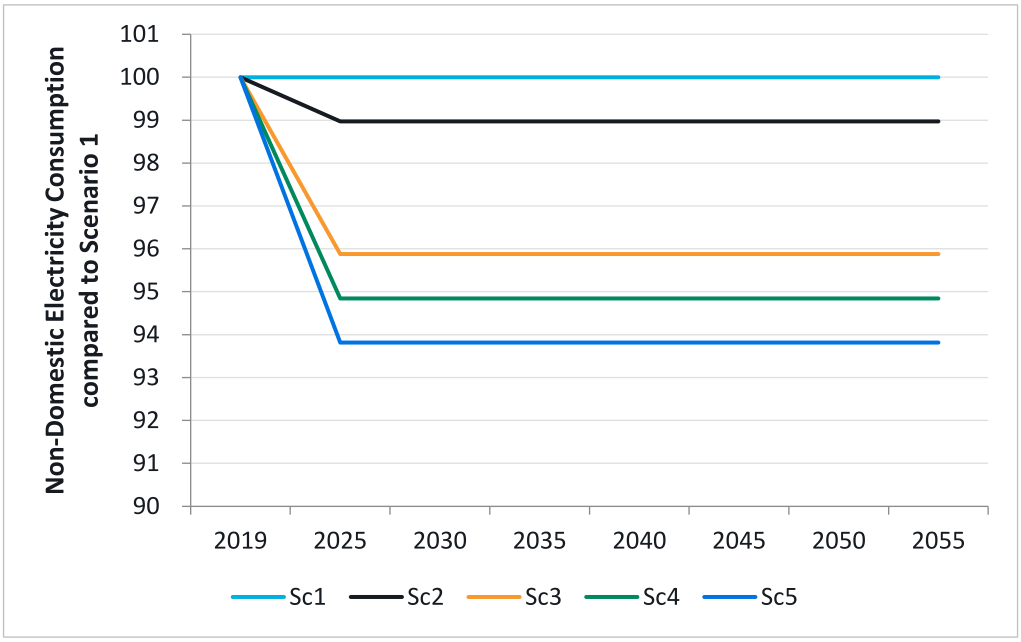
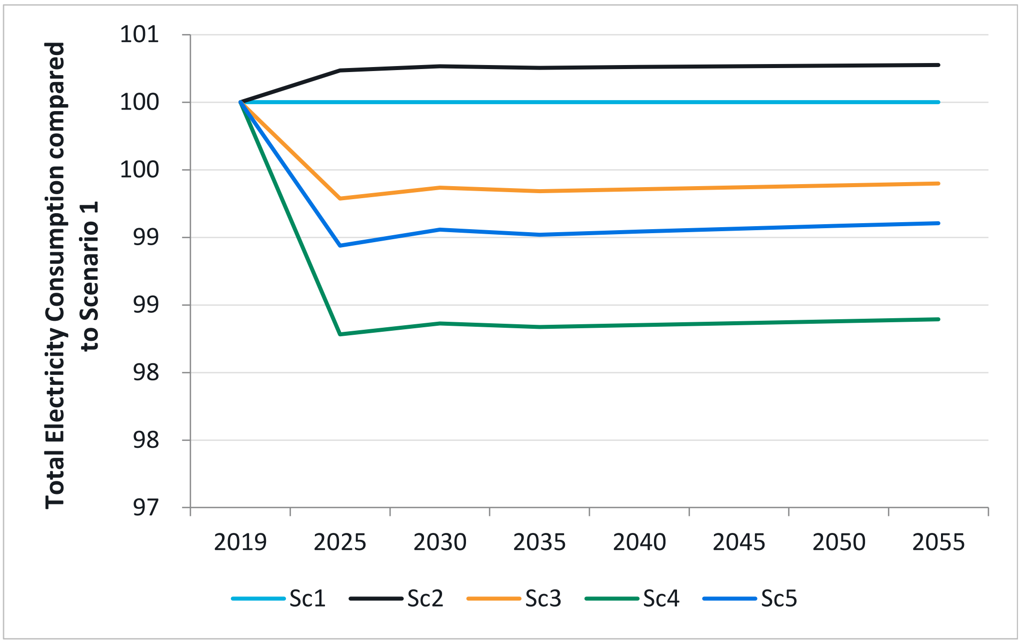


Figure 7.4: Total Electricity Consumption Compared to Scenario 1



Gas

Figure 7.5: Domestic Gas Consumption Compared to Scenario 1

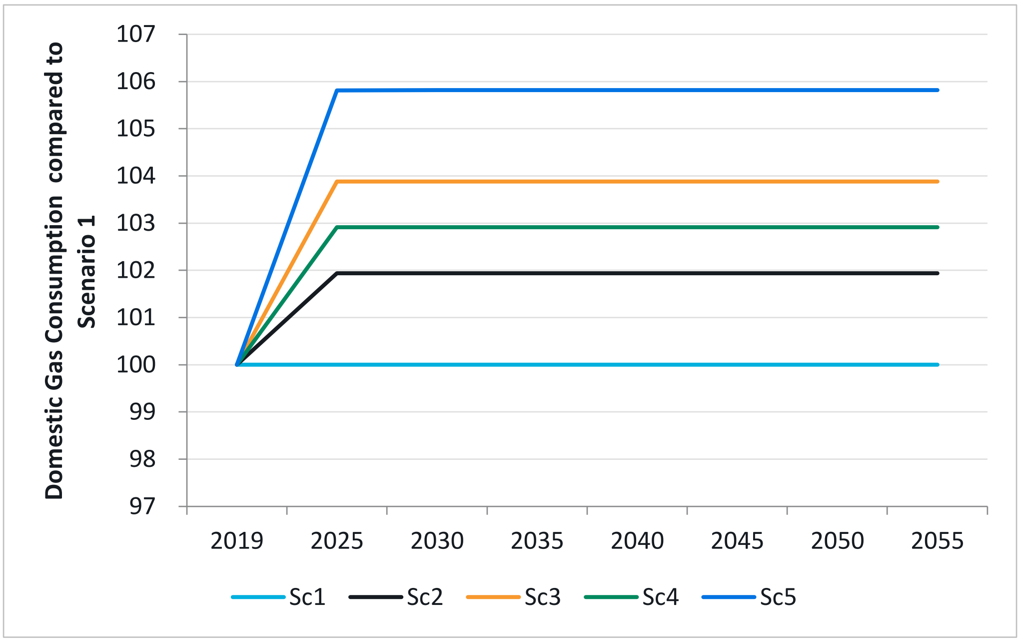


Figure 7.6: Non-domestic Gas Consumption Compared to Scenario 1

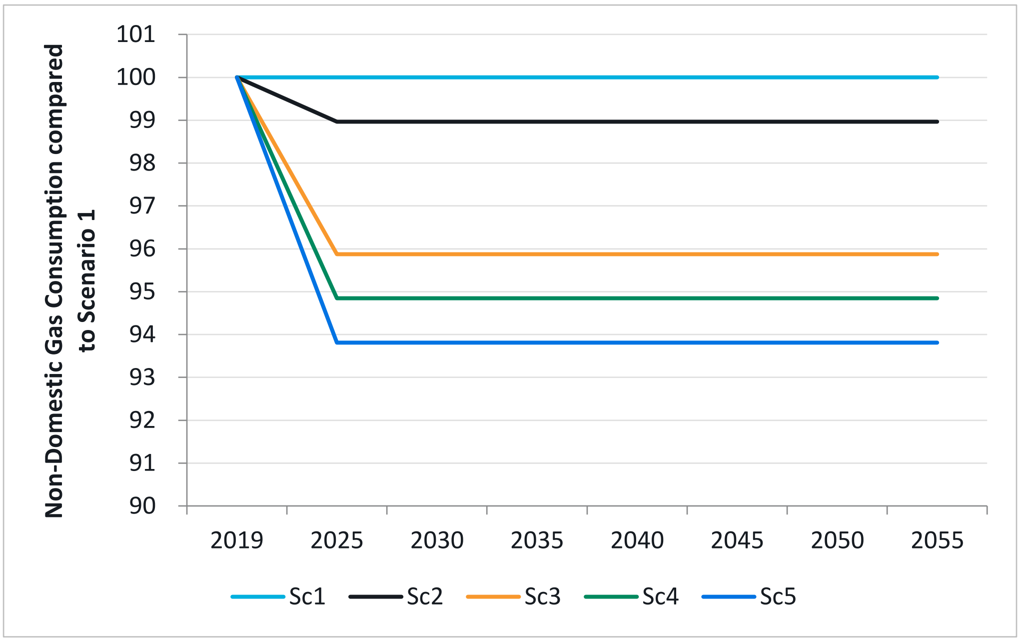
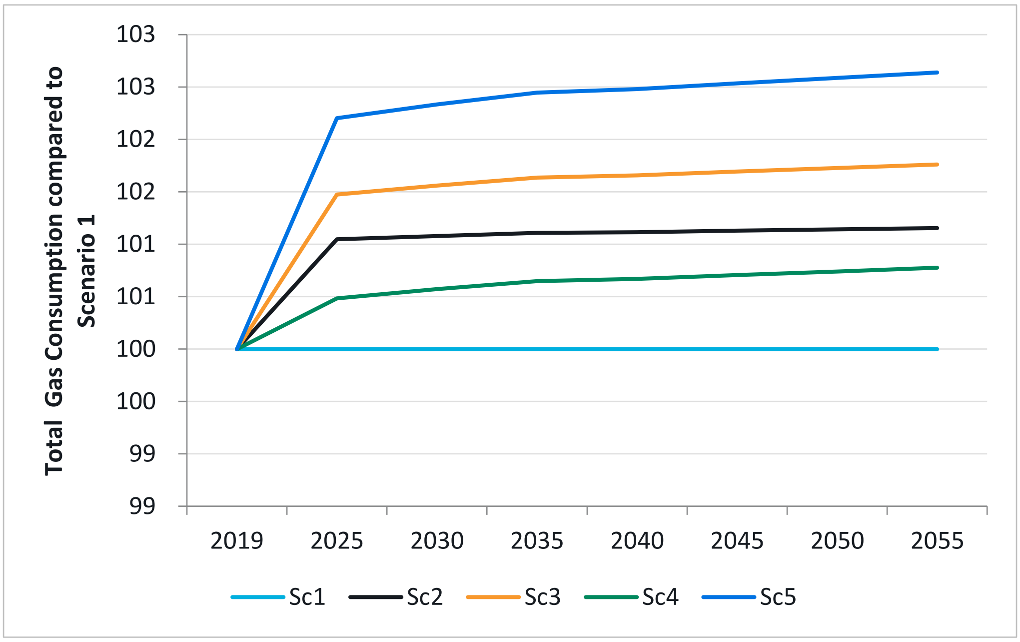
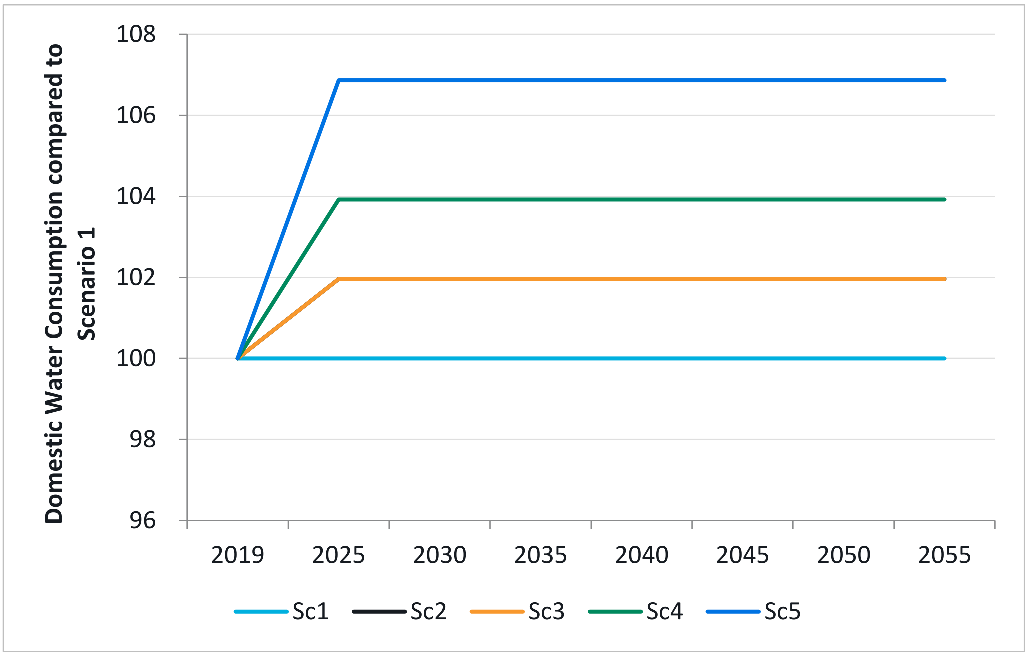


Figure 7.7: Total Gas Consumption compared to Scenario 1



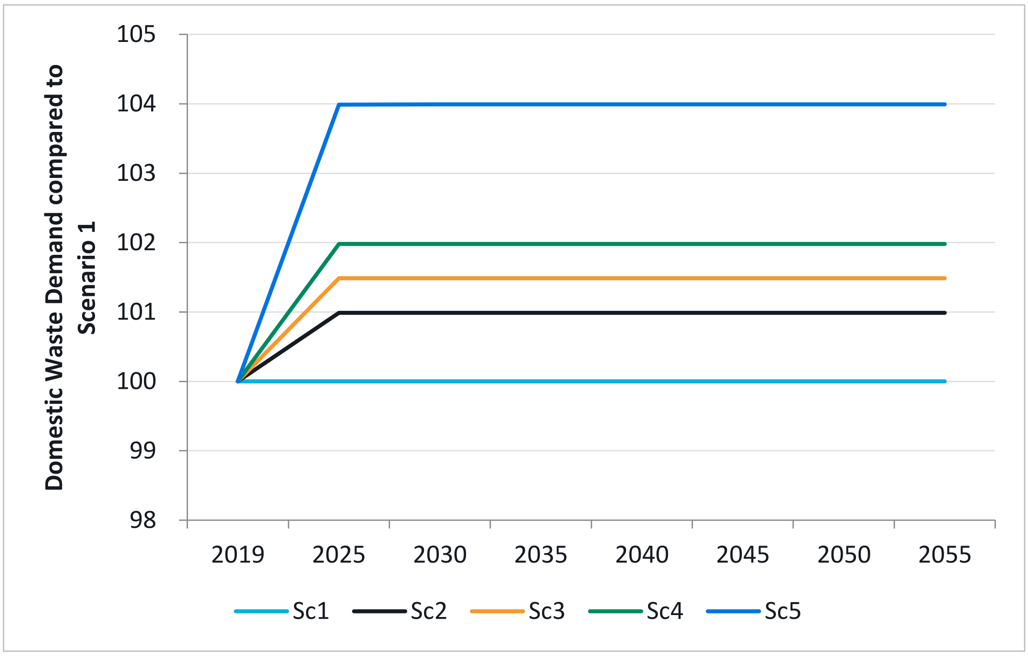
Water & Wastewater

Figure 7.8: Domestic Water Consumption Compared to Scenario 1



Waste

Figure 7.9: Domestic Waste Demand compared to Scenario 1



8 Future Modelling

Introduction

8.1 As well as developing quantified estimates of the impacts of the NIC's scenarios on a range of demand metrics, as part of this work consideration has been given to how a more in-depth and comprehensive assessment of the scenarios could be undertaken in the future.

8.2 Models in the transport sector tend to be complex and take substantial time and money to develop. Also, most are developed within the context of DfT's Transport Assessment Guidance (TAG), which sets out expectations for how data is used, and how models are calibrated and validated, as well as criteria for what is considered to be acceptable model performance. If the NIC were to model in more detail the land-use and transport impacts of its scenarios, the expectation is that it will need to make use of extant models, even if these are modified and/or developed.

8.3 While there are many models within the transport sector because of the influence of TAG there is a high degree of commonality with both the explanatory variables that they use as well as the formulation of the models and, because of this, the definition of the parameters within the models. To help understand how such models could be used to further explore the NIC's scenarios a small sample of models from each category above has been reviewed. The reviews were informed by available documentation as well as the experience of the study team.

8.4 There are three broad categories of transport models that can be used to model in detail the NIC's scenarios and what these mean for personal travel. These are:

- the Department for Transport's National Transport Model and associated National Trip End Model, which are the models used to produce its Road Traffic Forecasts ;
- Land Use Transport Interaction models with a sub-national focus (which could be a region (e.g. North of England), a conurbation (e.g. Greater London) or an administrative area (e.g. county/district)); and
- Fixed land use transport models, of which there are many across the country with scales ranging from regional to local and with different levels of model detail. Such models are routinely used to support the business cases for road and public transport capital interventions.

8.5 The models reviewed are:

- the Department for Transport's National Transport Model (NTM)/National Trip End Model (NTEM)
- Two Land Use Transport Interaction (LUTI) models:
  - SEELUM, a systems dynamics based model developed on behalf of Transport for the South East (TfSE)
  - LonLUTI, a neo-classical equilibrium LUTI model that has been developed for and applied by Transport for London (TfL)

- Two fixed land-use models:
  - MoTiON, a Variable Demand Model (VDM) of Greater London developed for and applied by TfL
  - Birmingham City Model, which is primarily a highway assignment model and has been developed by Birmingham City Council

8.6 There are very few freight forecasting models. The DfT currently use MDS Transmodal's Great Britain Freight Model (GBFM) to provide inputs to its National Transport Model. Transport for the North uses GBFM too, as do others. The NIC has previously commissioned and published work from MDS Transmodal that has used GBFM to look at alternative freight futures.

8.7 Further details of the model review can be found in Appendix F.

Findings

8.8 The findings from the model review are set out in two ways. First, the meta-trends that underpin the NIC's scenarios are considered. Then, consideration is given to how each reviewed model could be used to assess that transport impacts of the scenarios.

8.9 In Table 8.1 each meta-trend and its potential transport impacts are set out along with a modelling approach that can be used to assess these. While informed by the model review, these modelling approaches could be applied to almost any model developed within a TAG context.

Table 8.1: Potential Transport Modelling Approaches to Assess NIC Meta-Trends

Meta-trend	Transport impact compared to pre-Covid trend	Modelling Approaches
Working from Home	Fewer commuting journeys (journeys to work)	• Downward adjustment to trip production rates by person type and trip attraction rates by trip purpose in NTEM, or • Downward adjustment in TEMPRO outputs for selected areas
	Fewer business trips (employer's business)	• Downward adjustment to trip production rates by person type and trip attraction rates by trip purpose in NTEM, or • Downward adjustment in TEMPRO outputs for selected areas
Social Wariness	Fewer trips by public transport	• Increase mode specific constant and/or weighting on In Vehicle Time (IVT) in generalised cost/utility for public transport
	More trips by car	• No change – car absorb demand discouraged from using PT modes, and/or • Reduce IVT weighting in generalised cost/utility for car to represent 'pull' to car
	More trips by active modes	• For those models that consider active modes explicitly, reduce

Meta-trend	Transport impact compared to pre-Covid trend	Modelling Approaches
		weightings on elements of active mode generalised cost/utility
Use of Virtual Tools	Fewer leisure trips	• Downward adjustment to trip production rates by person type and trip attraction rates by trip purpose in NTEM, or • Downward adjustment in TEMPRO outputs for selected areas
	Fewer shopping trips	• Downward adjustment to trip production rates by person type and trip attraction rates by trip purpose in NTEM, or • Downward adjustment in TEMPRO outputs for selected areas
	Fewer education trips	• Downward adjustment to trip production rates by person type and trip attraction rates by trip purpose in NTEM, or • Downward adjustment in TEMPRO outputs for selected areas
Dispersal from Cities	Suburbanisation	• In NTEM, reallocate population (by person type) to represent move to suburbs, or • Adjustments to TEMPRO outputs for selected areas
	Regionalisation	• In NTEM, reallocate population (by person type) to represent move to suburbs, or • Adjustments to TEMPRO outputs for selected areas

National Transport Model/National Trip End Model

8.10 The NTM has previously been used for scenario modelling. For example, a number of alternative scenarios were reported as part of the DfT's 2018 Road Traffic Forecasts. In principle, NTM could be used to assess the potential impacts of the NIC's scenarios. However, NTM is most suited to looking at impacts on the road network. Impacts on rail demand may be better examined using DfT's rail forecasting models.

8.11 In principle, there is no reason why the journey purpose trip rates and future distributions of population and employment within NTEM could not be altered to capture the potential impacts of the NIC's scenarios on future trip making. The outputs of the adjusted NTEM could then be passed onto NTM, or alternatively used as inputs to other TAG-consistent models (such as the other models reviewed as part of this study).

8.12 Within the NTEM/NTM suite the following could be altered to model the NIC's scenarios:

- The segmented population and employment on different zones – this could be altering the split between different scenarios as well as the total population and employment in different zones.
- The production and attraction trip rates, for example, to represent a greater share of people working from home or lower retail activity.
- Coefficients in the road/public transport utilities, to represent changing preferences for one mode over another.

8.13 For each scenario, NTM would produce projections of road traffic by road type, time period and geographic area, along with projections of congestion and emissions.

8.14 Scenario testing within NTM/NTEM would be a significant undertaking and would require substantial effort to set up the models, run them and then verify the results. Any use of NTM/NTEM would require the proactive engagement of the DfT.

South East Economy and Land Use Model (SEELUM)

8.15 SEELUM is a simulation of how transport, population, land use and infrastructure interact together over long periods of time. Due to its iterative timestep nature and the changing dynamics, the model is appropriate for use when attempting to understand the implications of different post-pandemic scenarios.

8.16 The model generates a set of outputs allowing detailed examination of how and why conditions change in the simulated area. Detailed reports are available on:

- Travel patterns, volumes and mode shares;
- Changes in land-use in each zone (i.e. the number of housing units and number of employment premises (business space));
- Changes in households, population and the workforce in each zone;
- Changes in employment (jobs filled) in each zone and the unemployment rates;
- Changes on CO_2 emissions from transport activity; and
- Time savings benefits for appraisal, and the wider economic impacts on productivity and agglomeration.

8.17 Key high-level metrics usually reported on when comparing scenarios include:

- Travel patterns, volumes and mode shares;
- Jobs filled;
- Population; and
- Gross Value Added (GVA)

8.18 Within SEELUM the following have been identified as areas where adjustments could be made and/or further developed to assist in the modelling of the five NIC scenarios:

- Percentage of staff that can/would be expected to work from home
- The employment catchment area applied to businesses
- The capacity on transport systems
- The capacity on business space use
- Adjustments to retail expenditure habits
- Adjustments to office property values

8.19 Development of each of these would require interpretation of the NIC's scenarios and the development of a more spatially disaggregated assessment of what these may mean for the future (limits on the) location of population and employment.

8.20 As SEELUM takes the consequences of the virus, such as social wariness, as inputs and then demonstrates the effects of these, the changes illustrated by the model outputs will be a result of the assumed inputs used. The availability and appropriateness of data to infer the required input adjustments is a potential limitation on the usefulness of the model.

8.21 In summary, SEELUM is a potentially useful tool to assess the impacts of NIC's scenarios at a regional scale. For example, given SEELUM's geographic focus it may be particularly helpful to consider the impacts of greater homeworking supporting and facilitating migration of parts of the population from London.

London Land-use and Transport Interaction Model (LonLUTI)

8.22 The purpose of LonLUTI is to assess the land-use impact of transport schemes and provide analysis of the demographic, economic and transport outcomes of land-use proposals. The term 'land-use' in this context refers mainly to activities that use space and in particular, where people live and work. LonLUTI covers London as well as the East of England and the South East.

8.23 LonLUTI has four component models. It utilises a transport model and it has a model of the economy, an urban model that considers land use and a migration model, that considers movement of population.

8.24 Inputs to the model that could be adjusted to reflect different futures include:

- Overall growth in output/productivity;
- Supply of existing floorspace;
- Land available for (re)development for different property types by zone;
- Coefficients that represent the attractiveness of different areas for different activities by different segments of the population (e.g. the attractiveness of a zone as a residential or employment location);
- Coefficients that represent the attractiveness of a zone as a place for businesses to locate;
- Coefficients that represent how the local economy functions; and
- Via the transport model and by adjusting parameters in the equations that calculate modal utility, the relative attractiveness of different modes.

8.25 Outputs include total population and the number of households, children, resident workers, non-working adults, retired people and jobs. The model can also produce more detailed outputs by zone and individual activity, for example, number of jobs or households by a particular type of land-use. Total floorspace by land-use type in each zone and for each year can also be extracted, as well as greenfield and brownfield development floorspace, floorspace rent, permissible development floorspace, occupied and vacant floorspace, occupied floorspace density, quality of floorspace, and floorspace redevelopments and intensifications.

8.26 In principle, LonLUTI offer the functionality to explore the transport and land use impacts of the full range of the NIC's scenarios. The model is highly segmented socio-economically and so offers the potential to consider the impacts of different segments of the population responding in different ways to post-pandemic stimuli and having different behavioural responses. As a LUTI model, it also allows feedbacks to be considered. For example, a migration of those socio-economic groups who can work from home from (say) inner London to outer London would in the model lead to a drop in the relative house prices in the areas where people have migrated from, which in turn would make these areas more attractive to different segments of the population.

8.27 LonLUTI is, however, complex and undertaking a programme of work would be a major undertaking requiring specialist resources.

Model of Travel in London (MoTiON)

8.28 Model of Travel in London (MoTiON) is a multi-modal strategic transport model of London and the surrounding area. It is an improved version of LTS (the longstanding demand model for London), with additional functionality and more detail. MoTiON can model how many trips there are likely to be, their origins and destinations and their modes of transport. It imitates the impact of changing demographics in potential future scenarios, for example helping TfL plan for an ageing population, or to reflect the positive impact of urban regeneration.

8.29 Parameters for input into MoTiON include

- Land use – households, employment, retail floor space, numbers of education places, etc;
- Population information – age, gender, work status, income, car ownership;
- Transport networks - highway, public transport and cycling;
- Behavioural parameters – mode preferences, propensity to travel, etc;
- Parking information; and
- Calibrated 2016 base year matrices – developed from data sources including household surveys, mobile phone data, Oyster Card data, traffic and passenger counts.

8.30 Inputs to MoTiON can be updated to reflect the NIC scenarios. Inputs to the model that could be adjusted to reflect different futures include:

- Population and employment assumptions by area;
- Land use assumptions by area;
- Economic growth;
- Trip rates by journey purpose;
- Assumptions on average trip distance/ time travelled;
- Modal preferences;
- Car ownership; and
- Adjustments to the network assumptions such as reduced highway capacity to reflect improved pedestrian or cycling facilities, or a reduction in PT capacity or service levels.

8.31 Outputs would include:

- Number of trips by journey purpose;
- Number of trips by mode;
- Change in trips by time period;
- Distribution of trips across the model area to show changes in trip generation and attraction;
- Change in journey distance and time travelled; and
- Assignment models would show the change in network usage by scenario and the impact on network conditions (e.g. delays or crowding).

8.32 Detailed analysis on the impacts of the assumptions on different population demographics such as students, gender, blue or white collar and low or high income can also be carried out.

8.33 MoTiON has already been used by TfL to look at post-pandemic travel scenarios. In principle, the detailed segmentation of demographics, journey purposes and modal detail means that

MoTiON could be used to test the NIC's scenarios. However, the model is highly complex with numerous interactions between different elements of the model, so it may be challenging to interpret the results, or in scenario testing to 'fix' elements of the model to represent particular characteristics of a scenario. Changes in demographics and land uses (e.g. as part of the Dispersal from Cities meta-trend) are an input to the model and are not forecast as part of the model run. Model run times are long and this places a practical constraint on the number of tests that can be done as part of any programme and severely constrains a 'trial and error' approach to incorporating alternative scenarios in the model.

Birmingham City Model (BCM)

8.34 The BCM model is used to plan for future growth in Birmingham by forecasting how it will affect the highway network and to test highway interventions. Background traffic growth is sourced from the Transport for the West Midlands (TfWM) regional transport model, which allows BCM to be consistent with other transport and land use planning in the region.

8.35 The BCM model comprises a highway network model in the SATURN software that covers the whole of the City of Birmingham with detailed junction coding. There is a small buffer area in the Wider West Midlands to include the Motorway Box. Model coverage has recently been extended as part of the Commonwealth Games and HS2 construction study.

8.36 The SATURN model is linked to a Variable Demand Model (VDM) in the CUBE software. The VDM includes frequency choice for purposes of Home Based (HB) Employers Business, HB Commute and Non Home Based (NHB) Employers Business, and NHB Other, and a Destination Choice model.

8.37 Initial highway traffic growth is sourced from the Transport for the West Midlands (TfWM) PRISM model, which is a full demand model for the West Midlands that includes:

- DfT assumptions on demographic and employment changes (from TEMPRO, which in turn are derived from NTEM);
- West Midlands Combined Authority (WMCA) assumptions on where new development will be located.;
- A demand model incorporating trip frequency, mode shift and distribution; and
- A highway and public transport network model to feed the choice models.

8.38 The calibrated base year BCM SATURN matrices are updated based on PRISM growth to ensure that the trip patterns calibrated through matrix estimation on traffic counts are carried forward into the forecasts.

8.39 Future year runs are created by updating the base year highway network with committed network changes and run with the demand growth sources from PRISM. A 'Do Something' is then created with updated network assumptions as an input to the demand model. The costs from these runs are used as the input to the demand model.

8.40 The model outputs are focused on changes in the highway network model:

- Changes in link flows, congestion hotspots, etc;
- Overall change in distance and time travelled;
- Change in demand by traffic zone, between sectors; and
- Demand can also be interrogated to include changes by trip purpose.

8.41 The BCM is a potentially useful tool to assess the impacts of NIC's scenarios on the city's highway network and what this may mean in terms of congestion and air quality. However, the demand model cannot be used directly to forecast the impacts of the scenarios and work outside the model would be needed to derive changes to the demand matrices that represent the scenarios.

Summary

8.42 Informed by a review of a representative set of transport models it is clear that such models could be used to explore in more detail the potential transport implications of the NIC's scenarios. However, what is also clear from the review is that while it is possible to establish a set of general principles that can be used to reflect the NIC's scenarios, it is not possible to pre-define a set of changes to model inputs or model parameters. These would need to be derived on a case-by-case basis, taking into account the particulars of model structure, as well as how they have been developed and calibrated.

9 Concluding Remarks

Introduction

9.1 A principal purpose of the work described in this report has been to gain an understanding of the order of magnitude of the effects that different scenarios of behaviour change may have on the demand for different types of infrastructure in different sectors of the economy.

9.2 To help with the consideration of the outputs of our work we first set out a number of interpretive considerations and then comment on the results of the analysis.

Interpretive Considerations

9.3 The approach to projecting the impact of the NIC's behavioural change scenarios on the demand for different types of infrastructure has been to apply a rate of use to an independent variable. For example, projections of future travel have been derived by multiplying future population by a rate of per capita travel, all suitably segmented. This approach has a number of clear benefits that make it well suited to exploring the potential impacts of future scenarios: it can be applied quickly, and it is transparent. However, it also has a number of limitations and these need to be borne in mind when both considering the results of the work and thinking about subsequent analysis.

9.4 It should be noted that, with the exception of alterations made to capture the potential impacts of the NIC's scenarios, the rates used in the models are assumed to be constant over time. They do not attempt to model changes arising from other external drivers, such as wider macro-economic influences. This is deliberate as this enables the analysis to focus on behavioural changes that underpin the NIC's scenarios. It is likely that, in reality, consumption rates would be affected by other factors, including inter-related influences such as economic growth leading to greater disposable household income, societal changes (e.g. make-up of households) and technological developments. However, these impacts are not included in the models used for this study.

9.5 In the transport sector, findings from the National Travel Survey are that, between 2002 and 2019, there has been a gradual decline in the number of trips made per head and the average distance travelled per year, although average trip length has increased slightly. Commuting trips per head in 2019 were 15% lower than in 2002 and business trips were 20% lower. It is not just commuting and business trips that have been affected. Per head, shopping is the trip purpose that accounts for the largest number of average trips and these trips fell by 20% over the same period. Trips for other purposes fell too.

9.6 Potential reasons for these falls include, but are not limited to:

- More people working part time;
- Greater ability to work flexibly, including working from home and self-employment;
- Growth in trip-chaining and more people not having a fixed place of work; and
- The rise of e-commerce and internet shopping.

9.7 This said, analysis of trip rates by mode and distance band has suggested that changes in walking trips and short trips have made a significant contribution to the overall observed trends in trip rates:[19]

- For commuting trips per person, only those less than five miles have declined in number, whilst there has been no change in longer commuting trips;
- For shopping trips per person, declines have been most consistent in short trips of a mile or less; and
- For trips visiting friends and family, all distance bands show a similar decreasing trend, although there has been a shift towards longer (> 5 miles) trips.

9.8 As well as the reasons set out in Paragraph 9.6, a potential (partial) explanation is a rise in under-reporting of trips and especially short trips within the National Travel Survey.

9.9 As well as the pre-pandemic trends of changing working practices and a greater take-up of e-commerce, there are other uncertainties about the future of transport which existed pre-pandemic and will continue to be a factor post-pandemic. Many of these uncertainties were identified when the NIC undertook the first National Infrastructure Assessment (NIA) (see Appendix G) and include:

- Changing travel habits amongst the younger cohorts in society with lower than historically observed car ownership and driving licence holding, potentially driven by attitudinal changes as well as cost.[20]
- De-carbonisation of the private vehicle fleet and in particular what this may mean for the cost of travel by road, for example whether the drop in fuel duty revenue that this will lead to will be offset by new per mile charges.
- The potential impact of Connected and Autonomous Vehicles (CAVs).

9.10 Looking at other sectors, the greatest uncertainty is in the digital sector. As set out in detail in Appendix C, over the last five years digital data use as defined by this study was growing at 35% per annum. Strong growth in digital demand is expected to continue, at least in the medium term, although it is also expected that the high annual percentage growth rates will tend to reduce gradually over time. Modest differences in short term growth rates could lead to quite different levels of future demand.

9.11 There are uncertainties with other sectors too. For example:

- For Energy, changes to the scale and pattern of domestic consumption due to de-carbonisation, for example, the take-up of micro-generation (e.g. domestic solar panels), use of heat pumps, conversion of natural gas to hydrogen, and home storage. Widespread take-up of electric vehicles would increase demand and change the profile of electricity demand within the day.
- For Water, the impacts of climate change on both storage (reservoirs) and extraction (ground water) plus the changing balance of fiscal incentives to address network leakage.

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[19] See Para 2.2.1.1 Atkins *et al.* (2017) *Provision of Travel Trends Analysis and Forecasting Model Research - Analysis and Developer Report.* Report to Department for Transport

[20] Chatterjee, K., Goodwin, P., Schwanen, T., Clark, B., Jain, J., Melia, S., Middleton, J., Plyushteva, A., Ricci, M., Santos, G. and Stokes, G. (2018). *Young People's Travel – What's Changed and Why? Review and Analysis.* Report to Department for Transport. UWE Bristol, UK.

- For Waste, increases to the penetration rate of recycling which requires both local authorities to extend the range of recyclable materials that they will collect, as well as further shift of packaging towards recyclable material.

9.12 A further consideration is that the adopted approach does not consider the effect of the positive and negative feedbacks that are inherent within the economy. Take, for instance, the Dispersal from Cities meta-trend. Should there be an increase in suburbanisation and/or regionalisation this should be expected to have price effects. Property prices in areas where people move from should be expected to fall (at least in relative terms). This will make the areas where people move from more attractive to segments of the population who would otherwise by unable to afford to move there. Prices in the destination areas would increase, which in turn would reduce their attraction.

Commentary of Findings

Transport

9.13 Our analysis suggests that the most significant post-pandemic behavioural response is the number of people who chose to undertake activities at home, be this work or other activities such as shopping (online rather than at shops) or social activities (e.g. virtual rather than face-to-face). The Working from Home and Use of Virtual Tools rather than Dispersal from the Cities are potentially the more significant simply because of the scale of the population that they apply to.

9.14 The Working from Home meta-trend materially changes the number of people who choose to work from home, whether that be permanently or on a more flexible basis (i.e. some of the time). For the purposes of this work, we have defined Standard Occupational Classification (SOC) Groups 1 to 4 as those who have the potential to work from home. Together these SOC Groups account for 57% of the working population, which is 18.5 million people. Our high impact assumption for the Working from Home meta-trend implies that 32% of these four SOC Groups would work from home some or all of the time leading to a 7% reduction in commuting trips in Scenario 5. This will affect all modes of transport, but it is important to note that those in SOC Groups 1 to 4 are those with the highest propensity to use rail, both for commuting and other journeys. Given the nature of the jobs that people who can work from home have, it is reasonable to assume that the propensity to use rail is even higher amongst the sub-group of SOC Groups 1 to 4 who can work from home.

9.15 The Use of Virtual Tools meta-trend affects the entire population. Our high impact assumption is that the rate of trip making for other purposes – shopping, leisure, education – could reduce to 80% of its pre-pandemic levels. Per head, many more trips are made for these purposes than for commuting which means that the Use of Virtual Tools meta-trend has the potential to be the biggest single impact on the overall volume of travel.

9.16 The Social Wariness effect is also significant. Our high impact assumption is that this will reduce public transport demand by 15%. To put this figure in context, such a decline would set rail demand back from its pre-pandemic levels to those seen in 2012/13. For bus, which pre-pandemic was already experiencing a reduction in demand, such a further reduction would be equivalent to about ten years of trend decline. There would also be impacts on London Underground and metro and light rail services elsewhere. As well as affecting the strategic and economic case for future public transport capital investment, such a decline would have immediate impact on the finances of public transport. Should this lead to a service reduction this would make public transport less attractive, which in turn would have a further downward impact on patronage.

9.17 In contrast, the Dispersal from Cities meta-trend has a lesser impact. This is because the number of people who could feasibly move to the suburbs (‘surburbanisation’) or move out of towns and cities (‘regionalisation’) is small compared with the population who would potentially be affected by the Working for Home and Use of Virtual Tools meta-trends. Even if the people who do move then have a significant change of travel behaviour, the scale of the population affected is such that the effect is not as great as those that could arise from the Working for Home and Use of Virtual Tools meta-trends.

Digital

9.18 The defining feature of the digital sector is the rate of change of both network capacity and its use that has occurred in recent years. The projected future rate of change is such that there is no merit in looking at demand beyond 2025 as beyond this even modest upward or downward change to annual growth rates will lead to very different outcomes.

9.19 Pre-pandemic, the peaks in digital demand were leisure driven and occurred in the evenings and at weekends. While digital demand increased during the pandemic, available data suggests that the increase in weekday daytime demand did not exceed pre-pandemic evening use. Also, throughout the pandemic the digital networks have had sufficient capacity and capability to cater for the increase in leisure-driven digital demand.

9.20 Digital capacity is provided in a dynamic and commercial market. Looking to 2025, the conclusion of this work is that any behaviourally driven changes of demand can be accommodated by the commercial providers. Before and after that the commercial providers will both respond to market pressures and create digital markets through the products they offer.

9.21 Pre-pandemic, the challenge for digital was extending the high capacity network to ‘hard to reach’ places. This remains the case post-pandemic. If anything, should the NIC scenarios lead to an increase in digital demand this could shift the balance towards further commercially-driven roll out of enhanced network capacity across the country.

Other Sectors

9.22 We have found that the most significant influence on modelled future demand for the other sectors in the scope of this study (Energy, Water & Wastewater and Waste) is how much time people spend at home doing activities that pre-pandemic would have been done elsewhere. Working from Home and Use of Virtual Tools both suggest that more time will be spent at home and this leads to greater domestic energy and water use and, potentially, greater domestic waste, for example due to more packaging from internet shopping deliveries. To a degree there would be a concomitant reduction in commercial consumption. However, it would not be a one-to-one reduction – a shop doesn’t use less energy because it has lower footfall. Structural adjustments would be needed to realise material reductions in commercial consumption, e.g. smaller shops and/or fewer shops.

9.23 Dispersal from the Cities would change where individual households use energy and water and generate waste, but the scale of the population who might be part of this meta-trend is small. In contrast, the Working from Home and Use of Virtual Tools have the potential to affect a much larger share of the population. On top of this, without a shift in land-use policy those who move as part of a Dispersal from the Cities meta-trend will move to extant properties or new properties that would be built in any event. While the movers may consume more per household, this will be a marginal increase on the previous occupants of the property.

9.24 Finally, as described in Paragraph 9.11 each of these other sectors faces uncertainties which have the potential to have a greater impact than behavioural impacts of the NIC's scenarios.

Appendices

A Personal Travel

Introduction

A.1 This Appendix gives an overview of personal trip making and travel by different modes of transport. It also gives an overview of the historical trends of use of different modes over the last decade. The Appendix considers what are the determinants of future transport demand and an overview of pre-pandemic forecasts. The Appendix closes with an overview about how travel demand has been affected by restrictions introduced in response to the pandemic.

Transport Demand Metrics

A.2 There are two broad measures of transport demand. These are:

- Number of trips made, a simple summation of the number of trips made over a defined period. Conventionally, a trip is a journey made for a particular purpose such as travel to work. A multi-stage trip – for example, walking to the bus stop, catching a bus to a railway station, catching a train and then walking from the destination station is a single trip made up of multiple stages.
- Travel, which is the combination of number of trips (stages) and the trip (stage) distance. Travel is measured in units such as passenger-kilometres or vehicle-kilometres.

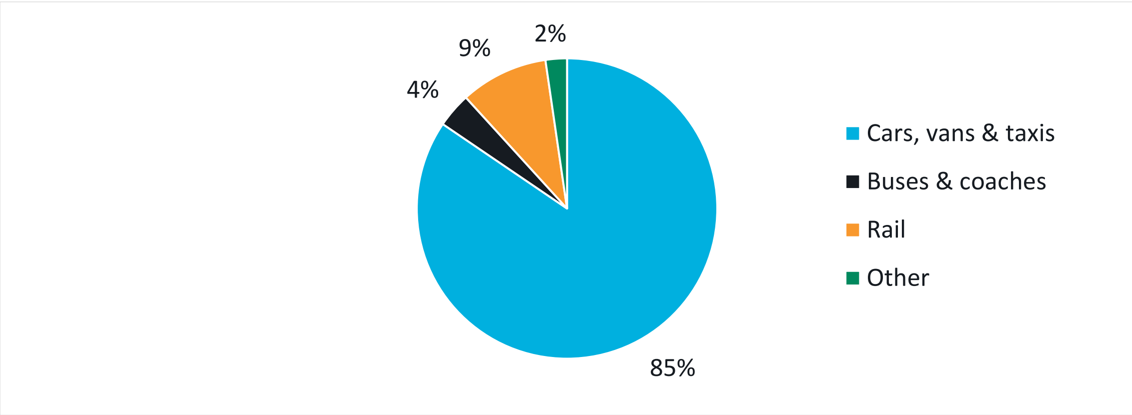
A.3 Data on the use of roads and public transport are collected in different ways. The use of roads is measured using travel data, that is vehicle-kilometres rather than trips. Data on public transport usage uses both measures of trips (stages) and travel.

A.4 The National Travel Survey is a sample surveys that collects data on respondents' trip making and travel, as well as their socio-economic characteristics. It offers a single source of data that treats all modes in a comparable and consistent way, but it only covers England.

Historical Trends in Transport Demand

A.5 As shown in Figure A.1, in 2019, 85% of passenger kilometres travelled in Great Britain were by cars, vans or taxis. In comparison, 9% of trips were by rail (including light rail and tram), 4% by bus and 2% by other modes.

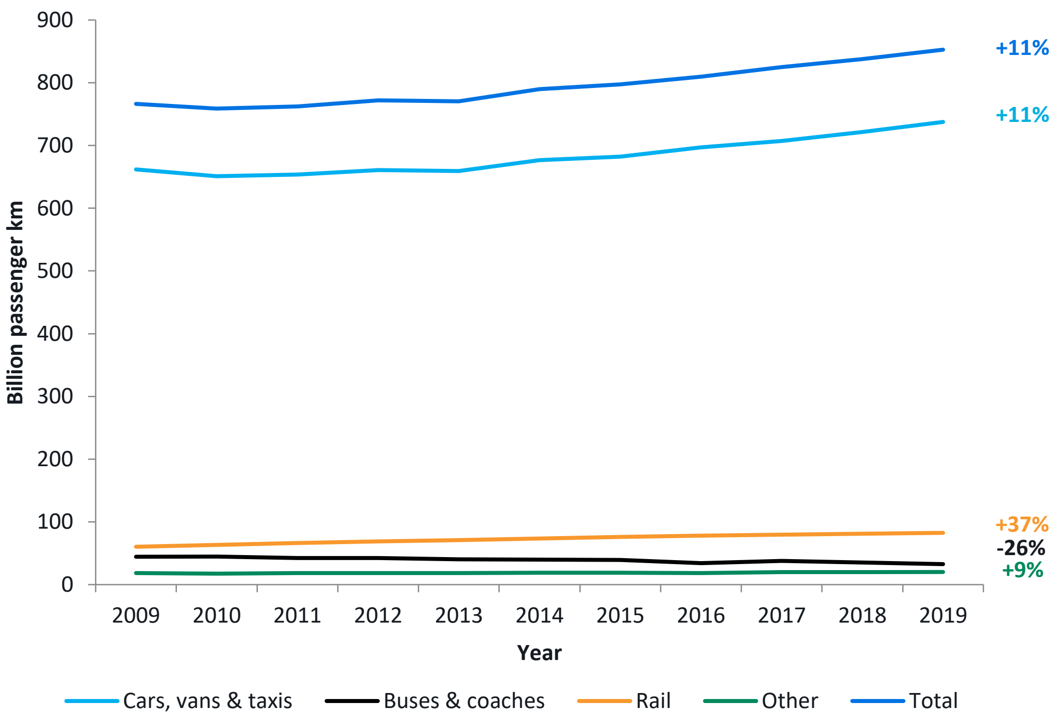
Figure A.1: Modal share by mode, based on passenger kilometres travelled, Great Britain, 2019



Source: DfT TSGB0101 (2019)

A.6 The aggregate amount of travel by all modes has continued to increase in recent years. Figure A.2 shows that the overall passenger kilometres travelled in 2019 were up 11% from 2009. Car and rail travel has increased in this time, while bus travel has reduced. Travel by other modes (which includes London Underground and local tram networks) has also increased.

Figure A.2: Change in passenger kilometres by mode, Great Britain, 2009-2019

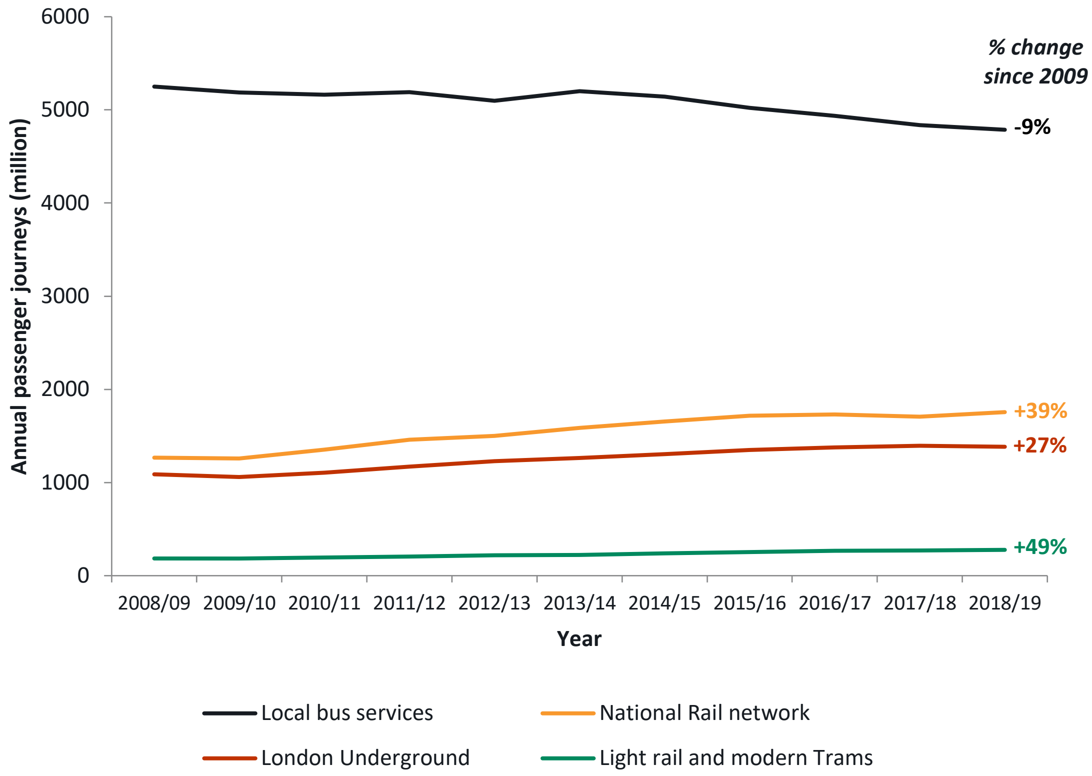


Source: DfT TSGB0101 (2019)

Public Transport Trends in Great Britain from 2009-2019

A.7 Figure A.3 illustrates public transport patronage by considering the number of passenger journeys. Local bus ridership fell by 9% in the past decade, a continuation of a historical downward trend. In contrast, the number of journeys by rail experienced growth in the past decade; with National Rail journeys increasing by 39%, London Underground journeys increasing by 27% and light rail/tram trips increasing by 49%.

Figure A.3: Public Transport journeys made in Great Britain, 2009-2019

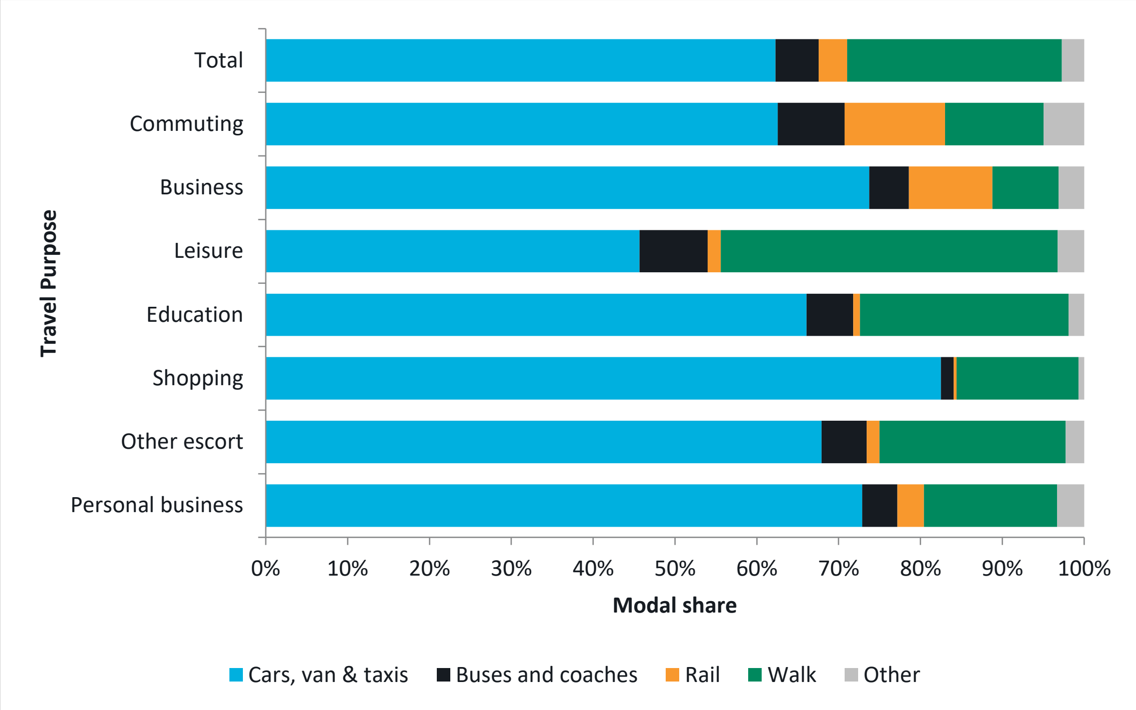


Source: DfT TSGB0102 (2019)

Purpose of Travel

A.8 Figure A.4 shows the modal shares based on the number of trips by the average person, broken down by purpose of travel, across Great Britain in 2019. As can be seen from the figure, car accounts for the majority of trips. Rail share is largest for commuting trips and while not evident from the chart, the bulk of rail commuting trips are made in London and the South East.

Figure A.4: Modal shares based on number of trips by the average person, by purpose of travel, Great Britain, 2019



Source: DfT NTS0409 (2019)

A.9 Figure A.5 compares the modal share by travel purpose in 2019 (Figure A.4) with the modal share by travel purpose in 2009, illustrating any shifts in modal share in the past decade. Rail's share of commuting trips has increased by 43% in the past decade and rail's share of business trips has increased by 21%.

Figure A.5: Matrix showing the change in modal share by travel purpose between 2009 and 2019

Journey Purpose	Cars, van & taxis	Bus and coach	Rail	Total
Personal business	-4%	-25%	14%	-7%
Other escort	-12%	-37%	-6%	-17%
Shopping	-11%	-41%	-39%	-10%
Education	-3%	-45%	-18%	-8%
Leisure	24%	-2%	-15%	11%
Business	-12%	1%	21%	-8%
Commuting	-11%	-9%	43%	-5%
Total	-5%	-25%	21%	-4%

Source: DfT NTS0409 (2019)

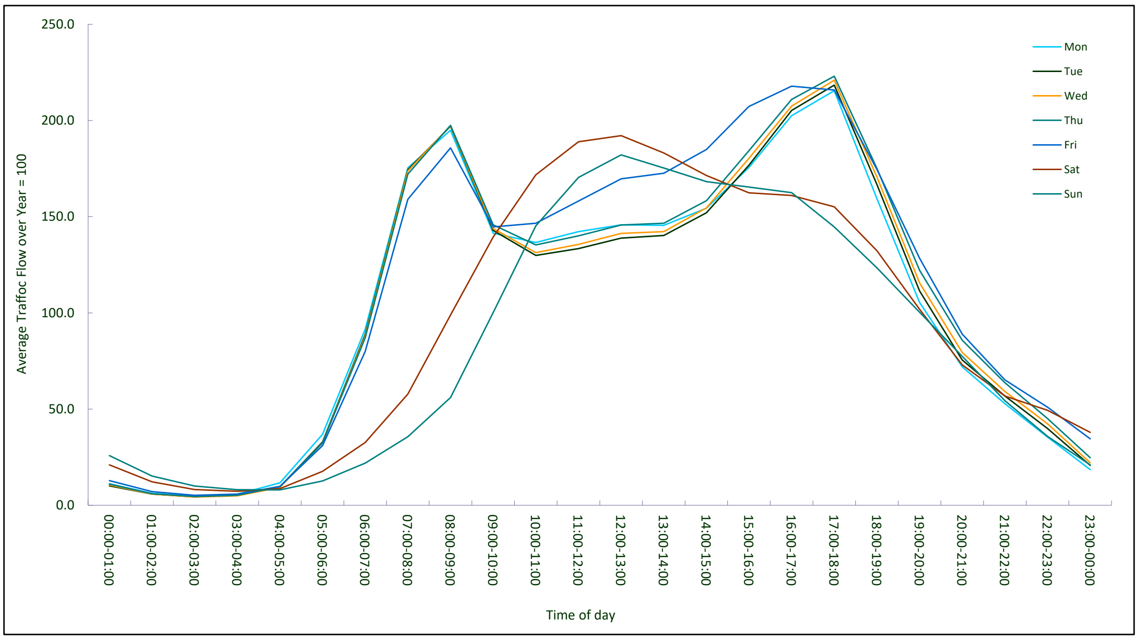
Time of Day

Road

A.10 Department for Transport data on the time of day and day of the week profile of road traffic is shown in Figure A.6. This figure is for car traffic only and excludes light vans and heavy good vehicles. It therefore represents the profile of personal travel by road. The data is shown as an index, with 100 being the average hourly traffic flow.

A.11 The figure clearly shows the morning and evening peaks that are the feature of Monday to Thursday travel, the extended Friday evening peak and the weekend profile where peak traffic occurs in the middle of the day.

Figure A.6: Traffic distribution on all roads by time of day and day of the week (2019)



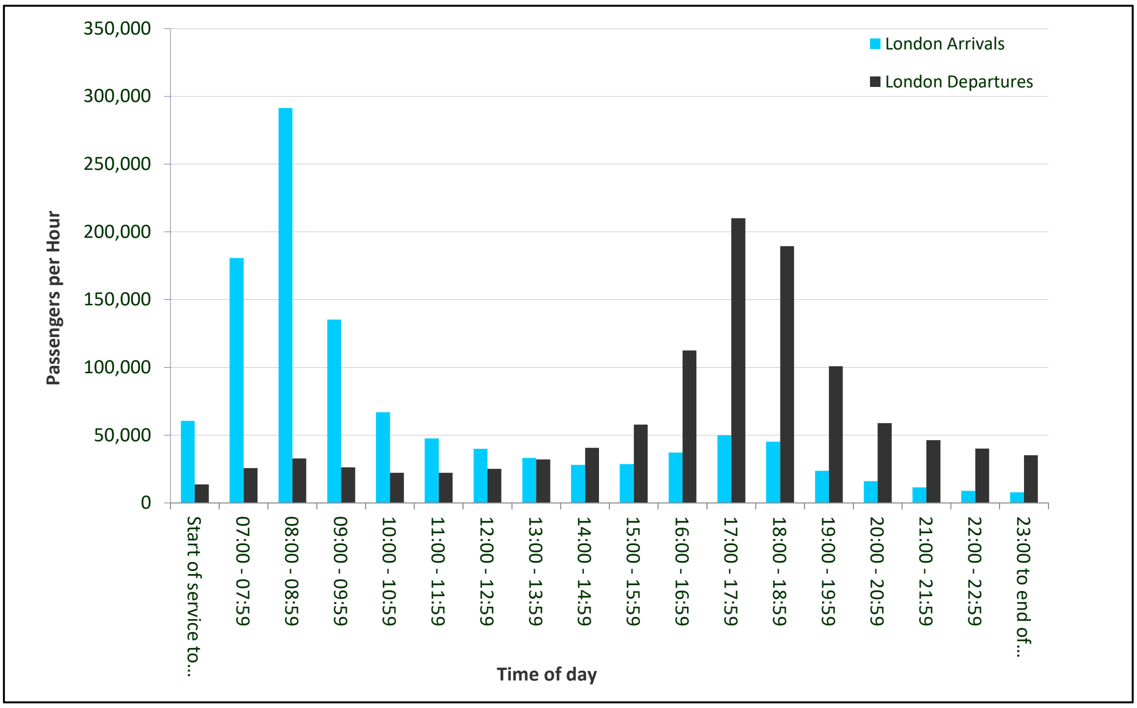
Source: DfT TRA0308 (2019)

Rail

A.12 There is also Department for Transport data that illustrates the profile of rail demand. This data shows hourly arrivals and departures from principal stations in 14 cities in England and Wales.[21] The data for London is illustrated in Figure A.7. and for the other 13 cities combined in Figure A.8. The two graphs have the same scale and what the data shows is that rail demand to and from the London terminal stations is much greater than the combined rail demand from the other 13 cities in the data set. The demand profile for the London stations is also more peaked and this is shown by Figure A.9. This reflects that relative importance of commuting and business travel to the London market.

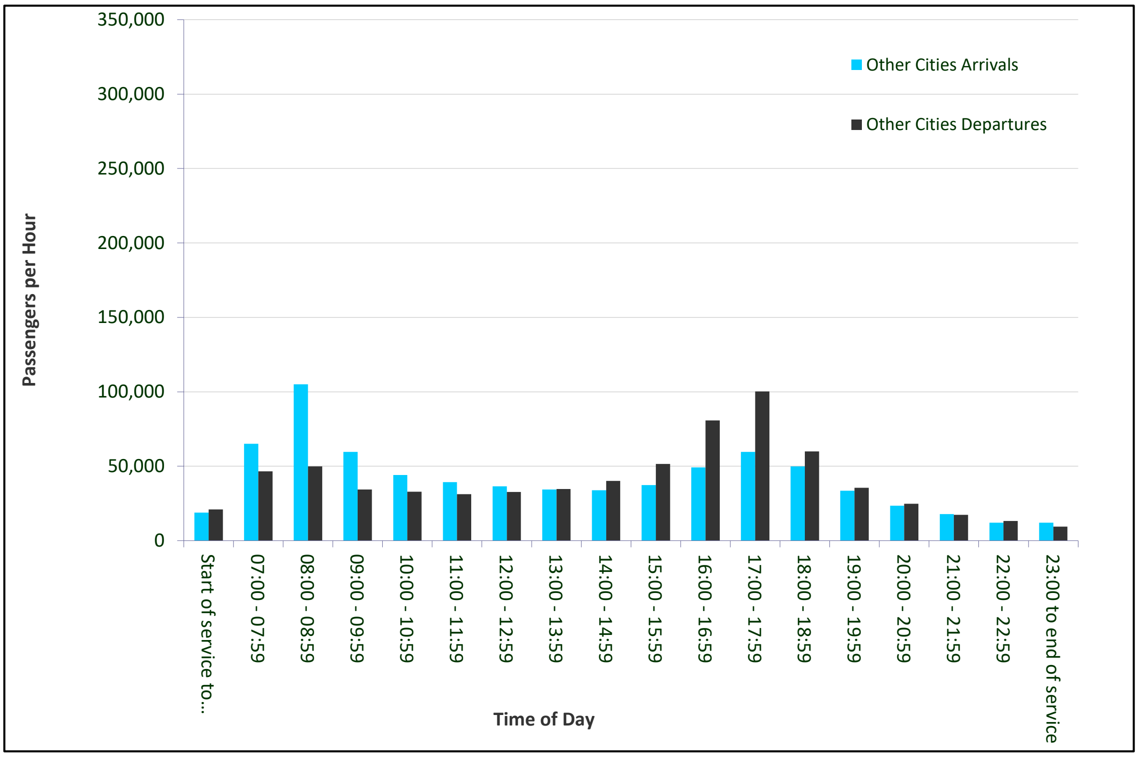
[21] These are: Birmingham, Brighton, Bristol, Cambridge, Cardiff, Leeds, Leicester, Liverpool, London, Manchester, Newcastle, Nottingham, Reading and Sheffield.

Figure A.7: London Arrivals and Departures by Rail on a Typical Autumn Weekday (2019)



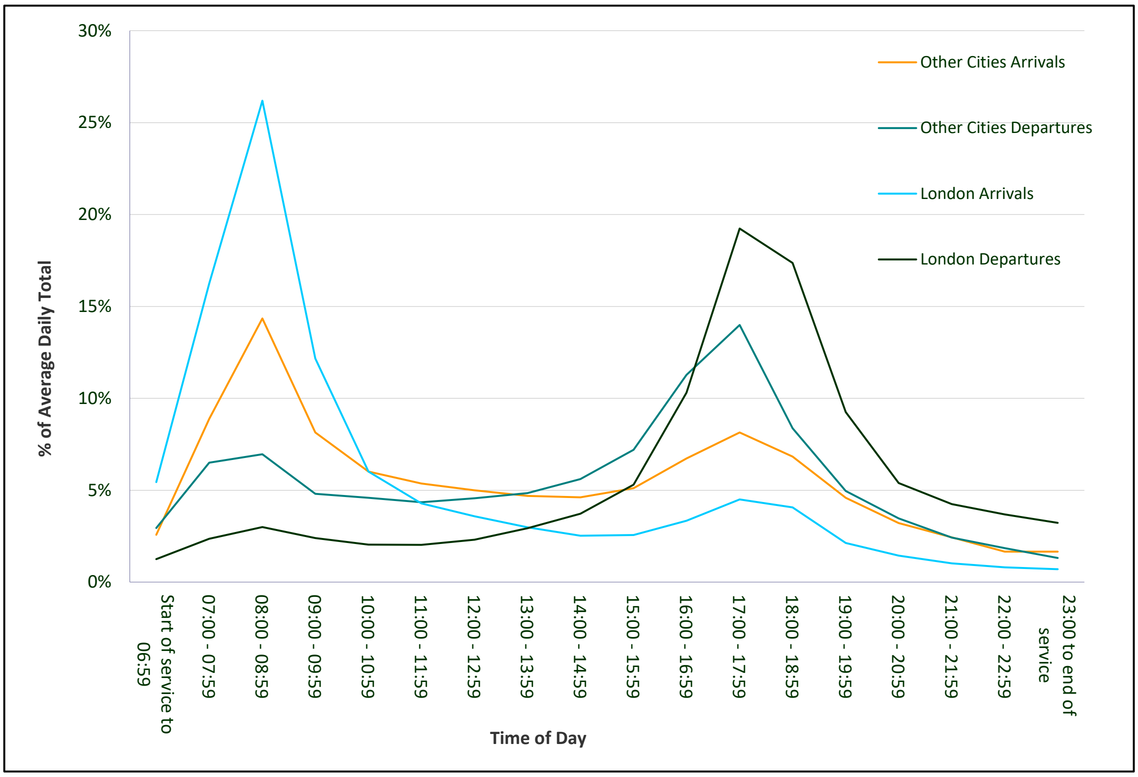
Source: DfT RAI0202 (2019)

Figure A.8: Other City Centre Arrivals and Departures by Rail on a Typical Autumn Weekday (2019)



Source: DfT RAI0202 (2019)

Figure A.9: Profile of City Centre Arrivals and Departures by Rail on a Typical Autumn Weekday (2019)

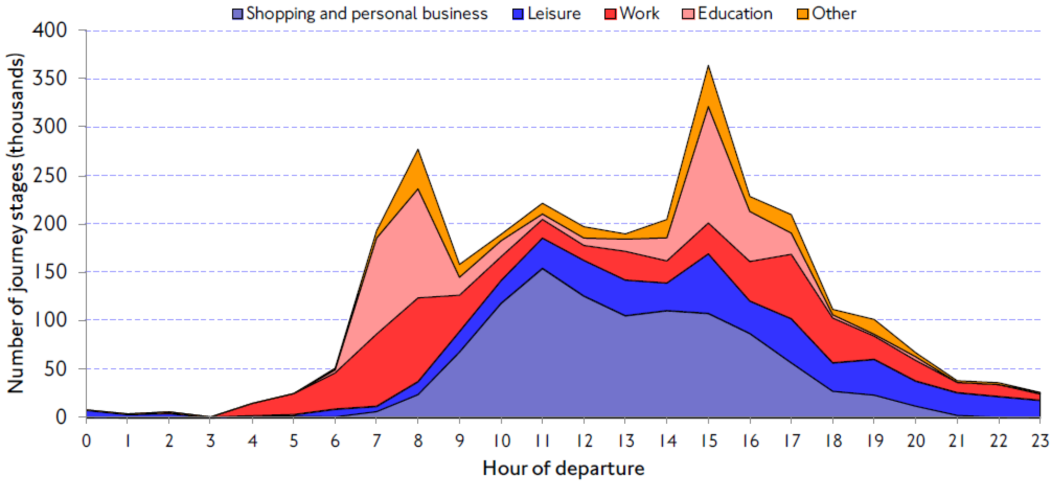


Source: DfT RAI0202 (2019)

Bus

A.13 There is no single source of data that shows the time profile of bus use across the country. The graph below (Figure A.10) is reproduced from TfL analysis and as well as showing the time profile of bus use show the purposes why people are travelling. What this shows is that the busiest period is in the afternoon coinciding with the end of the school day and the start of the return journey home for '9 to 5' commuters as well as substantial numbers of trips being made for shopping and leisure purposes. In contrast the morning peak is dominated by commuting and education trips.

Figure A.10: London Residents' Weekday Bus Trips by Purpose and Hour of Departure



Source: TfL (2013) *Roads Task Force - Technical Note 7 What are the Trends and Patterns of Bus and Coach Traffic in London?*

A.14 The profile of trip making will vary from city to city but the overall pattern seen in London is considered typical of that elsewhere. Also while communing is an important source of bus demand, bus is also well used for education trips and for other purposes. Again, this pattern is considered typical of bus travel across the country.

Factors Driving Transport Demand and pre-Pandemic Forecasts

A.15 There is an extensive literature that sets out factors that determine transport demand so what follows here can only be a high-level summary:

- Population and employment: all other things being equal a growing population and growing numbers in employment will lead to an increase in transport demand, partly through greater to journey to work travel and partly through more people travelling for other activities.
- Economic growth: economic growth increases per capita incomes, which in turn leads to spend on activities that lead to travel. Increases in per capita income have also supported growth in driving licence holding and car ownership, as well as making transport more affordable in real terms.
- Cost: in recent years the cost of motoring has been falling in real terms, while public transport fares have increased. However, the cost per mile of motoring is not the only factor that affects how many people use cars and how far they drive. The cost and availability of parking are important factors, especially for journeys to town and city centres.
- Public Transport Level of service: in general, rail services have improved in recent years with frequency improvements and journey time reductions. Outside London, the level of bus service provision has been in decline, although there are some notable exceptions to this. In some cities, the introduction/expansion of light rail and bus rapid transit has supported increased public transport patronage.
- Congestion: road congestion leading to extended and more unreliable journeys is a deterrent to using car. Congestion affects not just urban areas, it is also a feature of the strategic road network. On-train crowding is a deterrent to using rail.

- Location and type of employment: where jobs are located and the types of jobs influences how people travel. The growth of knowledge-intensive jobs within town and city centres has supported growth in rail demand and to an extent, rapid transit demand. These jobs are located in areas where congestion and parking cost and availability makes car travel unattractive and they are filled by people who tend to have a higher propensity to travel by rail-based modes (these two factors are clearly related). This said, growth in working from home some or all of the time, part time working and self-employment all reduce the demand for commuting and a trend to greater working from home existed pre-pandemic.
- Demographic changes: people are living longer and are economically and socially active for longer. Those who retire today have on average greater disposable incomes than those from earlier years, they are more likely to own a car and they are more likely to drive for longer before giving up their cars.
- Social trends: car ownership levels and driving licence holding among those in their twenties is falling compared with earlier generations. Reasons why this could be include cost (including insurance), changing lifestyles with a greater focus on the local and the virtual, delayed adulthood – that is people forming families and households later in life - and/or greater social and environmental awareness of the negative impacts of car travel.

Observed Impacts of the Pandemic on Transport Demand

A.16 Throughout the pandemic the Department for Transport has been publishing statistics showing the use of different transport modes. Figure A.12 shows the seven day moving average of the following modes which are of principal interest to this study:

- Car traffic on the Strategic Road Network (SRN) – this is the network owned and managed by Highways England and includes all motorways as well as some A roads
- Light Commercial Vehicle (LCV) traffic on the Strategic Road Network
- Passenger numbers on the
  - National Rail network
  - London Underground
  - Bus outside London
  - Bus within London

A.17 For the SRN the figures in the graph are compared with comparable data from the first week of February 2020 and for bus outside London the figures are compared to third week of January 2020, that is just before the pandemic. For national rail and TfL services, figures are compared to the equivalent week in 2019. This means a degree of caution needs to be applied when looking at the data. For example, weekly bus patronage in January would be expected around the average for the year, or potentially a little below average. In October, weekly bus patronage would be expected to be above the annual average. When the data says that bus use outside London in the first seven days of October was 56% of the pre-Covid levels, this means 56% of January 2020 levels, not 56% of October 2019 levels. As a percentage on October 2019 levels, this figure would be somewhat less than 56%.

A.18 The car and LCV figures are for the Strategic Road Network. Local traffic impacts are not necessarily the same as those on the SRN, which caters for a greater proportion of longer distance trips than the rest of the road network, which in turn have a lower share of commuting trips than shorter journeys. There is no single data source that shows what has happened elsewhere, but anecdotally the traffic impacts have been highly variable. During the periods of lower restriction free-standing towns and market towns have experienced relatively high traffic levels, while traffic to the centres of larger towns and cities has been much lower than normal.

A.19 Regardless of the nuances of how the data in interpreted, it is clear from the graph that the pandemic restrictions on economic and social activity have had a profound impact on transport demand.

A.20 There are two factors that have influenced use of transport:

1. For all modes, restrictions on social and economic activity. These were most severe in the first national lockdown when other than those deemed essential, all business and education premises were closed.
2. In the case of public transport, first the clear message from the Government for people to avoid using public transport unless absolutely necessary and then the introduction of social distancing requirements, which limit public transport capacity even when running at pre-pandemic service levels.

A.21 There is little data that shows how pandemic restrictions have had an impact on the time of day profile of transport demand. TfL's has covered this in some depth in its annual report on travel in London and this suggests that the impact of the restrictions has been to flatten the peaks, both for public transport and road traffic.[22] However, given the nature of the restrictions that have been in force, it is difficult to draw any lessons from this for future post-pandemic travel patterns.

A.22 As restrictions have been in place in one form or another since March 2020 what has happened to transport demand throughout the pandemic offers no guidance on what may happen in the short term once restrictions are removed. Here, the short term is considered to be the period up to 2025, that is the first year for which this study has produced scenario projections of transport demand.

A.23 Looking at countries that have be less effected by the pandemic does shed some light on potential future public transport demand, although as with all international comparisons cultural and socio-economic differences are explanatory reasons for the observed levels of public transport use. Data collated by the UITP[23] shows that:

- In Taipei (Taiwan) by the end of 2020 use of the Metro system had returned to between 90% and 100% of pre-pandemic levels.
- In Auckland (New Zealand), public patronage levels recovered to around 80% of their pre-pandemic levels and were increasing week on week before new local lockdown restrictions were imposed. The local consensus forecast was that in the absence of further local restrictions patronage would plateau at around 85% of pre-pandemic demand.
- In Oslo (Norway), by mid 2020 public transport demand had also returned to about 80% of pre-pandemic levels, again before restrictions were tightened later in the year.
- In Tokyo (Japan), by the end of 2020 public transport patronage was at around 70% of pre-pandemic levels.

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[22] TfL (2020) *Travel in London Report 13*

[23] UITP *Covid-19 Ridership Evolution*

A.24 To put these figures in context, Figure A.11 below reproduces the Coronavirius Government Response Tracker index developed by the Blavatnik School of Government at the University of Oxford. It compares the level of restrictions in each country with those in the UK. From the figure it can be seen that after the initial lockdown in Q2 2020, each country had restrictions less severe than the UK but none had returned to the pre-pandemic state (zero on the index scale).

A.25 The UITP evidence is that none of its case study cities have had public transport patronage return to pre-pandemic levels. This includes cities in China. However, at the Blavatnik index shows, nowhere has fully removed restrictions. What the evidence does show is that relaxation of restrictions can support recovery in public transport demand. Principal uncertainties in the maximum extent of this recovery are:

- Lasting economic impacts, for example an increase in unemployment reducing the number of journey to work trips;
- A lasting reluctance to use public transport due to perceived health risks;
- The degree to which new habits adopted in the pandemic become embedded (e.g. instead of travelling to city centre shops by public transport, driving to an out of town shopping centre).

Figure A.11: Government Response Stringency Index –New Zealand, Taiwan, Japan, Norway and UK

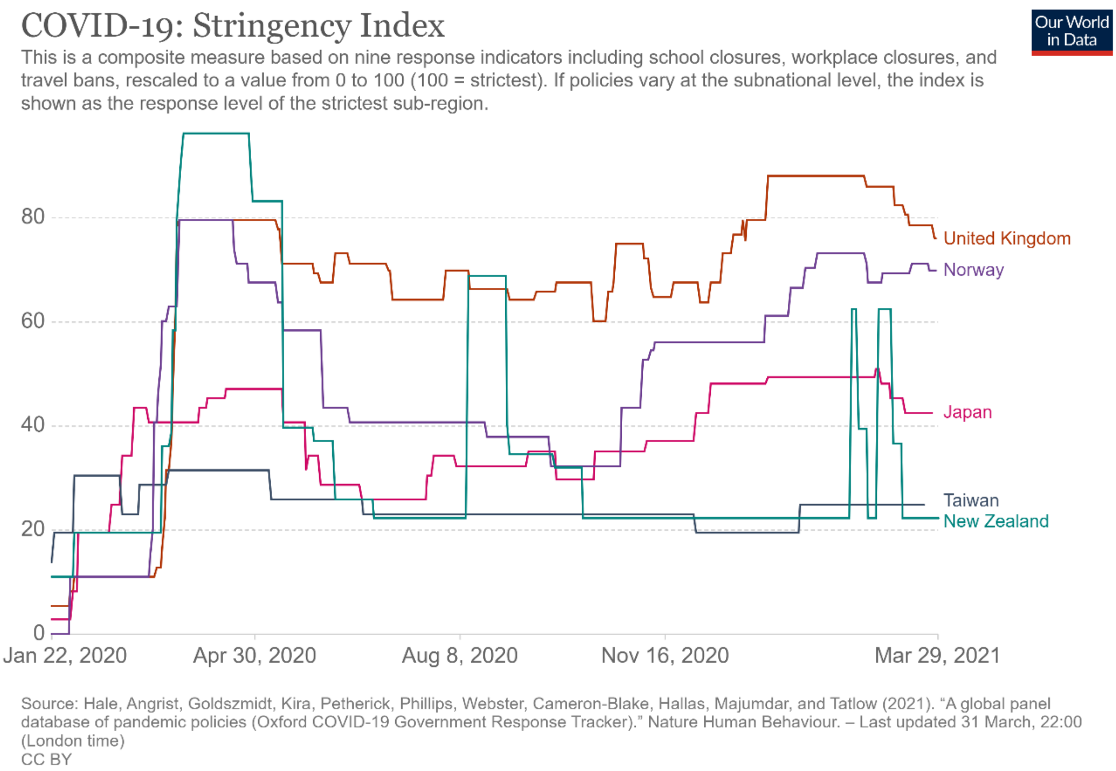
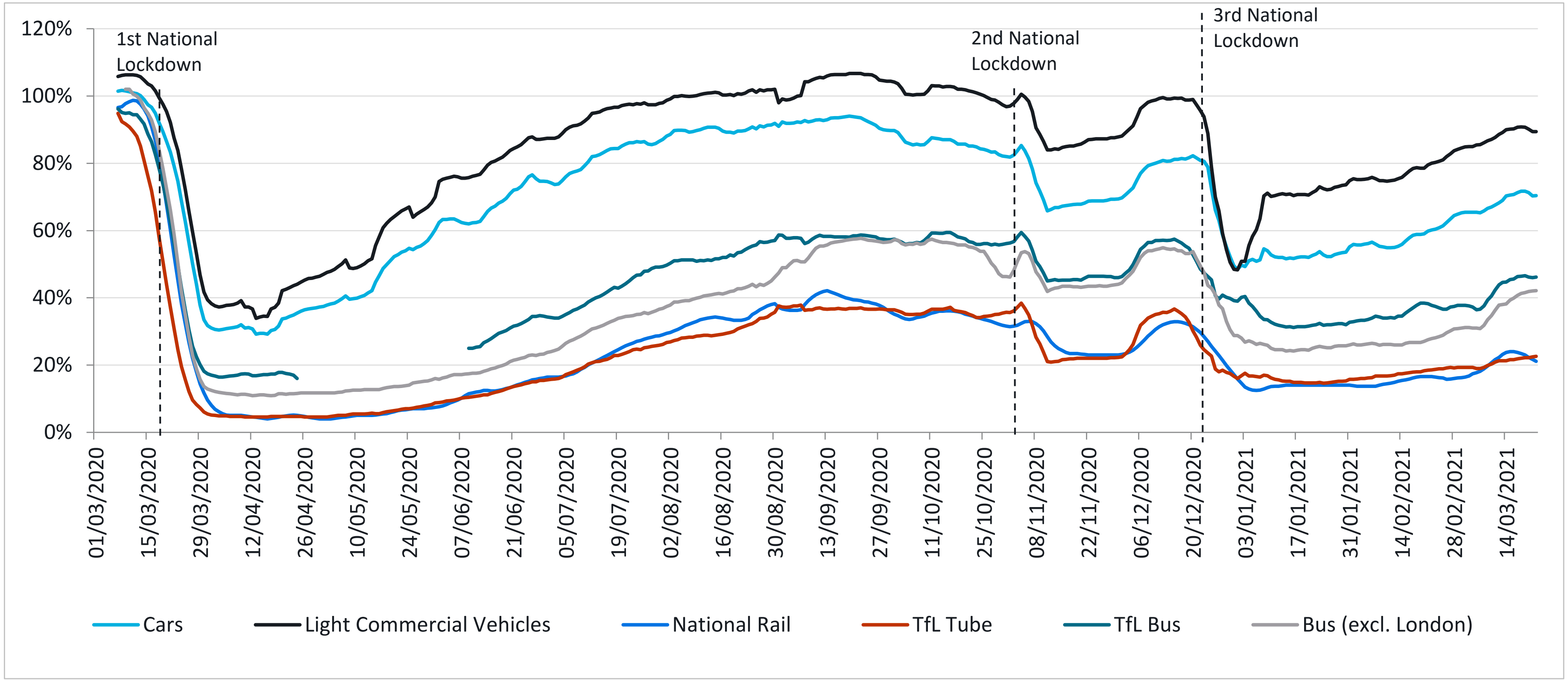


Figure A.12: Pandemic Transport Demand – Seven Day Moving Average (February 2020 = 100)



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B Light Freight

Introduction

B.1 This Appendix describes pre-pandemic context and for Light Goods Vehicles (LGVs) – also referred to in this note as "vans" – in Great Britain, summarises the key pre-pandemic trends affecting this sector, and considers the potential long term impacts of the COVID-19 pandemic on light freight in the UK.

Pre Pandemic Context

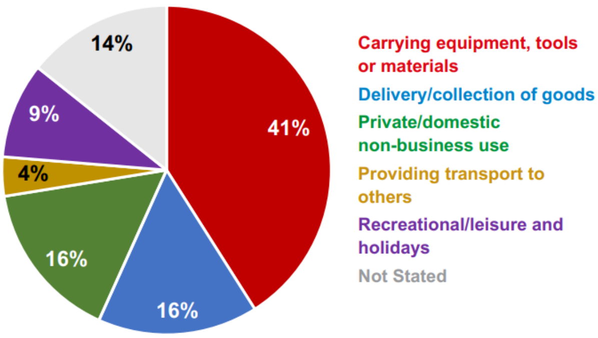
Overview

B.2 In 2019 there were 4.1 million LGVs in Great Britain, a number that has increased by 93% over twenty-five years.[24] The Department for Transport's (DfT) road traffic estimates indicate that LGV travel has grown substantially over the last 25 years, increasing by 106% to 55.5 billion vehicle miles in 2019.

B.3 The DfT's "Provisional Van Statistics 2019-20" publication[25] shows that:

- 58% of vans are owned by businesses and 42% are privately owned; and
- 41% of the licenced vans were used for "carrying equipment, tools and materials" with 16% used for "delivery/ collection of goods" (see Figure B.1) and other uses account for 29%, although it should be noted that the use of 14% of the van fleet is unaccounted for.

Figure B.1: Van usage in Great Britain, 2019-20



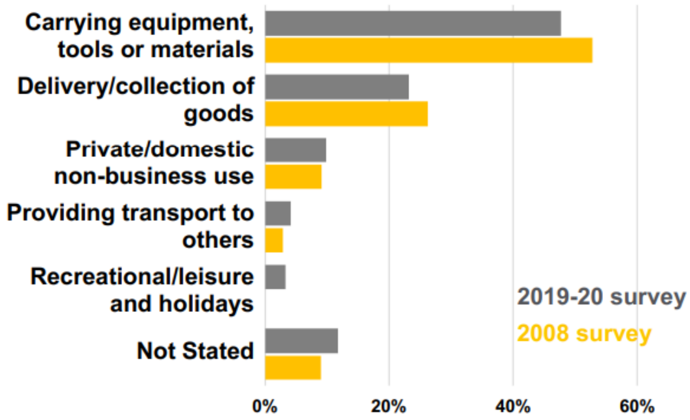
Source: DfT (2020) Provisional Van Statistics 2019-2020

[24] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/916508/provisional-van-statistics-2019-20.pdf

[25] It should be noted that this document (see previous footnote for link) was published in September 2020 and was based on the results completed by March 2020, which do not include the effect of the COVID-19 pandemic; the final stages of fieldwork were postponed until Autumn 2020

B.4 The annual mileage in the 2019-20 data is broadly aligned with the previous study conducted in 2008 (although for England only), which found that 48% of the overall annual van mileage fell in the "carrying equipment, tools or materials" category, while "delivery/ collection of goods" contributed to 23% of the overall mileage (see Figure B.2).

Figure B.2: Van mileage by primary usage, 2008 (England only) and 2019-20 (Great Britain)



Source: DfT (2020) Provisional Van Statistics 2019-2020

B.5 Nonetheless, while the delivery and collection of goods accounts for a minority of van miles, first mile/last mile deliveries are a major determinant of the growth of the LGV fleet and its mileage. In this context, the first/last mile refers to the movement of goods from a supplier or an out-of-town warehouse, to the final delivery address, such as offices and homes.[26]

In conclusion, pre-pandemic, only a quarter of van traffic was associated with the delivery and collection of goods. Nonetheless, first mile/last mile deliveries are a major determinant of growth.

B.6 In terms of fleet composition, at the end of 2019 96% of all vans were diesel with 0.3% ultra-low emission vans. The sector is relatively unconcentrated – in 2014, the 200 largest UK van fleets accounted for only 9% of all LGVs .[27]

B.7 Pre-pandemic, much of the recent growth of first/last mile freight has been attributed to the growth of e-commerce.[28] This trend has materially influenced changes in the types of goods being transported and customer expectations for the promptness of their delivery. Consequently, smaller but higher numbers of vehicles are being deployed in towns and cities to meet increasing demand – often with low levels of utilisation. There is also greater use of

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[2626] EST007-01-EST+DFT-Electrifying last mile deliveries guide-WEB.pdf (energysavingtrust.org.uk)

[27] Sewells Research and Insight, 2014 quoted in:

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/777682/fom_last_mile_road_freight.pdf

[28] Foresight, Government Office for Science (2019) *Last mile urban freight in the UK: how and why is it changing?*

various customer-controlled delivery mechanisms, such as Click & Collect, collection points and personal deliveries to the workplace.

B.8 In the following section, the pre-pandemic trends and factors contributing to the growth in LGV use for light freight are explored in more detail.

Pre-pandemic Trends

B.9 The key drivers of LGV growth include:

- Population;
- Gross Domestic Product (GDP)[29];
- Customer expectations and behaviour;
- Online retail;
- New retail and logistics business models;
- Consolidation;
- Sustainability; and
- New technology.

B.10 The relationship between demand and population/GDP is well understood and requires little explanation. Changes in customer service, online retail, business models, and consolidation/technology are explored in more detail below.

Customer expectations and behaviour

B.11 Customer insight research suggests the needs and expectations of customers are changing at a rapid pace. The following trends are influencing the purchasing behaviour:

- *Sustainability*: Customers' expectations for both environmental and social corporate responsibility are changing, and locally produced goods are gaining more popularity. According to a McKinsey report,[30] even luxury brands are anticipating a move toward sustainability and the desire for more-responsible consumption;
- *Desire for instant availability and delivery*: Customers increasingly expect same day availability and just-in-time delivery;
- *Personalisation of products and services*: Customers desire to purchase the products and services that are much more tailored to their individual preferences; and
- *Social media and influencers:* Social media is increasing affecting the purchasing decisions especially among Generation Z.[31]

B.12 Traditional delivery services have developed to include increasingly rapid delivery services – same day or in less than two hours (e.g. Amazon Prime Now) – that significantly reduce the waiting time between purchase and delivery. These changes have raised customer expectations, with potential buyers being more sensitive to delays, the high perceived price of delivery, and hourly constraints.

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[29] https://www.semanticscholar.org/paper/Drivers-of-Freight-Transport-Demand-and-their-Riet-Jong/a502fd99392047af047c195b2928961bd67125bc?p2df

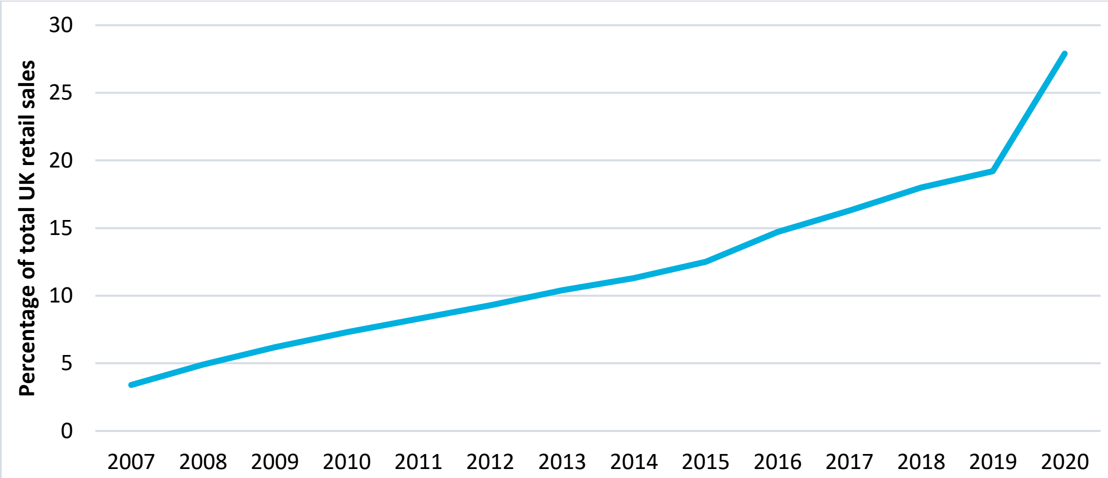
[30] https://blog.clear.sale/luxury-industry-statistics-and-insights-in-2020

[31] https://www2.deloitte.com/content/dam/Deloitte/de/Documents/consumer-business/Study_Retail%20Operating%20Model%20of%20the%20Future.pdf

Online retail

B.13 There has been a significant growth in online retail sales in recent years. The data from ONS presented in Figure B.3 shows that internet sales have been rising since 2007 steadily year-on-year. This growth has been accelerated by the COVID-19 pandemic.

Figure B.3: Internet sales as a percentage of total retail sales, UK



Source: ONS, 2021[32]

B.14 One of the key consequences of increasing online retail is the decline of "bricks and mortar retailing". As most goods are now available online, consumers may be less motivated to visit physical stores. Since 2016, more shops have been closing than opening in the UK.

New retail and logistics business models

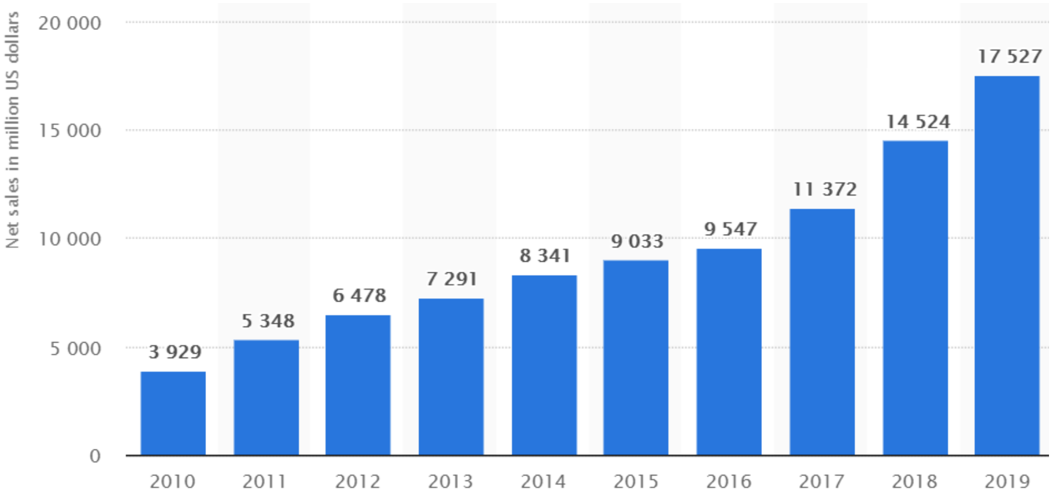
B.15 Several innovative start-ups have entered UK retail markets in recent years and are challenging the traditional retail business models. New entrants such as Amazon, Ocado, Plated, Farmdrop, Riverford and others have positioned themselves into the shopping experience between the consumer and the traditional supermarket through demand generation, innovative marketing, and home delivery models.[33] Pre-pandemic Amazon's sales grew by over 500% in the nine years to 2019 (see Figure B.4).[34] It has also transformed into a digital ecosystem functioning as an on-line marketplace.

[32] https://www.ons.gov.uk/businessindustryandtrade/retailindustry/timeseries/j4mc/drsi

[33] https://www.accenture.com/za-en/_acnmedia/PDF-53/Accenture-KSA-Food.pdf

[34] https://www.theguardian.com/technology/2021/feb/03/amazon-reports-uk-sales-rose-by-51-in-2020

Figure B.4: Amazon Net Sales, UK



Source: https://www.statista.com/statistics/1035592/net-sales-amazon-united-kingdom-uk/

B.16 The impact of online retail on light freight demand depends on the product type, supply chain arrangements, and decisions made by the customer. Some of the faster growing emerging business models include:

- **Inventory-based business models:** where companies like Amazon and Ocado are responsible for purchasing and storing the inventory from various suppliers in their own warehouses.
- **Hyperlocal business models:** where companies target customers within a limited geographical area and focus on fast delivery time. For example, Instacart supplies local on-demand grocery delivery by connecting customers with personal shoppers. This model includes crowdsourced deliveries with the companies like Deliveroo and Uber Eats, which provide a platform for restaurants to sell their products, and which are delivered by riders on mopeds and bikes. Gorillas,[35] a grocery delivery start-up that operates its own hyper-local fulfilment centres and, has been highly successful in Berlin and has plans to expand to London soon.
- **Click & Collect business models:** this is a blend of online and offline shopping experience where customers buy products online and collect them in-store. In 2016, Click & Collect accounted for 25% of all online clothing and footwear sales in the UK. [36] Click & Collect is expected grow as more partnerships develop between pure online retail and bricks-and-mortar stores to host collection outlets for customers. This could see more freight delivery and private car activity into certain postcodes where outlets are hosting such facilities. A study undertaken by Post and Parcel suggests that by 2025, approximately

[35] Home | Gorillas

[36] Verdict (2016) *E-retail in the UK* Quoted in:

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/777682/fom_last_mile_road_freight.pdf

10% of sales will be made through Click & Collect.[37] Collection points are also proving popular with convenience retailers as they provide an additional source of revenue.

- **Vertical integration/disintermediation:** this is where manufacturers deliver goods directly to the customers and eliminate the need for intermediaries such as wholesalers and retailers.

B.17 The relative rate of take-up of each of the models described above will have different implications for total light freight traffic. For example, increasing use of Click & Collect services and collection points could lead to decreased mileage, minimise the rate of failed deliveries, and help mitigate the adverse trend of rising LGV demand.

Consolidation

B.18 Consolidation is an approach used by on-line retailers and/or their shipping agents to reduce unit delivery costs by maximising the utilisation of their vehicles and drivers. From a public policy perspective, this is seen as a way of reducing negative impacts of light freight traffic. In its *Rethinking Deliveries Report*[38] Transport for London (TfL) defines consolidation as "the process of rearranging and combining goods shipments into fewer deliveries. The goal is to "reduce the number of vehicles carrying freight entering a city by making sure that their carrying capacity is fully utilised". The same report defines micro-consolidation as "the consolidation of goods at a facility much closer to the delivery point (not outside the city boundaries) … [micro-consolidation centres] usually serve smaller size areas, handling relatively small and light weight goods".

B.19 Consolidated operations are less reliant on regional distribution centres (e.g. large warehouses) and instead focus on micro-consolidation and micro-distribution centres. Micro-consolidation and micro-distribution centres are more centrally located and process a lower volume of goods than regional distribution centres. The key difference between the two "micro" varieties is that micro-distribution centres only involve one operator, whereas micro-consolidation centres are served by multiple operators.

B.20 Several micro-consolidation/distribution centres have been recently established in London. There is evidence that the approach of locating smaller centres deeper inside larger urban areas is helping to reduce (or at least limit) the number of LGVs delivering parcels in each area, as well as reducing carbon emissions.[39]

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[37] Types of Business Models For Online Grocery Shopping and Delivery | by Akanksha Chandan | Growcer- eCommerce grocery software | Medium

[38] Transport for London (2016) *Rethinking Deliveries Report*

[39] http://content.tfl.gov.uk/rethinking-deliveries--summary-report.pdf

Table B.1: Examples of micro consolidation/distribution centres with electric vehicle fleets in London

Examples
DPD, London • Fleet: 10 electric vans and eight micro-vehicles • Operation: parcel distribution by electric vehicle, heavy investment in the depot • Area: two square miles in central London
Gnewt Cargo, London • Fleet: EVs • Operation: a “carrier’s carrier” working with likes of Hermes and TNT, use electricity from renewable sources • Area: several micro-consolidation centres in central London, including Grosvenor Estates head office

B.21 As discussed above, there is an increasing expectation from customers that goods and services should be delivered faster (i.e. same day or next day). However, faster deliveries rely on there being sufficient available stock close to customers. This has driven Amazon to increase the number of smaller warehouses it manages within urban areas[40] and rely less on its much larger regional distribution centres. It is expected that more retailers adopt a similar approach to Amazon. For example, companies such as Takeoff Technologies are introducing “dark warehouses” which serve as the micro-distribution centres and employ up to 15 employees to sort and pack goods for local deliveries.[41]

Case study: City of London Corporation and Amazon
Working in partnership with the Planning and Transportation Committee at the City of London Corporation, Amazon will transform 39 parking spaces in the London Wall Car Park into a last mile logistics hub. Delivery vehicles will deliver packages to the hub, with the last mile being done by e-cargo bikes or on foot to the customer’s door. The expected outcomes include reduced number of delivery vehicles on central London roads. Chair of the Planning and Transportation Committee at the City of London Corporation, Alastair Moss, said: “The Amazon Last Mile Logistics Hub alone will take up to 85 vehicles off the roads each day, meaning up to 23,000 fewer vehicle journeys in central London every year”. [42] The City of London Corporation aims to deliver two additional Last Mile Logistics Hubs by 2022 and a further five by 2025.

Focus on Sustainability

B.22 The rise of electric vehicles has a significant impact on LGVs and, across Europe, electric delivery vehicles are becoming more popular. In 2019-20, the proportion of low-emission van stock in the UK was only 0.3% ,[43] although the number of licensed ULEV vans is increasing (10,400 ULEV vans were recorder 2019 compared to 4,200 in 2018).

B.23 The Government’s commitment to ban the sale of new petrol and diesel cars from 2030 also extends to LGVs, so the proportion of new LGVs that are sold each year which are ULEV should increase rapidly as that date approaches. Alongside the policy push, it is expected the future

[40] https://www.forbes.com/sites/stevebanker/2020/07/24/what-will-last-mile-delivery-look-like-post-coronavirus/?sh=52d3053e3b22

[41] What Will Last Mile Delivery Look Like Post-Coronavirus? (forbes.com)

[42] https://www.supplychaindigital.com/logistics-1/londons-last-mile-logistic-hub-sustainable-practices

[43] [43] Provisional Van Statistics 2019-20 (publishing.service.gov.uk)

uptake of the ULEV vans will increase as the cost of new vehicles drop, the travel range and battery technologies improve, and charging infrastructure becomes more widely available.

B.24 In the UK, DPD has recently opened its third all-electric depot in central London for last-mile delivery. Over 10% of DPD's UK van fleet is now electric with a million parcels a month delivered by EVs.[44] The UK electric van manufacturer Arrival has secured £340m order from UPS[45] and Amazon has introduced its first customised electric delivery vehicle, expected on the roads in 2022.[46]

B.25 Cycle freight (involving cycles, cargo bikes or electric bikes) can be the fastest, cleanest, and most efficient option for transporting goods in cities. These vehicles are zero emission at point of use, light, quiet, and can use both highways and specific cycling infrastructure. This means cycles can take "short cuts" through areas restricted for general traffic (such as Low Traffic Neighbourhoods), which gives them a competitive advantage over other highway traffic.

B.26 There are numerous examples of successful cycle schemes in the UK. Some of these come from established operations, such as Gnewt Cargo in London, and some come from more recent trials such as Sainsbury's. OXWASH, a laundry business based in Oxford, uses zero-emission fleet of e-cargo bikes to collect and deliver laundry to its customers.[47] Zedify, which is a partnership between six independent e-cargo bike delivery operators, provides businesses with sustainable first and last mile deliveries including e-cargo bikes and electric vans. Royal Mail has also trialled electric three-wheel trikes on delivery routes in three cities in the UK.[48]

New Technologies

B.27 While most technologies look likely to have marginal impacts on the freight system, robotics, automation, and Connected and Autonomous vehicles (CAVs) could fundamentally alter the operation of freight in the UK

B.28 Consumer demand for shorter delivery times is leading to the development of new services underpinned by new technology. These can be split into three categories: aerial delivery drones; last-mile or even 'last-yard' wheeled robots that roam pavement and deliver to homes or apartments; and autonomous vehicles for the road. These include standard self-driving cars by Toyota, GM, Ford and others, and unique bot-like vans such as Udelv and smaller prototypes from Nuro or Robomart. Major retail players, including Walmart and Kroger, are investing heavily in technology and capabilities that anticipate significantly more online ordering and delivery.

Summary

B.29 A summary of the key trends discussed above, and their likely impact on light freight demand, is presented in Table B.2 below.

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[44] https://www.dpd.co.uk/content/about_dpd/press_centre/dpd-smashes-ev-target-five-months-early-with-over-700-electric-vehicles.jsp

[45] **UK electric van maker Arrival secures £340m order from UPS | Automotive industry | The Guardian**

[46] **Amazon's Rivian-designed electric van is 'future of last-mile delivery' (vanfleetworld.co.uk)**

[47] https://energysavingtrust.org.uk/sites/default/files/EST007-01-EST%2BDFT-Electrifying%20last%20mile%20deliveries%20guide-WEB.pdf

[48] **Royal Mail to trial e-Trikes for letter and parcel deliveries | ITV News**

Table B.2: Summary of the Key Trends

Key trends	Impact on the use of LGVs
Customer expectations and behaviour	Customers' desire for instant availability and delivery of the products drives the number of LGVs on the streets used for deliveries. Move towards sustainability can lead to more electric LGVs on the roads.
Online retail	Online retail is increasing demand for LGVs on the roads as these are the primary method of delivering goods to customers.
New retail and logistics business models	The relative rate of take-up of each of the models will have different implications for total light freight traffic. For example, increasing use of Click & Collect services and collection points can lead to decreased mileage and minimise the rate of failed deliveries balancing the adverse trend of rising number of LGVs.
Consolidation	Consolidation aims to reduce the number of LGVs carrying freight entering a city by making sure that their carrying capacity is fully utilised. It is expected that more retailers will build more warehouses in urban areas trying to compete against each other and provide the fastest deliveries to their customers.
Sustainability	The proportion of new LGVs that are old each year which are ULEV should increase rapidly as 2030 approaches.
New technology	These are highly uncertain but could offer productivity increases that could reduce (or at least temper) demand for LGVs.

Impact of the COVID-19 Pandemic

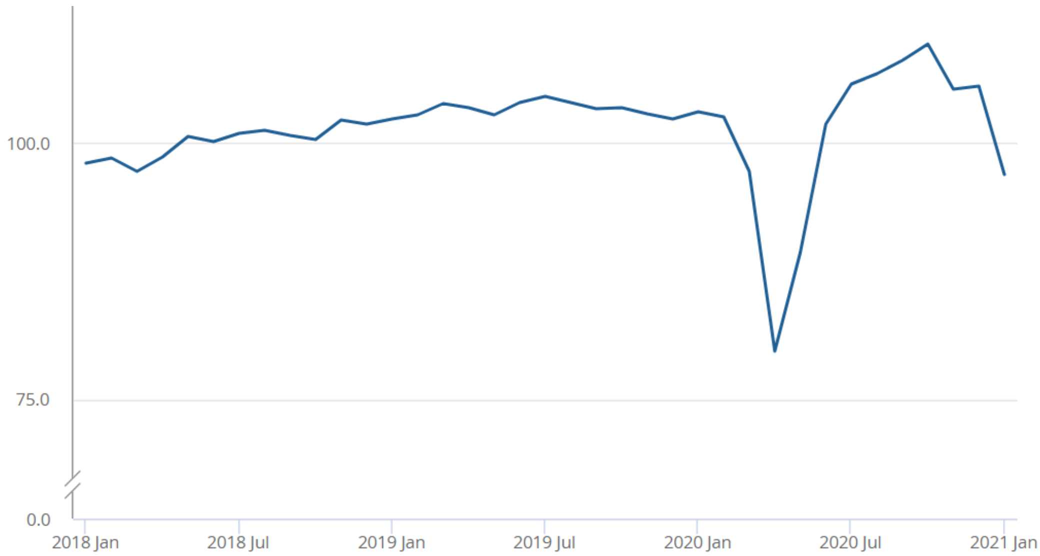
B.30 The 2020-21 COVID-19 pandemic has accelerated several trends that were already under way pre pandemic. These include digitalisation, online retail, consolidation of logistics, and development of contactless and/or autonomous delivery technologies.[49] In particular, we have considered the impact on retail, the future of the high street, diversification, and technology.

Retail

B.31 The retail industry experienced a significant contraction at the beginning of the pandemic. In April 2020 overall retail sales fell by 22.2% compared to the previous year. In January 2021, sales declined by 8.2% compared to December 2020. This underlines the impact the first and third national lockdowns has on the UK retail sector (see Figure B.5).

[49] https://www.automotiveworld.com/articles/rethinking-last-mile-logistics-post-covid-19-facing-the-next-normal/

Figure B.5: Volume sales, seasonally adjusted, Great Britain, January 2018 to January 2021



Source: ONS, 2021[50]

B.32 The impact of the second national lockdown In November 2020 is more nuanced. In this month the proportion of retail sales on-line reached 31.4%. (the trend over previous years is in Figure 3).[51] Of food retail, 10.3% was online. The proportion of all non-food retail that was online was 32.2%, although this include so-called 'Black Friday' shopping. [52]

B.33 By January 2021, the proportion spent online has increased to 35.2%. All store types reported significant increase in online sales this month ,with food retailers gaining a historical high of 12.2% of online sales. Deliveroo's[53] CEO mentioned that the COVID-19 pandemic has accelerated consumer adoption of their food delivery services by two to three years.[54]

B.34 Around 93%[55] of the UK's internet users are believed to shop online. This represents the highest level of online shopping in Europe, which has subsequently led to a significant rise in first/last mile freight.

B.35 This rising demand for online shopping inevitably places extra pressure on urban transport networks. For example, last mile deliveries are rising leading to increased number of vehicles on the roads. This has been experienced not just in the UK. DHL in Germany reported an increase in parcel shipments from 5.3 to 9.0 million parcels per day in 2020.

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[50] https://www.ons.gov.uk/businessindustryandtrade/retailindustry/bulletins/retailsales/january2021

[51] Retail sales, Great Britain - Office for National Statistics (ons.gov.uk)

[52] https://www.ons.gov.uk/businessindustryandtrade/retailindustry/bulletins/retailsales/november2020#online-retail

[53] Deliveroo is an online food delivery company

[54] https://www.cnbc.com/2020/12/03/deliveroo-ceo-says-covid-has-accelerated-adoption-of-takeaway-apps.html

[55] https://www.statista.com/topics/2333/e-commerce-in-the-united-kingdom/

B.36 A 2020 study developed jointly by the World Economic Forum, McKinsey, and the World Business Council for Sustainable Development (WBCSD)[56] estimated that urban last mile deliveries would grow by 78% by 2030. This study also suggests that rising last mile demand could boost the number of delivery vehicles in the cities globally by 36% through to 2030, which risks exacerbating urban traffic and congestion. Faster (i.e. instant and same-day) deliveries are also growing fast, respectively by 36% and 17%, which points to similar outcomes for urban traffic.

Future of the High Street

B.37 Several UK retailers have unfortunately gone into administration or closed stores during the pandemic, with Arcadia Group being amongst the highest profile. Other brands that have gone into administration include Karren Millen, Laura Ashley, Oasis and Warehouse. There are also signs of consolidation in this sector. online retailer Boohoo recently acquired Debenhams and is negotiating similar deals with other brands from Arcadia Group such as Dorothy Perkins, Wallis and Burton.[57] Another on-line retailer, ASOS, has acquired the Topshop brand. Neither Boohoo nor ASOS are taking over the physical shops of the brands they are purchasing leading to a closure of lots of the shops and affecting the High Street. Another example includes the John Lewis Partnership, which has recently announced that it lost £517m over the last year and the closure of a further eight stores.[58] While many of the shop closures have been associated with companies that pre-pandemic had poor profitability and/or high debts, the John Lewis example shows that it is not just these sorts of firms that have been affected.

B.38 Pre-pandemic, the makeup of the High Street was already changing as “bricks and mortar” retailers responded to the take up of e-commerce. It appears the pandemic has accelerated a pre-existing trend and brought forward the time that some retailers would have closed. The speed of change has probably removed the opportunity for some retailers to adapt and respond to rise of e-commerce.

B.39 Nevertheless, a recent study by Deloitte[59] suggests that that the High Street will not disappear but will reinvent itself in response to the structural shift in working and shopping patterns that has resulted from the COVID-19 pandemic. This report indicates that the High Street has experienced a vacancy rate of 12.5%, which is broadly the same as in 2013 and highlights the resilience of the High Street. The study highlights the opportunity for the High Street to become a diverse environment where new concepts, stores, pop-ups and services are being tested and can be accelerated by:

- The rise of the independent shops seizing the opportunity to occupy the empty shops;
- The localisation trend with people shopping for more locally produced goods;
- Home working replacing commuting with one or two days working from home being new normal in future (it has been estimated that working from home one day per week may transfer 20% of lunchtime spending from the city centres to local high streets); and

[56] Rethinking last-mile logistics, post-COVID-19: Facing the ‘next normal’ | Automotive World

[57] https://theconversation.com/future-of-high-streets-how-to-prevent-our-city-centres-from-turning-into-ghost-towns-154108

[58] John Lewis announces it will permanently close more branches after losing £517 million - Essex Live

[59] What next for the high street? | Deloitte UK

- Changing spending habits from buying a physical product to spending money on health, beauty and socialising.

B.40 This suggested there will be fewer shops selling goods and more services selling experiences, for example, nail salons, escape rooms, ping pong bars etc. More showrooms will appear, providing a chance for customers to touch the product before ordering online or purchasing it through Click & Collect service. For example, the former Debenhams in Wandsworth is set to become an entertainment hub, with an e-karting area, ping pong and pool tables, bowling lanes, and a cocktail bar.[60] Crazy golf chain Swingers has already successfully converted part of the former BHS flagship store to provide their services in the West End.[61]

Diversification

B.41 Several retail companies are using the pandemic as an opportunity to diversify their businesses and test new business models. For example, the John Lewis Partnership plans to expand its online food delivery and introduce new budget ranges with the key aim to move up to 70% of it is sales online by 2025.[62] They also plan to move to new areas of business such as insurance and savings markets and social housing (with plans to submit two planning applications next year).

Autonomous Delivery Technologies

B.42 The COVID-19 pandemic has accelerated demand for contactless delivery robots with companies such as Amazon, Google, FedEx, Starship Technologies, Robomart and Kiwi using autonomous pods to deliver food to students at over a dozen campuses in the US in Harvard, Stanford and Cornell.[63]

B.43 Autonomous vehicles could significantly reduce delivery times and costs for many consumer goods, while addressing congestion issues and other transport challenges such as poor air quality. A key factor determining the pace of change will be the extent to which commercial and, to a lesser extent, public demand presses governments and regulators to encourage or slow down these developments.

Summary

B.44 A summary of the key trends discussed above, and their likely impact on light freight demand, is presented in Table B.3 below.

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[60] https://www.ft.com/content/8edfb238-48b6-43a3-ab8b-1a0d951f811c

[61] https://www.standard.co.uk/business/leisure-retail/high-street-town-centre-b917987.html

[62] **John Lewis Plans New Services in Shift from Retail (ceotodaymagazine.com)**

[63] **Demand For Autonomous Delivery Robots Rises As Pandemic Continues (forbes.com)**

Table B.3: Summary

Key trends	Description
Online retail	The proportion of online purchases has increased and more customers in the UK are shopping online. This is driving a significant rise in demand for first/last mile freight.
Future of the high street	It is expected that the High Street will have fewer shops selling goods and more showrooms and services selling experience. Either way, customers will still wish to travel to the High Street.
Diversification	Several retailers are seeking to diversify their businesses and test new business models, including property development and insurance. It is not clear what impact this might have on transport demand.
Autonomous delivery technologies	The COVID-19 pandemic has accelerated demand for contactless delivery robots with companies testing autonomous delivery technologies at a wider scale. Again, it is hard to say (at this time) how this will impact transport demand.

Conclusion

B.45 While just 16% of LGVs are currently used for deliveries (or at least were, pre-pandemic) and less than a quarter of LGV miles are associated with deliveries/collections, the number of LGVs on Britain's road is growing, and much of this growth is being driven by growth in demand for deliveries.

B.46 The COVID-19 pandemic has accelerated many of the drivers contributing to growth in LGV demand, notably online retail. Some of this growth will be tempered by other developments in logistics, such as the development of micro-consolidation/distribution centres and Click & Collect services, as well as changes in the "peakiness" of highway demand that might arise from other recent trends (e.g. homeworking).

B.47 While it is probably too early to quantify the net impact of this recent growth in light freight demand, at a qualitative level, it is probably reasonable to concluded that this growth the potential to exacerbate congestion on some parts of the highway network within and near to urban areas.

B.48 That said, despite this growth in LGV demand, it should be acknowledged that cars and taxis place much greater pressure on the highway network (in 2019 LGVs accounted for 16% of the total highway vehicle kilometres in 2019).[64] It is therefore difficult to see how recent LGV demand growth alone would drive a need for a significant change in highway capacity. Instead, there may be a role for targeted local policy responses, such as implementing Traffic Regulation Orders limiting drop-off times and/or promoting more productive consolidation centres.

B.49 At the same time, in order to enable the light freight sector to meet its commitments to decarbonising by 2050, a growing number of electric LGVs will drive a requirement for more EV charging infrastructure.

[64] https://www.gov.uk/government/statistical-data-sets/road-traffic-statistics-tra#traffic-volume-in-miles-tra01

B.50 Finally, Table B.4 sets out how the key drivers for LGV demand should be modelled to reflect the NIC Scenarios that have been developed for this study. The arrows indicate the degree of change we assume for each parameter.

Table B.4: Variables and the NIC scenarios

Variable	Online Retail	LGV trips and miles
SC1: Reversion and reaction	No change	No change
SC2: A more flexible future	↑	↑
SC3: Low social contact urban living	↑↑	↑↑
SC4: Social cities	↑↑	↑↑
SC5: Virtual local reality	↑↑↑	↑↑↑
Comments	Online shopping accelerates due to increased flexible working	Number of LGVs on streets is driven by increased online sales

C Digital

Introduction

C.1 The very high and sustained annual growth rates in digital demand (in the order of 20% to 50% p.a.) make it a very different sector from the others considered within the NIC Behaviour Change Project, and modelling the impacts of COVID-19 induced behaviour changes will therefore require a very different approach. This Appendix sets out the key issues and recommends the way forward. It is structured as follows:

- Digital demand metrics
- Factors driving digital demand
- Historical trends in digital demand
- Forecasts and extrapolations for future digital demand
- Observed impacts of the pandemic on digital demand so far
- Implications for modelling digital demand by NIC scenario.

Digital Demand Metrics

C.2 There are various metrics which could be used to quantify 'digital infrastructure demand'. They include the following:

- Premises **coverage** of various levels of broadband service – e.g. superfast (30 Mbps+) coverage; gigabit-capable (1 Gbps+) coverage, full fibre coverage, 5G coverage etc. While these are measures of availability (analogous to miles of motorway/major roads in transport), they could also be taken to reflect infrastructure demand to some extent, in that commercial operators will only invest in making such services available where and when they consider there to be sufficient demand and competitive advantage to make it worth doing so. Over the time horizons involved in the NIC Behaviour Change Project (to 2055), we will almost certainly be seeing generations of technology rolled out which simply don't yet exist for mass market services (e.g. 10 Gbps, 100 Gbps etc. services on fixed broadband; and yet-to-be-defined 6G, 7G and 8G mobile services).
- **Household take-up** of fixed and/or mobile broadband internet connectivity (% of households). This is one measure of demand that is <u>not</u> now increasing exponentially, as it is approaching saturation: 89% of UK households had internet access at home by early 2020 (and of these, 90% had fixed broadband).[65]
- **Maximum download speed** on fixed broadband connections (in Mbps) reflects the top speeds available to mass market consumers. This is the measure used for Nielsen's Law of

[65] Source: Nations & Regions Technology Tracker 2020, Ofcom. Note that ONS's Internet Access – Households and Individuals data for 2020 puts the proportion of Great Britain households with internet access significantly higher, at 96%, but this used an online+ telephone backup survey method, while the Ofcom survey was face-to-face and had a larger sample size (c. 4k vs c. 2.7k).

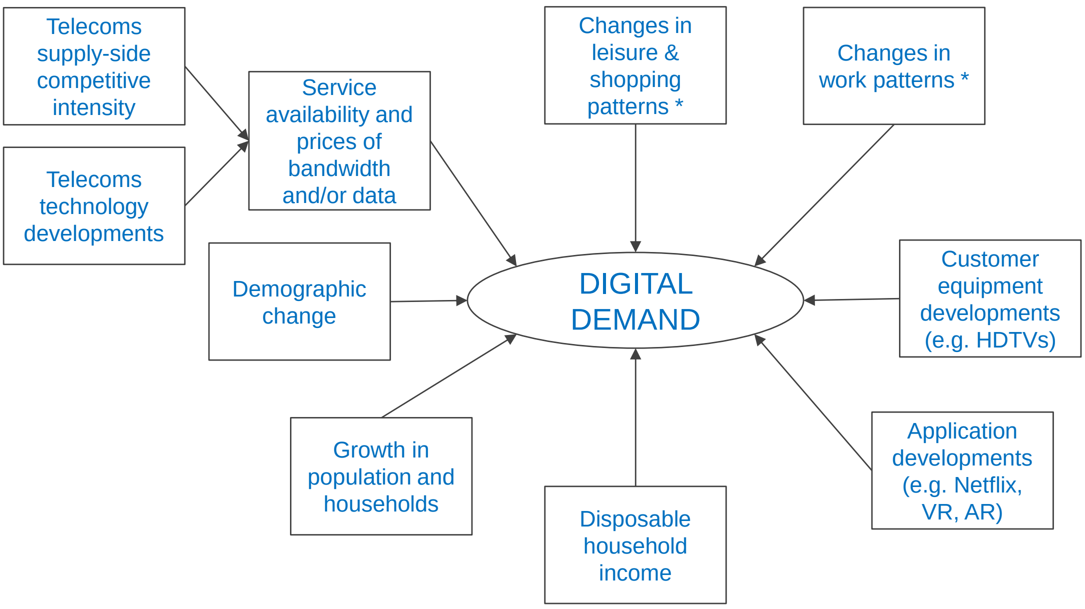
Internet Bandwidth[66] which states that a high-end user's connection speed increases at 50% p.a.

- **Average download speed** on fixed broadband connections (in Mbps) is perhaps a more relevant measure of digital demand, as it reflects the services *actually used* by consumers (as opposed to those available to them). The mean can be skewed to some extent by a few particularly high-end users in a given area (and the median download speed may be a more relevant metric for some purposes), but it does have the advantage of reflecting capacity – and capacity growth - that operators need to cater for. **Average upload speed** is also a relevant demand metric, which is becoming more important with the increase in home-working. **Mobile speeds** (download and upload) are of course also important – though historically, these have tended to lag a few years behind the average speeds on fixed broadband connections.
- **Average monthly data usage** on fixed broadband connections (in GBytes per month per connection), also reflects consumers' actual usage of digital infrastructure. We suggest that this measure (analogous to vehicle-miles in transport) is the most relevant demand metric for the purposes of this NIC project, as it reflects how intensively consumers' connections are being used overall (including both upstream and downstream data transfers) – irrespective of the speeds that are available to them, or that they can afford.

Factors Driving Digital Demand

C.3 When considering how COVID-19 induced behaviour changes will affect digital demand, we need to put this into the context of various other factors which have a major influence on the extent to which we will use digital infrastructure in the future (measured, for example, by monthly data usage). The diagram below illustrates this, with asterisks against the two factors of most relevance in the NIC scenarios.

Figure C.1: Factors Driving Digital Demand



[66] Source: Nielsen's Law of Internet Bandwidth, Nielsen Norman Group, updated February 2019

Source: DMS Research & Consulting

C.4 **Technology developments** are arguably the most important factors here – in telecoms technology, customer equipment, and new or enhanced applications. Combined with strong competition in their respective markets, and with the unit cost reductions represented by Moore's Law,[67] these technology developments bring new digital services, equipment and applications to consumers at affordable prices, and many of these have very important impacts on the extent to which our digital infrastructure is used. Facebook's CEO, for example, recently set out a vision of people being able to effortlessly 'teleport' to socialise via Virtual Reality by the end of this decade.[68]

C.5 In that context, the key COVID-19 related behaviour change parameters – changes in work patterns, and changes in leisure and shopping patterns – may have only modest incremental effects, which may get swamped in the long term by the changes in demand driven by technology change. The *uncertainties* around the counterfactual growth in demand out to say 2055 may well be orders of magnitude greater than the effects of behaviour changes outlined in the NIC scenarios.

Historical Trends in Digital Demand

C.6 Over the last several decades, **digital demand – as measured by various indicators – has tended to grow exponentially,** i.e. at roughly constant percentage growth rates each year. Compounded over several years this has resulted in **enormous growth over long time spans**. For example, Figure C.2 illustrates the historical growth of three speed-related parameters, and Figure C.3 shows the growth of monthly data usage. With logarithmic y-axes, the exponential growth gives linear trendlines, with a Compound Annual Growth Rate (CAGR) of c. 52% p.a. for the capacity per system of new trans-Atlantic cables,[69] 32% p.a. for mean download speed, 44% p.a. for mean upload speed and 43% p.a. for mean monthly data usage.

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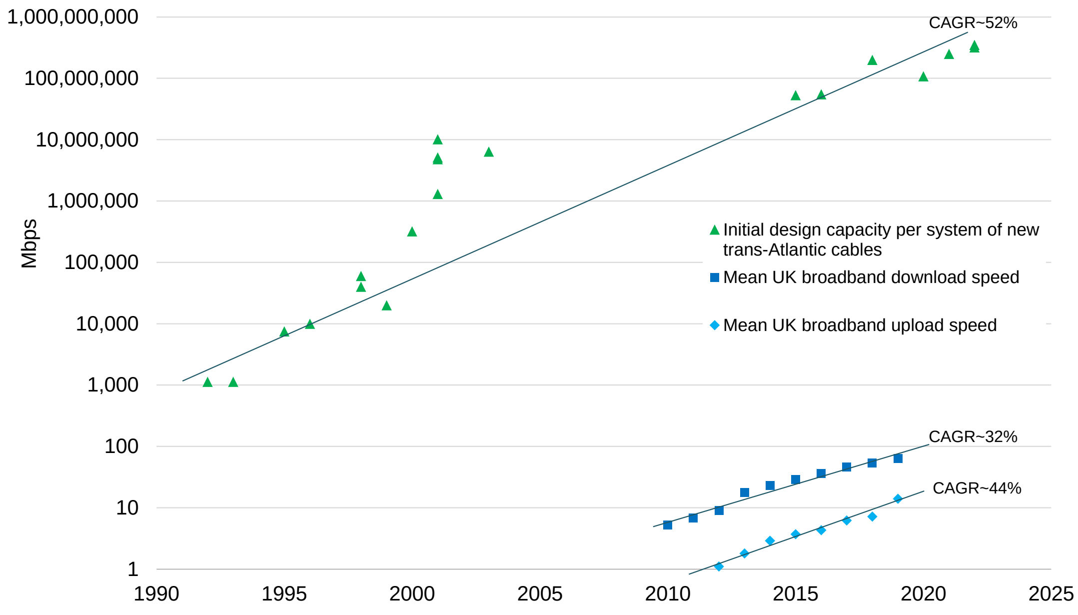
[67] And the less well-known Butter's Law of Photonics: the data coming out of an optical fibre doubles every 9 months

[68] Source: Facebook sets out plan for 'effortless' virtual reality socialising, The Guardian, March 2021

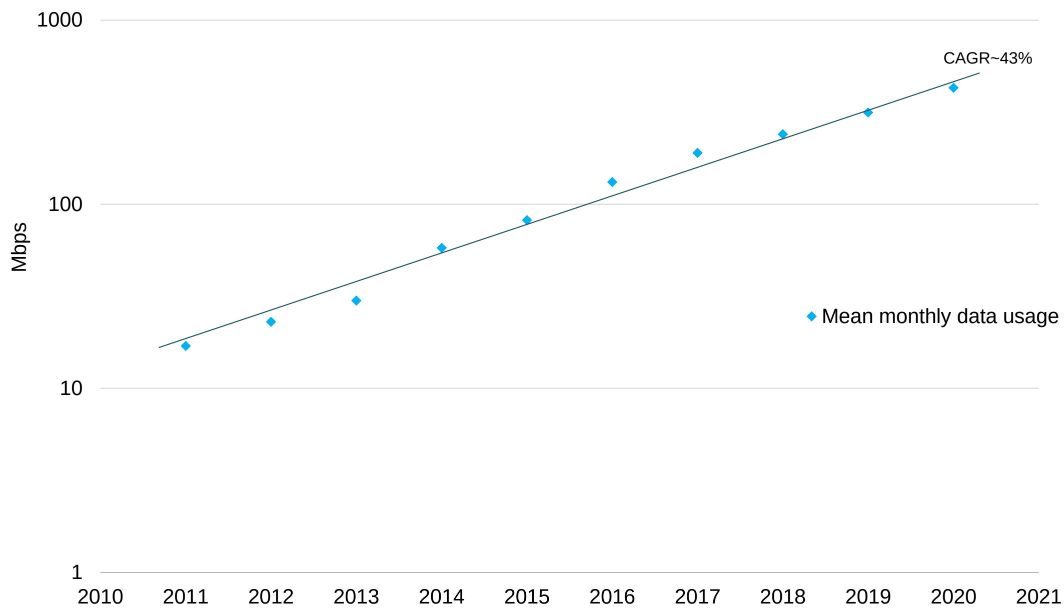
[69] Trans-Atlantic cables are included here as we have a long time series available, and because they provide evidence of long term technology advances and a glimpse into the very long term potential future for mass market services (e.g. the total system capacity of the TAT-10 trans-Atlantic cable launched in 1992 was roughly equal to the 1Gbps services now being offered to consumers in many parts of the UK over FTTP). The over-investments in the late 1990s/early 2000s dot.com bubble are treated as outliers for the purpose of the trendline.

Figure C.2: Historic time series for various speed parameters: capacity of new trans-Atlantic cables, UK mean download speed on fixed broadband, and UK mean upload speed on fixed broadband (note the logarithmic y-axis)



Source: Various submarine cable websites; Ofcom Broadband Speeds Reports

Figure C.3: UK mean monthly data usage over fixed broadband (note the logarithmic y axis)



Source: Ofcom Connected Nations and Infrastructure Reports

C.7 Although exponential growth will not last forever (we would expect average upload speeds eventually to converge with download speeds rather than overtake them, for example), this data does serve to emphasise that high annual growth rates can be sustained, in the digital domain, over decades.

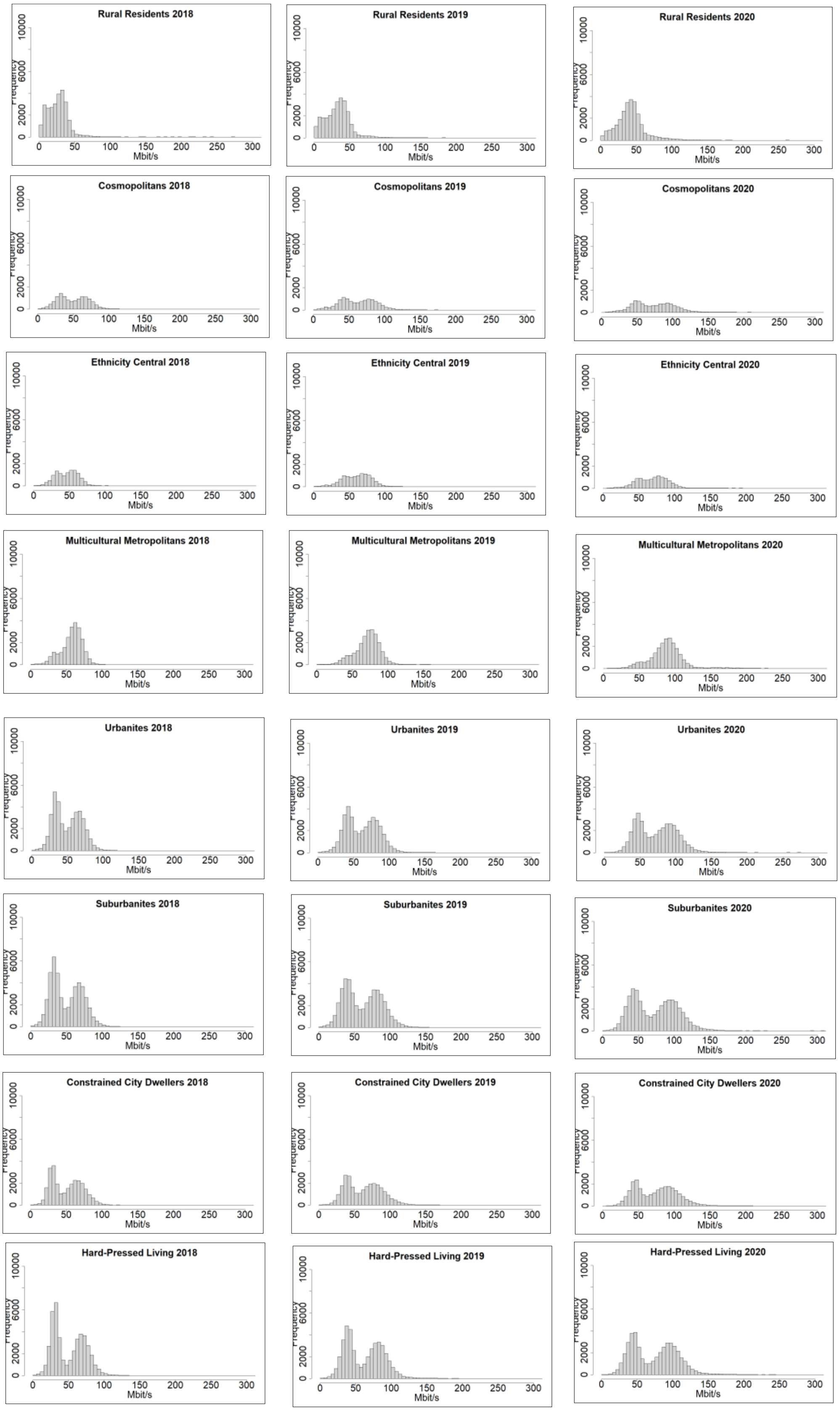
C.8 The UK averages are useful for observing general trends over time, but further insight can be gained from more granular information at Output Area level. For each of the eight Output Area Classification supergroups used in this NIC Behaviour Change study, Figure C.4 and Figure C.5 show how the distributions of mean download speed and mean monthly data usage have changed over time.[70]

C.9 Some points to note from these are that:

- Most of the download **speed distributions have a distinctive 'dual-hump' profile**. This will reflect differences in the *availability* of services by Output Area within each OAC – with those Output Areas on the faster side of the distributions having access to ultrafast services (e.g. from Virgin Media and FTTP providers), while those at the slower end of the distributions don't yet.
- Both the download speed and the data usage **distributions are flattening and spreading out** towards the right. In some respects this reflects a widening inequality between different areas as FTTP services become available in some areas but not in others. For example, some Output Areas are now seeing average speeds of 200 Mbps+, while others still have average speeds of less than 20 Mbps.
- In contrast to the download speeds, the monthly data usage distributions all have a single peak, which suggests that in many areas **relatively slow broadband connections are being used just as intensively** (in terms of total data transfer) as faster broadband connections.
- **Some of the highest average data usage per fixed broadband line is seen in the more deprived neighbourhoods**. The data usage distribution for Hard Pressed Living Output Areas sits to the right of that for Suburbanites, for example. It may be that there is more extensive use of data-intensive leisure applications such as video streaming and gaming in Hard Pressed Living areas. As noted in the Ofcom observations on the pandemic impact below, major games releases are an important factor in broadband traffic and data usage. It should also be remembered, however, that this data refers only to *fixed* broadband lines; in less affluent communities there will be significantly higher proportions of households who rely solely on *mobile* connectivity for their internet access (and who don't appear in the above data).

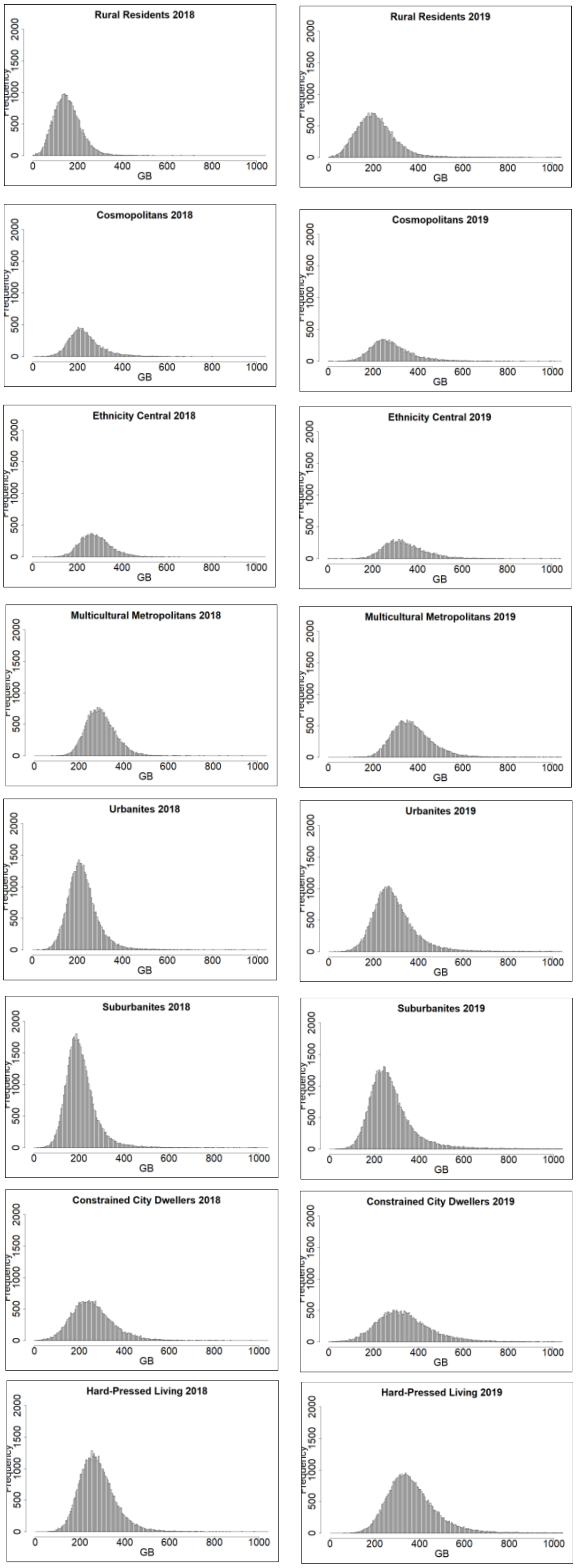
[70] Note that the usage data in the published detailed geographic breakdowns from Ofcom is currently incorrect (by a factor of 1,000), so we have not been able to use the 2020 data for the usage histograms.

Figure C.4: Distribution of Output Areas' mean download speed by Output Area Classification supergroup and year



Source: Steer analysis of Ofcom's Connected Nations datasets by Output Area

Figure C.5: Distribution of Output Areas' mean monthly data usage by Output Area Classification supergroup and year



Source: Steer analysis of Ofcom's Connected Nations datasets by Output Area

Forecasts and Extrapolations for Future Digital Demand

C.10 Strong growth in digital demand is expected to continue, at least in the medium term. For example:

- IDC[71] predicts that the amount of data created over the next three years will be more than the data created over the past 30 years, and the world will create more than three times the data over the next five years than it did in the previous five. The amount of data created, captured, copied, and consumed in the world is forecast to increase at a compound annual growth rate (CAGR) of 26% through to 2024.
- For the UK, Cisco[72] forecasts that average fixed broadband speed will grow at a CAGR of 20% from 2018 to reach 93.4 Mbps by 2023; and average mobile speeds will grow at a CAGR of 21% from 2018 to reach 55.1 Mbps by 2023.
- In early 2020, Telegeography[73] set out projections for trans-Atlantic telecoms cable capacity requirements, which conservatively assumed growth rates reducing from c. 60% p.a. in 2019 to c. 25% p.a. by 2035.

In the tables below, we extrapolate at various potential growth rates over the 2055 time horizon of the NIC Behaviour Change Study, for the two most relevant digital metrics: average download speed, and average monthly data usage. They use the observed CAGR over the last five years as a starting point for the extrapolations. These are not forecasts, but they demonstrate that even the lowest of these growth scenario leads to enormously high growth by 2055 versus the 2020 baseline position, and that there are extremely large uncertainties in projecting digital demand over such a long time period (see Table C.1 and Table C.2)Table C.2: Extrapolations to 2055 for average UK monthly data usage over fixed broadband

C.11 .[74]

Table C.1: Extrapolations to 2055 for average UK download speeds for fixed broadband

	High growth scenario	Medium growth scenario	Low growth scenario
Average download speed in 2020	72 Mbps		
Observed CAGR 2015 to 2020	20% p.a.		
Extrapolated growth rates	20% p.a.	20% reducing to 10% p.a. by 2055	20% reducing to 5% p.a. by 2055
Extrapolated average download speed in 2055	42,410 Mbps	9,451 Mbps	4,310 Mbps
Extrapolated increase 2020-2055	59,000%	13,000%	5,900%

Source: Ofcom (for actuals) and DMS Research & Consulting

[71] Source: IDC's Global DataSphere Forecast Shows Continued Steady Growth in the Creation and Consumption of Data, IDC, March 2020

[72] Source: Cisco Annual Internet Report - Cisco Annual Internet Report Highlights Tool, Cisco, February 2020

[73] Source: How Much Growth is Too Much Growth?, Telegeography, January 2020

[74] For comparison, the average download speed in 2020 was c. 250,000% faster than the 28.8 kbps dial-up modems that were available in the mid 1990s (i.e. 25 years ago, as opposed to the 35 years between 2020 and 2055).

Table C.2: Extrapolations to 2055 for average UK monthly data usage over fixed broadband

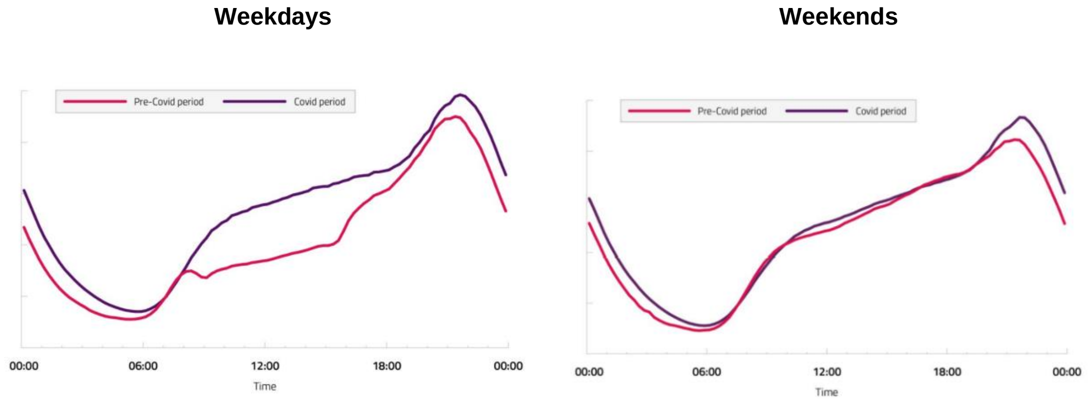
	High growth scenario	Medium growth scenario	Low growth scenario
Average download speed in 2020	429 GB		
Observed CAGR 2015 to 2020	39% p.a.		
Extrapolated growth rates	35% p.a.	35% reducing to 10% p.a. by 2055	35% reducing to 5% p.a. by 2055
Extrapolated average download speed in 2055	15,640,000 GB	490,000 GB	230,000 GB
Extrapolated increase 2020-2055	3,645,000%	114,000%	54,000%

Source: Ofcom (for actuals) and DMS Research & Consulting

Observed Impacts of the Pandemic on Digital Demand

C.12 Turning to the observed impacts of the pandemic, analysis by Ofcom based on data from operators helpfully shows a comparison in relative traffic by time of day for the pre-Covid period versus the first national lockdown (Figure C.6).

Figure C.6: Typical average traffic profile (Gbit/s) on weekdays [left] and weekends [right] before national lockdown (27 Jan to 22 March) and during national lockdown and subsequent restrictions (23 Mar to end July)



Source: Connected Nations 2020, Ofcom

C.13 Key points to note from this are that:

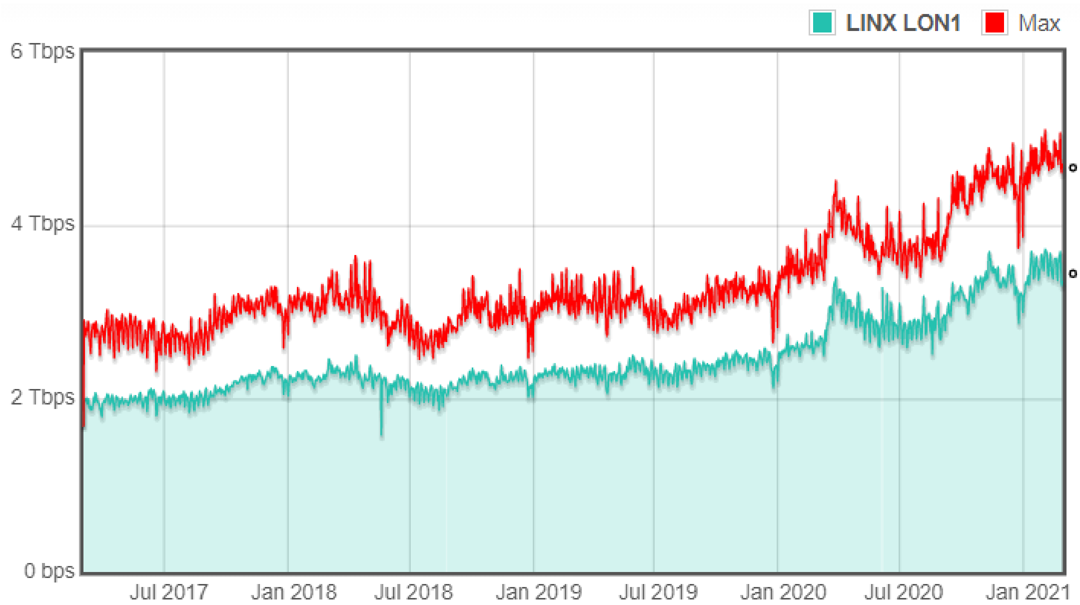
- There was clearly **a large increase in daytime traffic during weekdays** (08:00 to 18:00). This will have been driven by the traffic demands of millions more people working or studying from home (and using video conferencing tools such Zoom and Microsoft Teams heavily), but also by the traffic generated by millions of people put on furlough, many of whom will have turned to online entertainment during the lockdown, including video-streaming applications such as Netflix, and online gaming. During the restrictions, the traffic profile by time-of-day during weekdays became similar to that at weekends.
- The **peak period for traffic is in the evenings** (c. 20:00 to 22:00), both at weekends and weekdays. Telecoms operators (of mass market broadband services) dimension their networks to handle this peak, with headroom, and the anticipated growth in that peak.
- **The increase in typical traffic during the peak period was significant but relatively modest**, both for weekdays and weekends. Presumably this was driven by more people

using video-streaming and gaming etc. at home, rather than going out to socialise with friends.

C.14 Ofcom also noted that there were **significant increases in upstream traffic**, especially during the daytime: consistent with the shift to home working and the use of business services from home, such as video conferencing.

C.15 A further indication of the effects of COVID-19 restrictions on digital demand can be seen in the traffic statistics from the London Internet Exchange (LINX) for its largest network (Figure C.7). Note the considerable uptick in average and maximum traffic in the middle of March 2020, when the first work-from-home advice was issued.

Figure C.7: Average and maximum traffic on the London Internet Exchange (LINX) LON1 network



Source: LINX statistics, retrieved 17 March 2021

C.16 Overall, the UK's internet infrastructure has coped very well with the step-changes in behaviours enforced by the COVID-19 lockdowns. Ofcom's Connected Nations 2020 report noted that:

- **ISPs, content providers and Ofcom worked together to effectively manage demand**: At the start of the lockdown period, major streaming sites including Netflix, YouTube, Amazon Prime and Disney+ (which launched around the start of lockdown in the UK) took action to reduce the streaming rates of their services. These controls were slowly lifted during the lockdown period as traffic on the networks became stable and ISPs were confident in the capacity available to carry streaming traffic with higher definition. In addition, Ofcom worked with the gaming industry, the Content Delivery Networks (CDNs) that distribute gaming downloads and the major ISPs to manage games releases so as not to adversely impact network congestion.
- For major networks, peak traffic increased during the early phase of the first lockdown in late March and April. However, **this generally remained below the spikes in peak traffic seen immediately prior to lockdown** when major gaming releases coincided with the

peak times. After this initial increase, **peak traffic remained largely constant on average, meaning traffic levels remained higher than prior to lockdown**, though this varied across different networks.

- Providers plan their networks to have spare capacity to cope with year-on-year traffic growth and spikes associated with especially busy events. This has provided **sufficient headroom to cope with any increased peak demand** during the pandemic.
- Despite the pandemic, providers have not reported a clear or consistent pattern of increased demand from customers seeking faster or more reliable broadband connections. Analysis of provider data shows that some providers saw increased demand from their customers for faster connections, while others did not observe such demand changes (and others did not specifically track this). One provider offering full fibre services saw a small shift in demand towards slower (but still at least superfast) speeds, perhaps reflecting increased price sensitivity.

C.17 As we emerge from lockdown we would expect to see some easing off in traffic levels, especially in the daytime. Use of online entertainment (e.g. video streaming and games) during the daytime will reduce as furloughed employees return to work. The use of online business collaboration tools (e.g. video conferencing) during the daytime is likely to reduce somewhat as employees who are currently working from home return to their offices and resume face-to-face meetings; however, the use of full-time or part-time home-working may well remain significantly higher than their pre-pandemic levels, and many businesses will keep using online business collaboration tools much more than they were before the pandemic. The average peak traffic is likely to reduce as people take advantage of the opportunities for going out in the evenings again. Such reductions will, however, be in the context of the long-term trend of strong year-on-year growth in demand: post-lockdown traffic will almost certainly be significantly higher than its pre-pandemic levels.

Implications for Modelling Digital Demand by Scenario

C.18 In the light of the context and issues described above, we suggest the following way forward for modelling the digital demand aspects of the NIC Behaviour Change Study:

- Focus on **monthly data usage over fixed broadband** as the key digital demand metric for the purposes of this study. This has the benefit of reflecting both download and upload usage in a single metric, and the observed distributions per OAC are relatively 'well-behaved' (e.g. not subject to the 'dual hump' effect seen in the distributions of average speeds, caused by differences in infrastructure availability).
- Given the very high and sustained counterfactual growth rates in digital demand (in the order of 43% p.a. for average monthly data usage), there is little point in attempting to model digital demand out to 2055. The *uncertainties* around the counterfactual growth in demand over such a long period may well be orders of magnitude greater than the effects of behaviour changes outlined in the NIC scenarios. Any projections of digital demand over such a long period – even with the most aggressively conservative assumptions on a reduction in growth rates from the historical trends - would generate numbers for 2055 that would currently seem outlandish, and distract from the main purpose of this NIC study. We propose to **focus on the <u>2025</u> time horizon** for the digital aspects of the study.
- Modelling should seek to quantify the changes by 2025 in total monthly data usage (over fixed broadband lines) per OAC supergroup by NIC scenario. This would be generated by combining:

- The 2020 baseline mean monthly data usage per broadband line (see below) and the total broadband lines, by OAC supergroup.
  - Different average monthly data usage growth rate assumptions per OAC supergroup, by NIC scenario, over the period 2020 to 2025.
  - The scenario-specific modelled spatial changes in the distribution of households/population between the OAC supergroups.
- Bearing in mind the very high counterfactual growth rates, driven largely by technology developments, we anticipate that the differences attributable to the NIC behaviour change scenarios may only account for relatively small proportions of the total change in digital demand over the period.

D Energy

Introduction

D.1 This Appendix considers the impact of COVID-19 pandemic on energy demand and examines the implications for the modelling of that demand. It provides a definition of energy demand, the components of demand and key income, price, structural and price drivers behind that demand, before looking at historical levels of final energy demand and various government and energy company projections of future demand. Evidence of the pandemic's impact on final energy demand is summarised with a particular focus on electricity consumption. Finally, our initial thoughts on an approach to modelling future energy demand are outlined.

What is Energy Demand?

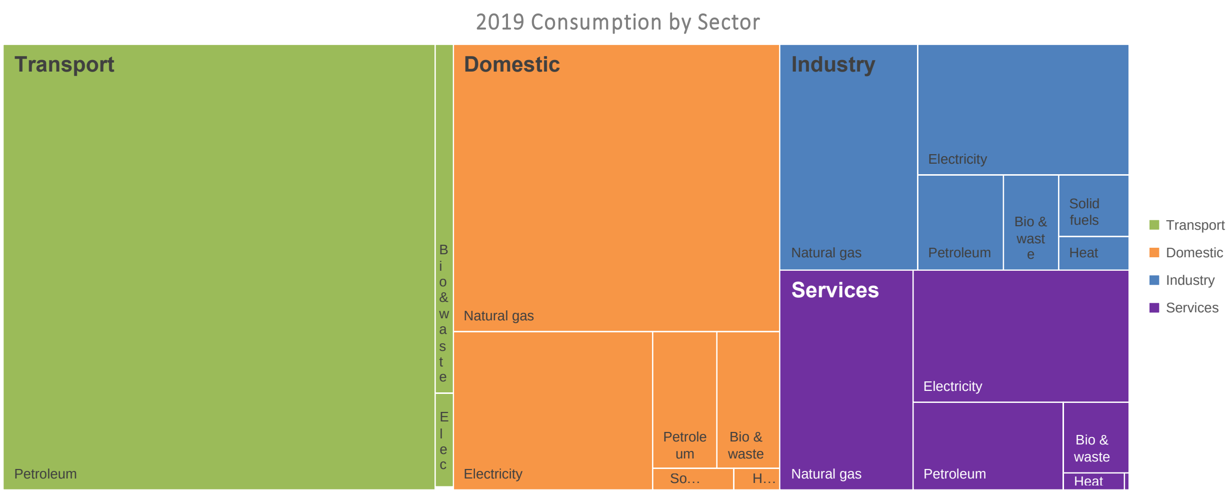
D.2 Energy is the foundation for the modern economy. It is an essential ingredient for many human activities including cooking, heating, lighting, industrial production and transport. Energy demand describes the consumption of energy by human activity and influences:

- the total amount of energy utilised;
- the types of fuel used in energy supply; and
- the end use technologies that consume energy.

D.3 Energy demand covers all uses of energy: electricity, transport fuels, fuels for heating and industrial processes.

D.4 In the UK there are four main distinct sectors that utilise energy: transport, domestic, industry and services. Within these four sectors, different types of energy are consumed: electricity, natural gas, petroleum, bioenergy and waste, coal and other solid fuels, and heat. Figure D.1 below illustrates energy demand in the UK for 2019, showing overall demand for the four main sectors with a breakdown of consumption in each.

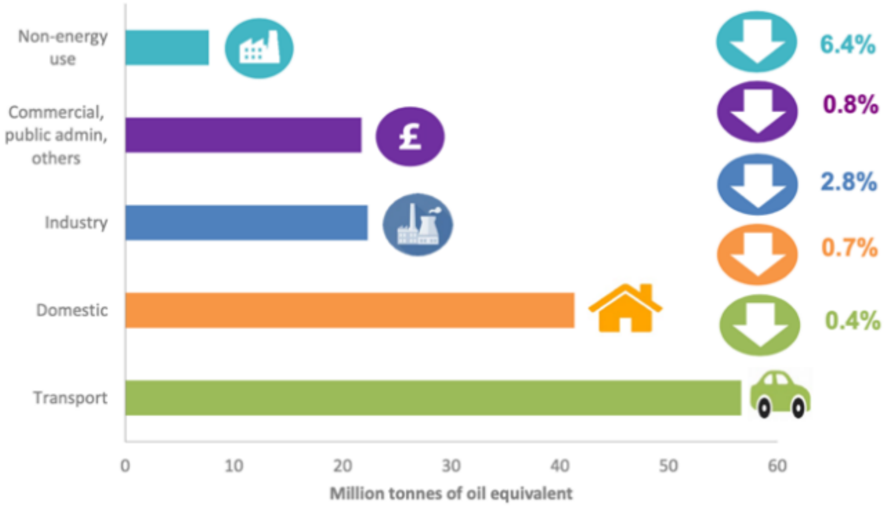
Figure D.1: UK Energy Demand, 2019, thousand tonnes of oil equivalent



Source: BEIS (https://www.gov.uk/government/statistics/energy-consumption-in-the-uk)

D.5 Figure D.2 shows consumption by sector (including non-energy use) in 2019, with domestic and transport use accounting for nearly two-thirds of final consumption. Final consumption overall declined by 1.2% when compared to 2018, with sector specific declines highlighted in the figure.

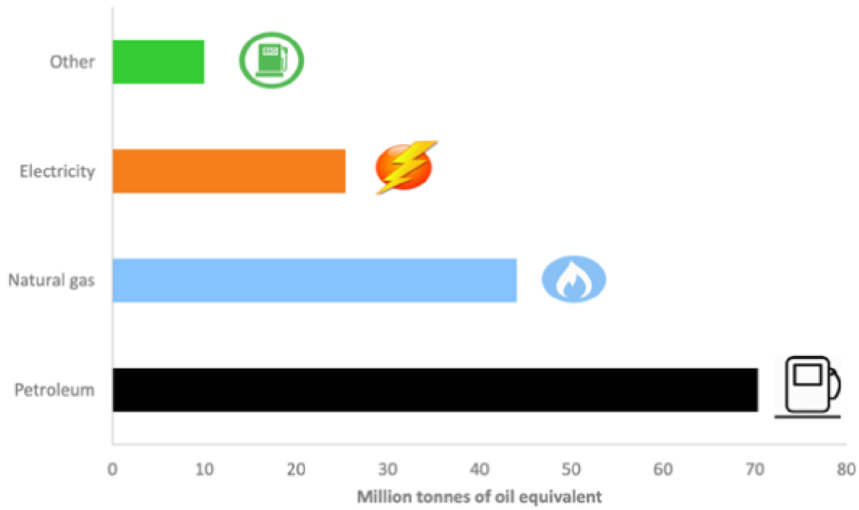
Figure D.2: Final Consumption by Sector, 2019



Source: BEIS (https://www.gov.uk/government/statistics/digest-of-uk-energy-statistics-dukes-2020)

D.6 As illustrated in Figure D.3, the main fuels used by consumers in 2019 were petroleum products (46%), natural gas (29%) and electricity (17%).

Figure D.3: Final Consumption by Fuel, 2019



Source: BEIS (https://www.gov.uk/government/statistics/digest-of-uk-energy-statistics-dukes-2020)

Factors Driving Energy Demand

D.7 Energy has various end uses which drives demand, which varies by sector:

- In the **domestic** sector, it is used for space and water heating, cooking and lighting, as well as by various household appliances and consumer electronics;

- In **industry**, it is used for operating machinery, production chains, etc.;
- In the **service** sector, it is used, for example by hospitals, schools, etc. for heating purposes and power electronic equipment, etc.; and
- In the **transport** sector, it is used in the different modes i.e., road, air, rail, water.

D.8 Energy demand drivers can be categorised in to: income, price, structural as well as policy drivers:

- **Income** drivers are macroeconomic and demographic factors such as GDP growth, growth in disposable income, population growth, growth in the number of households, living space per capita, etc.
- **Price** drivers relate to the price level for a particular energy source and other energy sources that could be substitute for this. For example, electric space and water heating can be replaced by other kinds of space and water heating e.g., natural gas boilers, heat pumps, district heating, etc.
- **Structural** drivers include seasonal, weekly and within day variations which influence peak loads, energy intensity, industry structure and technological development:
  - Residential demand is driven by a distinct *seasonal* pattern, with high peaks in winter due to space heating requirements, compared to a lower profile in the summer, when heating systems are not required. As well as distinct patterns over the course of the year, energy demand varies *within day* and over the course of a *week*. In order to meet *peak loads*, the energy system must have the ability to supply the energy to meet demand at peak times.
  - The *energy intensity* of economies has declined over time. For example, the UK has become less industrialised and has developed a more service orientated economy. This means that energy in less important in the overall productive capacity of economy than in the past.
  - Closely related to energy intensity is *industry structure*, where economic activity has shifted from industry towards the service sector.
  - *Technological development* which helps save energy and optimise energy consumption can also have a significant impact on energy demand.
- Public **policy** can have a significant impact on energy demand. For example, it can raise awareness of issues such as climate change and in turn alter preferences and behaviours. Policy can also be used to offset market failures and externalities in order to achieve greater economic efficiency. Subsidies, in the form of direct or indirect payments to firms and individuals, can change relative prices for different energy sources. For example, subsidies for certain types of energy technologies (e.g., solar panels, heat pumps, etc.) can influence demand materially. Other subsidies (e.g., better insulation for buildings) can used to reduce overall energy consumption by households and office buildings.

D.9 The UK energy system is going through a period of significant change. There is need to eliminate fossil fuels in order to respond to climate change. This will mean decarbonising fuels used in electricity generation, heating and transport:

- For electricity generation, as the costs of wind and solar energy are falling rapidly this has resulted in higher proportions of renewables in the generation mix allowing the move away from fuels such as coal. However, electricity demand and supply have to be constantly balanced and, with solar and wind being variable sources, this makes balancing more difficult. Energy storage (e.g., electric vehicle batteries) and greater flexibility in demand (e.g., doing clothes washing at different times) can help address this.

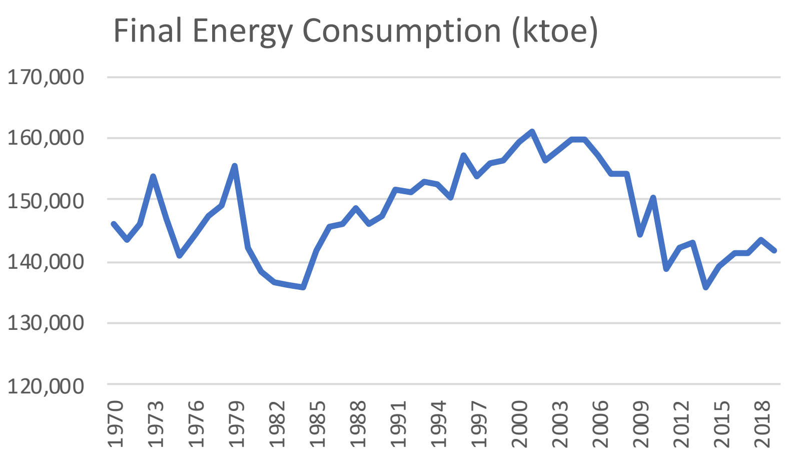
- For heating and transport, electrification is likely to play a big role, particularly for cars and domestic heating. However, it is likely hydrogen will be needed for things like freight transport, aviation, shipping and various industrial processes.

What is Changing?

Historical Trends in Energy Demand

D.10 In the UK, energy consumption peaked in 2001 at 161 million tonnes of oil equivalent (mtoe) and now (2019) stands at 141 mtoe, a decline of 12% or around 0.8% per year on average (see Figure D.4).

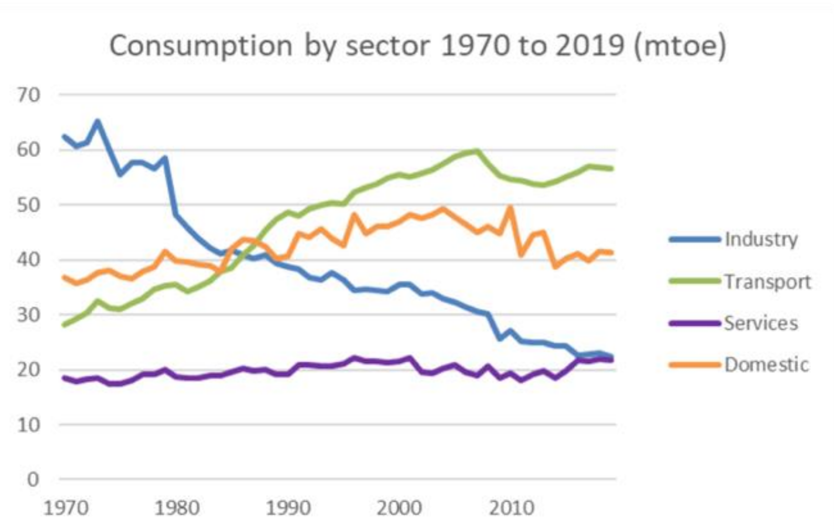
Figure D.4: UK Energy Demand, 1970 to 2019



Source: BEIS (*https://www.gov.uk/government/statistics/energy-consumption-in-the-uk*)

D.11 Figure D.5 illustrates the long-term sectoral trends with notable growth in transport consumption, which has doubled between 1970 and 2019, and the fall in industrial, which has declined by almost two-thirds over the same period.

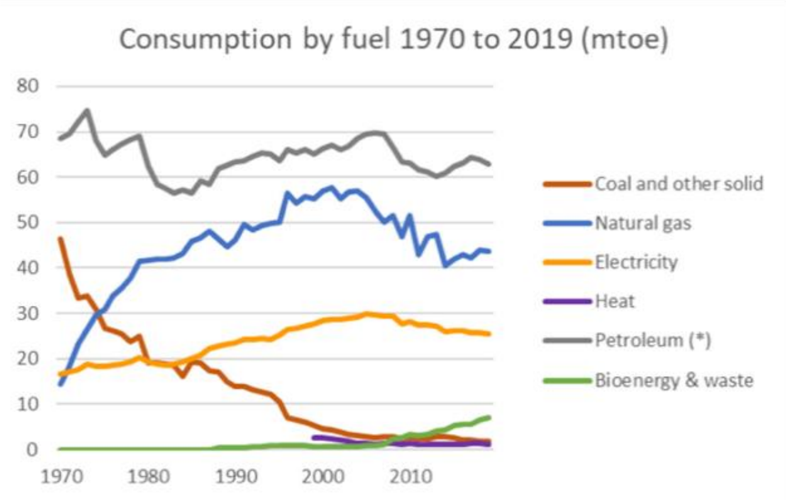
Figure D.5: UK Energy Demand by Sector, 2019



Source: BEIS (*https://www.gov.uk/government/statistics/energy-consumption-in-the-uk*)

D.12 Figure D.6 illustrates the long-term fuel trends with the notable decline in coal consumption, which has fallen by 96% since 1970, and the tripling of natural gas consumption over the same period (though this has fallen by a quarter since it peaked in 2001).

Figure D.6: UK Energy Demand by Fuel, 2019



Source: BEIS (*https://www.gov.uk/government/statistics/energy-consumption-in-the-uk*)

Domestic Energy Consumption

D.13 Tables D.1 and D.2 outline the key summary statistics covering the number of households, mean, median and other statistics for domestic energy consumption in England and Wales, and Scotland respectively. The median consumption is considered the more appropriate measure of typical consumption because the mean can be influenced by a relatively small number of high-consuming households. Across both geographies, median gas consumption is four times than that for electricity consumption. Energy consumption in Scotland is marginally higher than England and Wales reflecting differences in climate.

Table D.1: Annual consumption summary statistics for England and Wales, 2018 (kWh)

	N (million)	Mean	Standard Deviation	Lower Quartile	Median	Upper Quartile
Gas	18.2	13,200	7,600	8,100	12,000	16,900
Electric	22.7	3,700	2,900	1,900	3,000	4,500

Source: BEIS (https://www.gov.uk/government/statistics/national-energy-efficiency-data-framework-need-report-summary-of-analysis-2020)

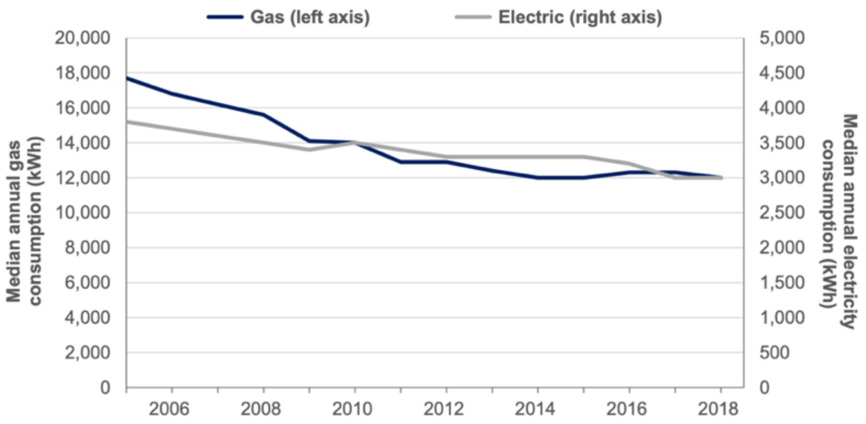
Table D.2: Annual consumption summary statistics for Scotland, 2018 (kWh)

	N (million)	Mean	Standard Deviation	Lower Quartile	Median	Upper Quartile
Gas	1.6	14,100	8,200	8,400	12,600	18,000
Electric	2.1	3,800	3,100	1,900	3,000	4,600

Source: BEIS (https://www.gov.uk/government/statistics/national-energy-efficiency-data-framework-need-report-summary-of-analysis-2020)

D.14 Figure D.7 illustrates the median gas and electricity consumption for all households in England and Wales. This highlights that since 2005 median consumption for both gas and electricity has been generally declining. Gas consumption has fallen by almost a third between 2005 and 2018, equivalent to 3% per year on average. Over the same period, the fall in electricity consumption has been steadier, declining by just over a fifth, at 1.5 per cent per year on average.

Figure D.7: Median Annual Gas and Electricity Consumption, 2006 to 2018

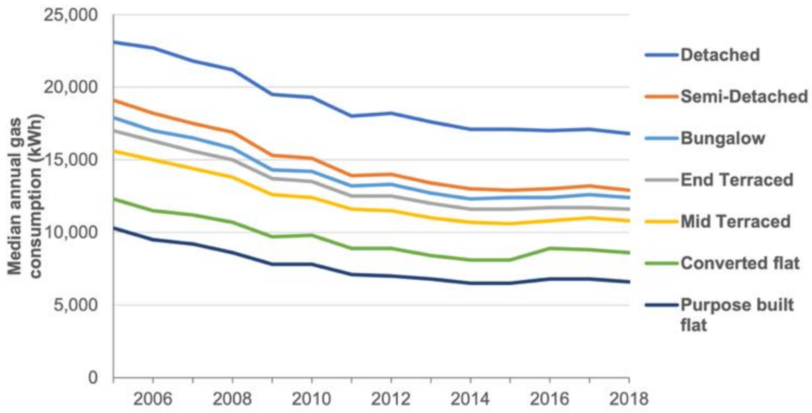


Source: BEIS (https://www.gov.uk/government/statistics/national-energy-efficiency-data-framework-need-report-summary-of-analysis-2020)

Note: Data for 2005 to 2010 covers England only; 2011 onwards covers England and Wales

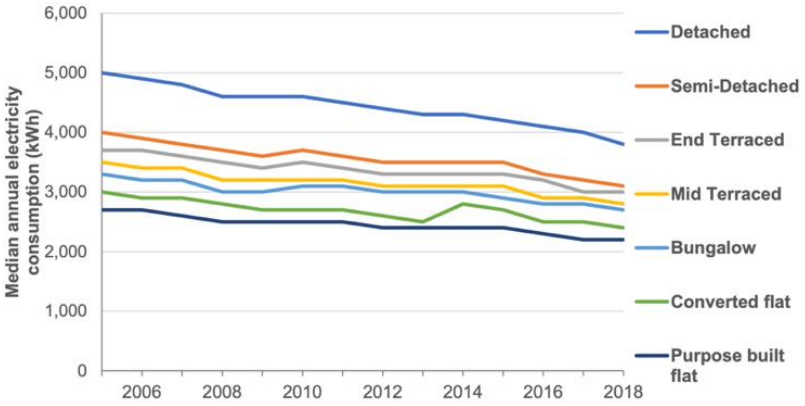
D.15 This fall in median gas and electricity consumption is seen consistently across all property types, household characteristics, geographies and socio-demographic classifications. However, detached houses consistently use more energy than other property types, and flats, particularly purpose built flats, use the least, as illustrated in Figures D.8 and D.9.

Figure D.8: Median Gas Consumption by Property Type, 2006 to 2018



Source: BEIS (https://www.gov.uk/government/statistics/national-energy-efficiency-data-framework-need-report-summary-of-analysis-2020)

Figure D.9: Median Gas Consumption by Property Type, 2006 to 2018



Source: BEIS (https://www.gov.uk/government/statistics/national-energy-efficiency-data-framework-need-report-summary-of-analysis-2020)

Non-Domestic Energy Consumption

D.16 Figure D.10 presents a summary of the key statistics covering the non-domestic building stock and associated energy consumption in England and Wales. The analysis identifies that there are 1,656,000 non-domestic buildings (at end of March 2020), with the top three uses being shops (29%), offices (20%) and factories (14%). Total energy consumption of non-domestic buildings in England and Wales in 2018 was 293 TWh, with factories (34%), other (15%) and offices buildings (10%) consuming the most. Hospitality building use had the highest energy intensity.

Figure D.10: Annual consumption summary statistics for England and Wales

Source: BEIS (https://www.gov.uk/government/statistics/non-domestic-national-energy-efficiency-data-framework-nd-need-2020)

Note: Non-domestic building stock figures are at end of March 2020.

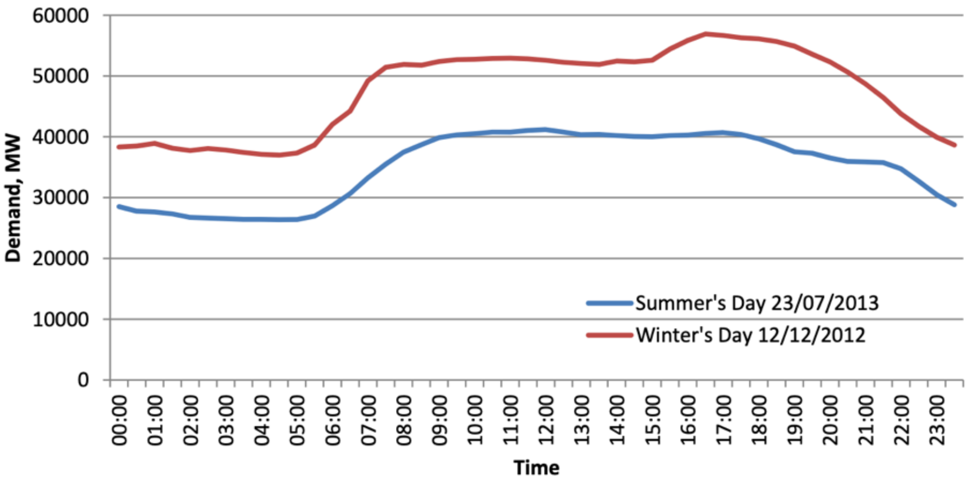
Energy Demand Profiles

D.17 The pattern of energy usage varies by between seasons (i.e., winter versus summer), day (i.e., weekday versus weekend) and within day (e.g., evening versus overnight), and also during extreme weather and televised events.

Electricity

D.18 Figure D.11 presents electricity demand profiles for Great Britain as a whole on a winter's day (in December 2012) and a summer's day (in July 2013), and illustrates that whilst there is a similar trend for both days, the demand on a winter's day was 36% higher than a summer's day, with a notable peak in the early evening in winter:

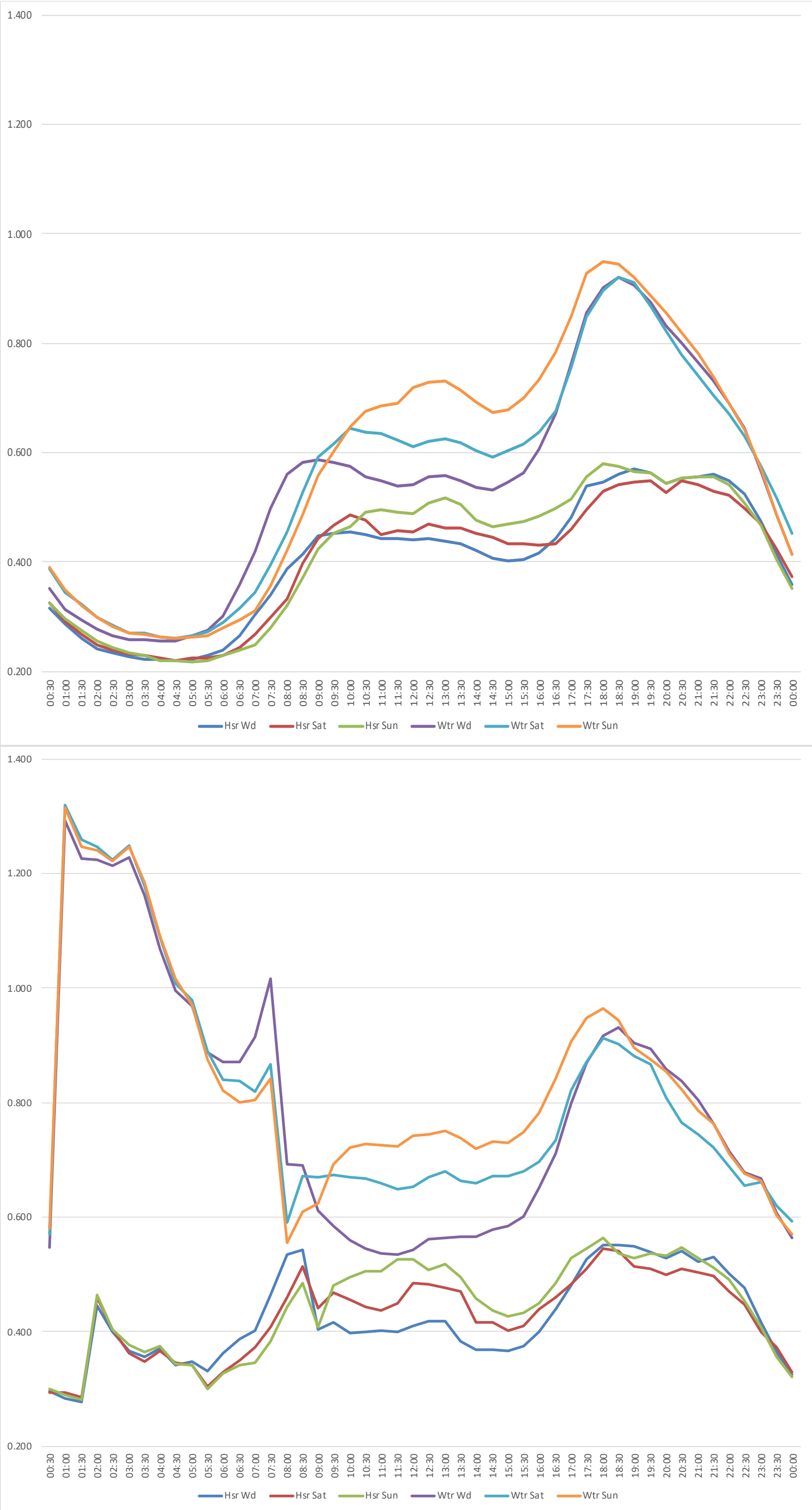
Figure D.11: GB Electricity Demand Profiles, Summer versus Winter



Source: BEIS (https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/295225/Seasonal_variations_in_electricity_demand.pdf)

D.19 As shown in Figure D.12, daily domestic electricity demand profiles also highlight these seasonal, type of day and within day variations, as well as the differences between whether the property is heated by electricity or gas.

Figure D.12: Daily Electricity Demand Profiles for Average Domestic Unrestricted (Profile 1, left-hand side) versus Average Domestic Economy 7 Customers (Profile 2, right-hand side), 2013-14, kW

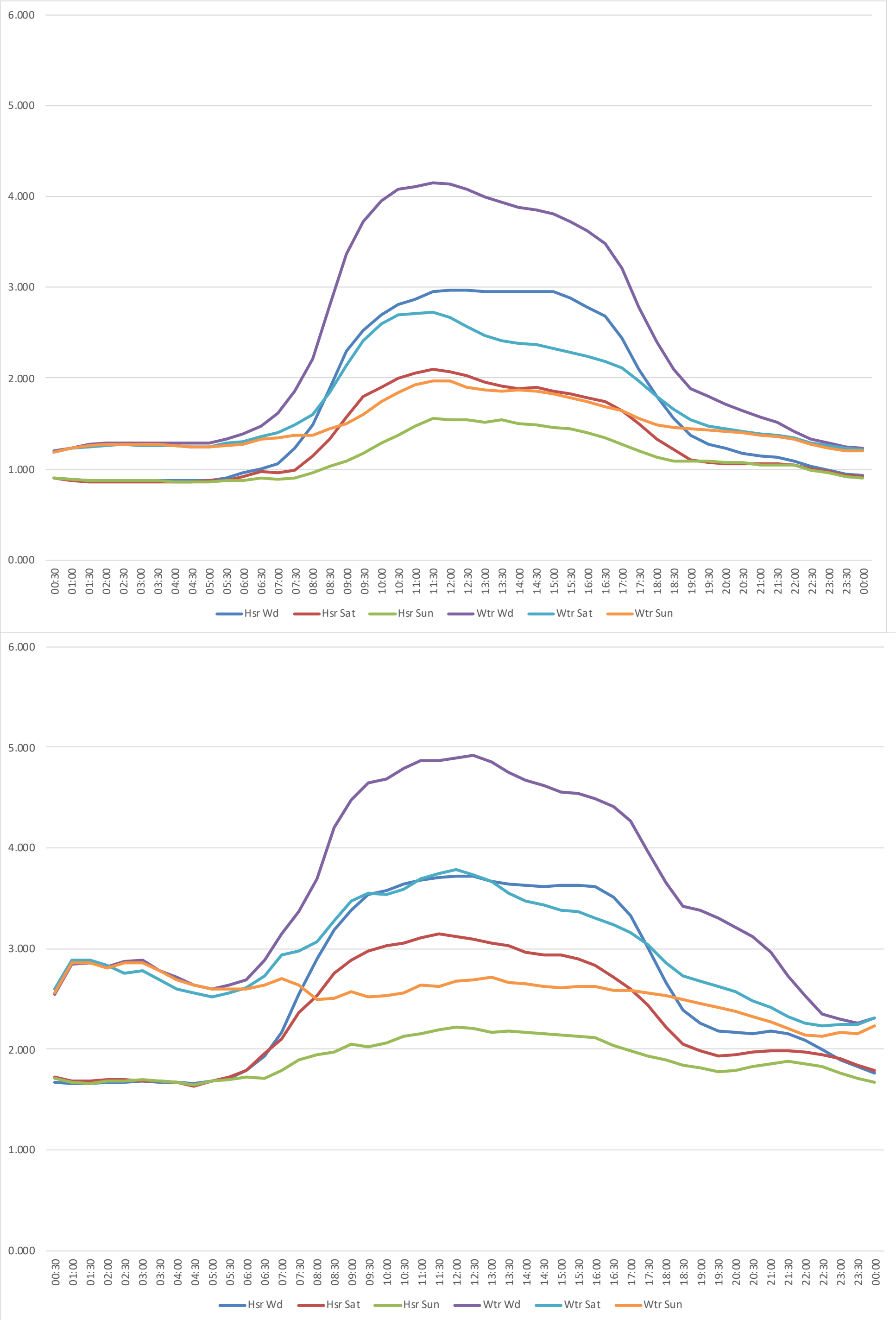


Source: Elexon (https://www.elexon.co.uk/operations-settlement/profiling/)

Key: Hsr (High Summer), Wtr (Winter), Wd (Weekdays), Sat (Saturday), Sun (Sunday) (https://www.elexon.co.uk/wp-content/uploads/2012/01/Definitions-of-seasons-and-day-types_v1.01.pdf)

D.20 Non-domestic customers have different profiles when compared to domestic ones reflecting core office hours, as illustrated in Figure D.13. Other non-domestic customers (Profiles 5 to 8) exhibit similar profiles albeit at higher levels of demand.

Figure D.13: Daily Electricity Demand Profiles for Average Non-Domestic Unrestricted (Profile 3, left-hand side) versus Average Non-Domestic Economy 7 Customers (Profile 4, right-hand side), 2013-14, kW



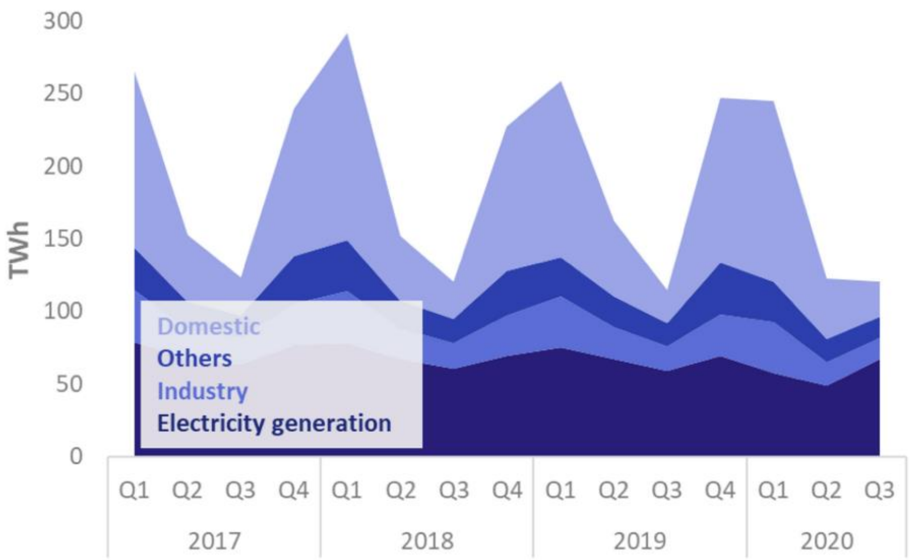
Source: Elexon (https://www.elexon.co.uk/operations-settlement/profiling/)

Key: Hsr (High Summer), Wtr (Winter), Wd (Weekdays), Sat (Saturday), Sun (Sunday) (https://www.elexon.co.uk/wp-content/uploads/2012/01/Definitions-of-seasons-and-day-types_v1.01.pdf)

Natural Gas

D.21 On a similar basis to electricity, patterns in gas demand varying according to the season, day of the week and time of day, being driven by gas demand sources. In Great Britain, the three main sources of gas demand are: residential gas demand covering domestic and small businesses primarily used for space heating; gas used by gas-fired plants to generate electricity and industrial gas demand.

Figure D.14: UK Gas Demand, Q1 2017 to Q3 2019



Source: National Statistics (https://www.gov.uk/government/statistics/gas-section-4-energy-trends)

Forecasts for Future Energy Demand

D.22 One of the UK Government's priorities is ensure the country has a reliable, low cost and clean energy system. Since 2017, energy policy has been made in line with the Government's Clean Growth Strategy,[75] which sets out proposals for decarbonising all sectors of the UK economy through the 2020s. In 2019, the UK become the first major economy to adopt a legally binding obligation to reach net zero greenhouse gas emissions by 2050.[76] At the end of 2020, a Ten Point Plan for a Green Industrial Revolution[77] and an Energy White Paper were published with new policies and commitments across many aspects of the energy system including consumers, power generation, hydrogen, transport, buildings and industrial energy. The Climate Change Committee also published its Sixth Carbon Budget, with a recommended pathway requiring a 78% reduction in UK territorial emissions between 1990 and 2035.[78]

D.23 Decarbonising energy means that energy markets are witnessing high rates of change. The scale of transformation in energy markets is likely to open up a range of potential radical new

[75] https://www.gov.uk/government/publications/clean-growth-strategy

[76] https://www.gov.uk/government/news/uk-becomes-first-major-economy-to-pass-net-zero-emissions-law

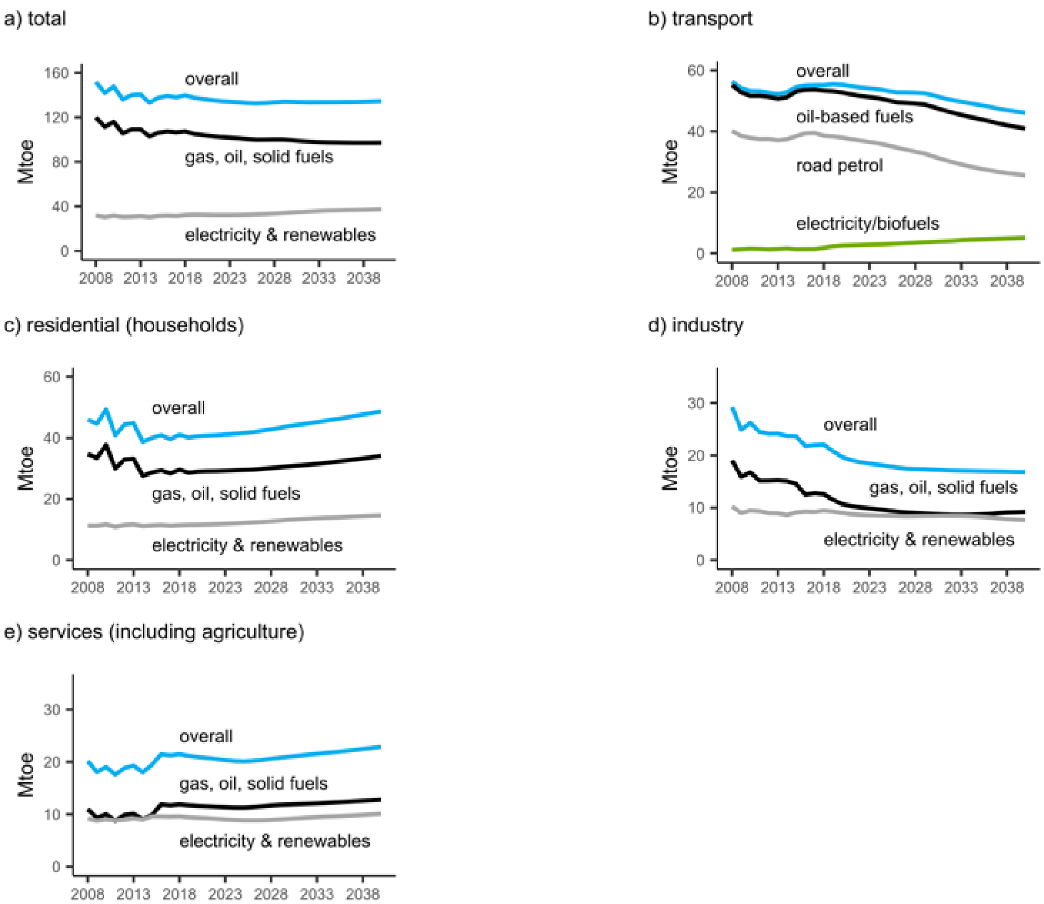
[77] https://www.gov.uk/government/publications/the-ten-point-plan-for-a-green-industrial-revolution

[78] https://www.theccc.org.uk/publication/sixth-carbon-budget/

business models and opportunities for new and innovative products and services. Energy consumers are likely to assume a completely new central role as active participants in the market. Historically, energy use by households and businesses was largely passive, with the emphasis on availability when it was required and little concern about how much energy was consumed so long as it was affordable. However, the emergence of advanced technology (e.g., smart energy systems, heat technologies, electric vehicles, etc.) means that smart consumers can potentially make more informed choices about when and how much energy they consume, and ultimately becoming energy producers and storers – or prosumers – themselves.

D.24 The Government predicts that final energy demand will fall until the year 2026. Demand then rises slowly as the effects of policies diminish and macroeconomic factors continue to push it up. By 2040, it is predicted final energy demand will be 4% lower than in 2018, representing about a 14% reduction in per capita demand.

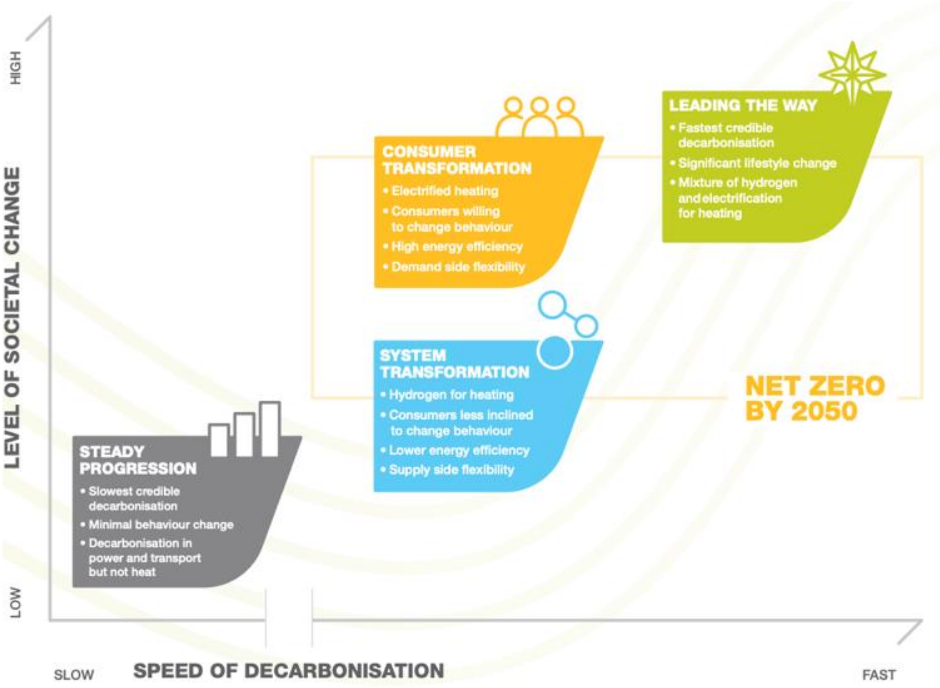
Figure D.15: Final Energy Demand by Sector and Fuel, 2008 to 2040



Source: BEIS (https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2019)

D.25 National Grid ESO, the electricity system operator for Great Britain, has developed a set of scenarios which have net zero at their core and explore how the level of societal change and speed of decarbonisation could lead to range of possible pathways.

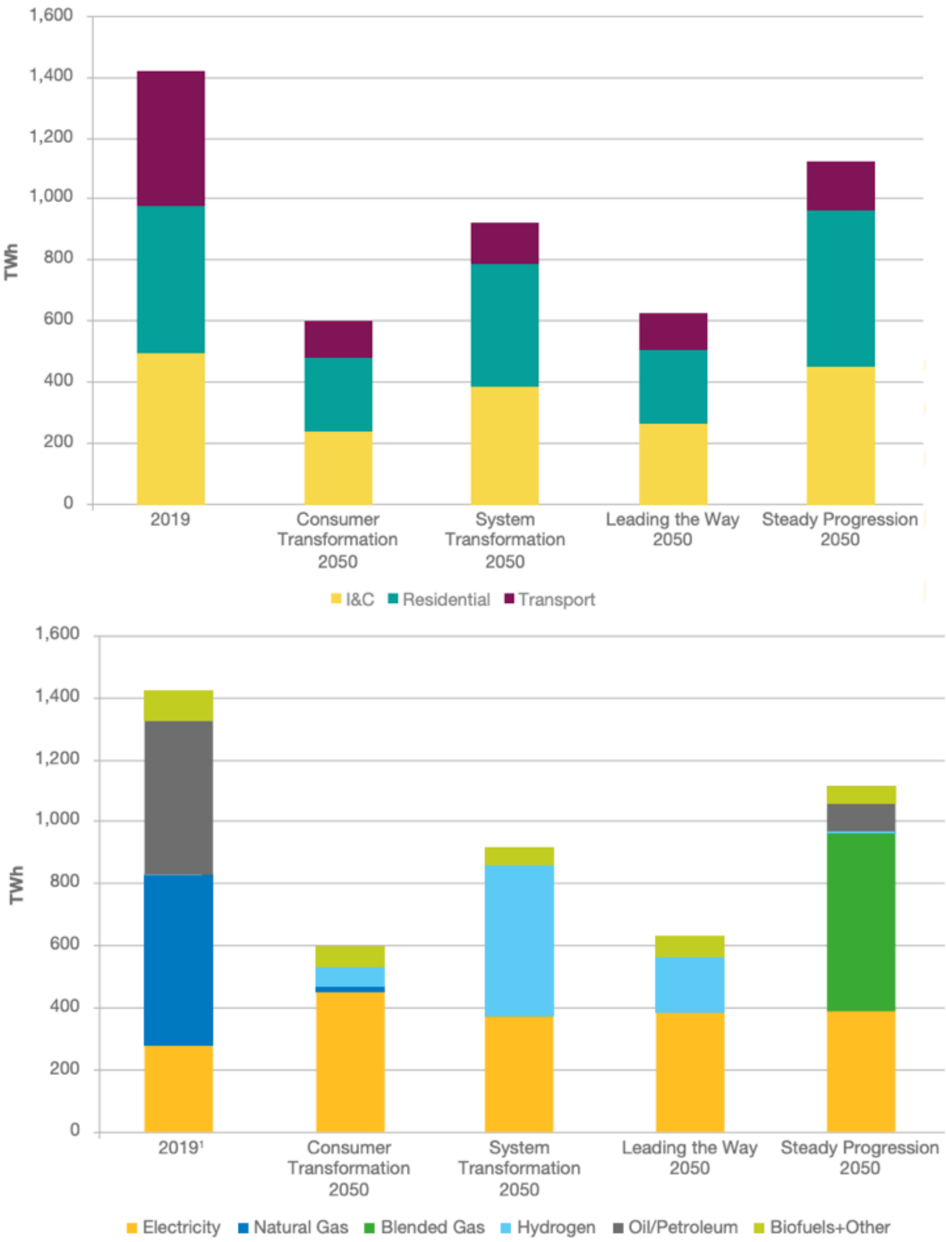
Figure D.16: National Grid Future Energy Scenarios 2020



Source: National Grid (**https://www.nationalgrideso.com/future-energy/future-ener1gy-scenarios/fes-2020-documents**)

D.26 Annual end consumer energy demand in 2050 in these scenarios is illustrated in Figure D.17.

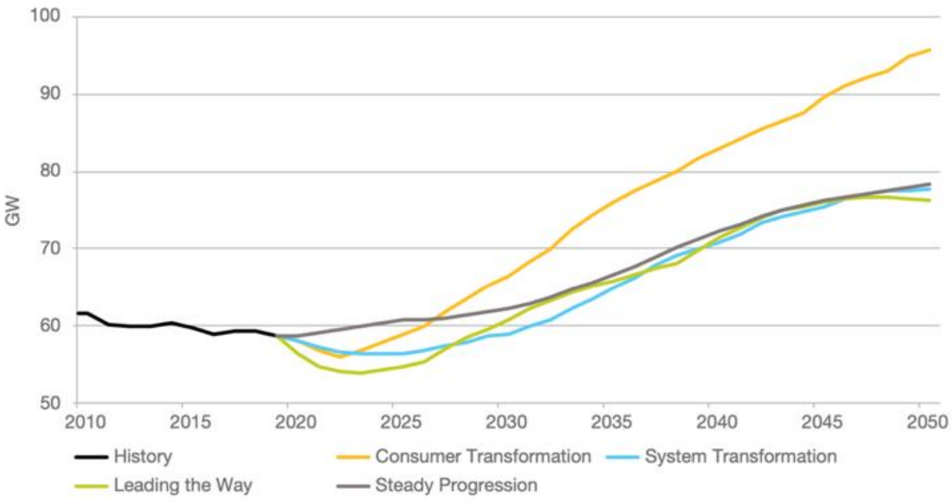
Figure D.17: Annual end consumer energy demand, By sector and fuel, 2019 and 2050



Source: National Grid (https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2020-documents)

D.27 The scenarios predict that as demand becomes smarter and end consumers begin to increase their consumption at times of low prices caused by high renewable output on the energy system, it could be possible that the consumption at these times could exceed the traditional peak demand. The emergence of electricity demand from technologies (e.g., electric vehicles, hydrogen electrolysers) will significantly amplify this effect. On the other hand, when renewable output is low, flexible demand will reduce its consumption and storage technologies (e.g., battery storage, vehicle to grid) will discharge power back into the system.

Figure D.18: Electricity peak demand (including losses)



Source: National Grid (https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2020-documents)

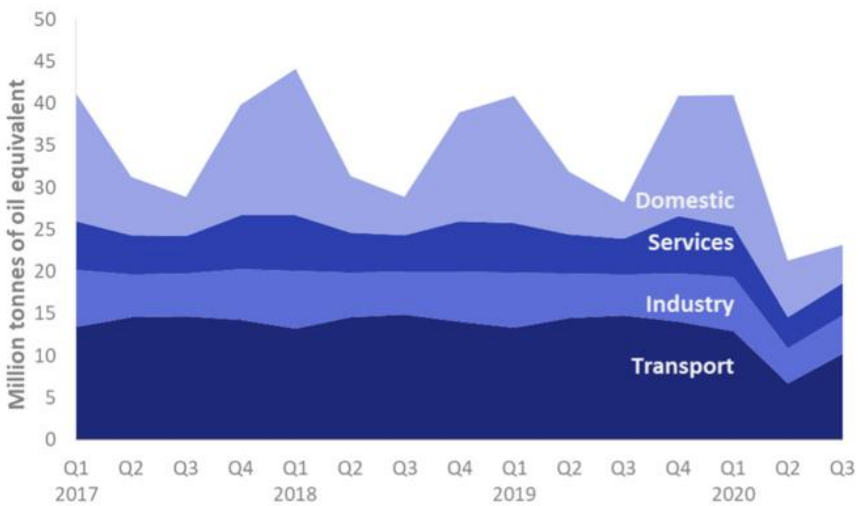
Observed Impacts of the Pandemic on Energy Demand

Overall Energy Consumption

D.28 Energy consumption in the UK has been affected by the pandemic as the COVID-19 restrictions affect economic output, leisure activities and travel. Total final energy consumption fell by 18% between Q3 2019 and Q3 2020, though there were notable differences by sector:

- Domestic sector consumption increased by 2.5%, as home working became more common;
- Transport sector consumption fell by 30%, as lockdown restrictions affected both domestic and international travel;
- Service sector consumption fell by 7.8% as many shops and offices were closed; and
- Industrial sector consumption fell by 8.4%.

Figure D.19: Final Energy Consumption by Sector, Q1 2019 to Q3 2020

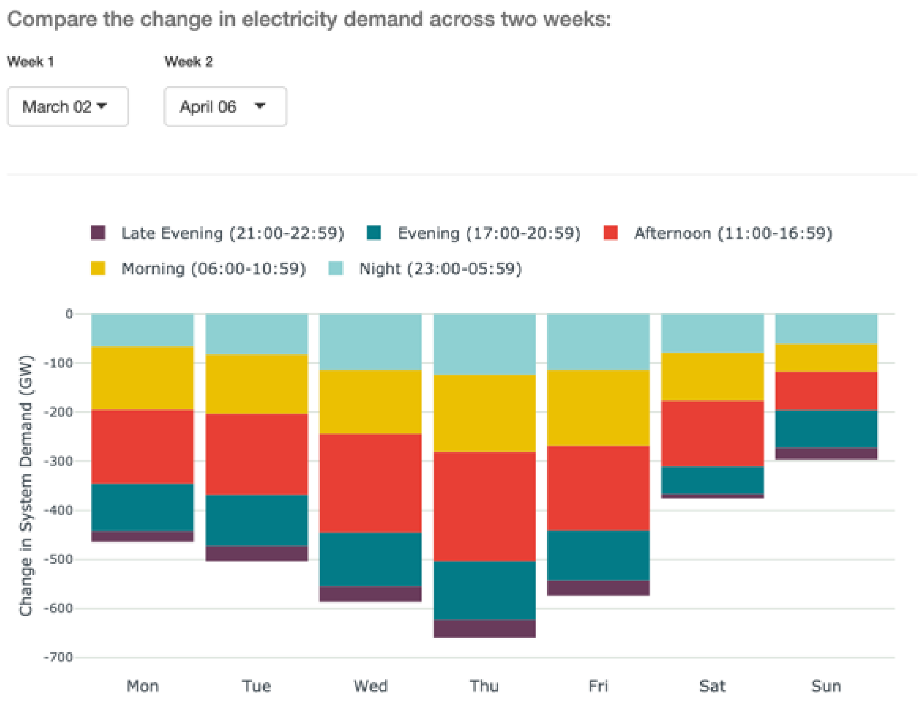


Source: BEIS (https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/946748/Energy_Trends_December_2020.pdf)

Electricity Consumption

D.29 During the first lockdown in 2020, with people working from home and children doing home schooling meant that routines around the start of the day, the school run, commuting and mealtimes, were either spread out or not undertaken. This caused weekday morning peak in demand to flatten out. Afternoon demand also flattened but this was largely due to embedded solar generation lowering transmission system demand when it was sunnier than usual.

Figure D.20: Comparison of change in daily transmission level electricity demand by week

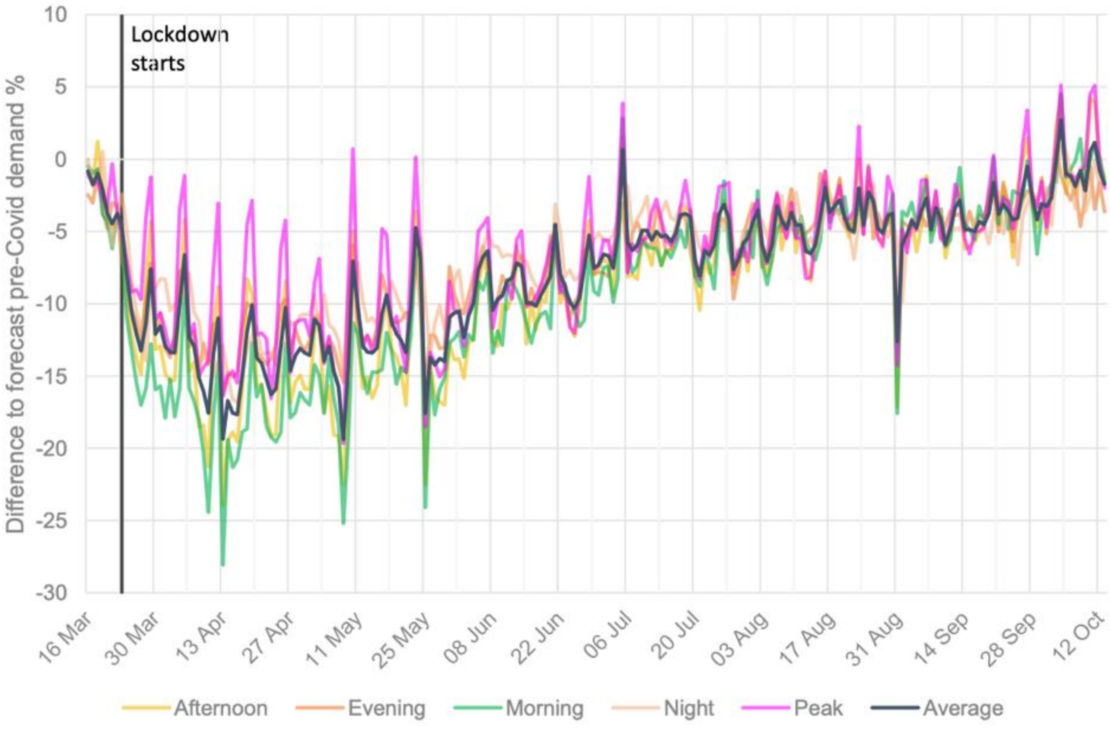


Source: Frontier Economics (https://www.frontier-economics.com/uk/en/news-and-articles/articles/article-i7214-how-is-covid-19-impacting-the-uk-electricity-system/#)

Note: Transmission system demand is net of distributed generation (solar and wind). Increased generation from these embedded sources reduces transmission system demand.

D.30 The impact of the 2020 lockdown on electricity demand is presented by Figure [x], which illustrates how demand returned to around 5% below pre-COVID-19 expectation in August and September, with some evidence that it was moving toward expectation as restrictions were further eased:

Figure D.21: Percentage change in demand relative to pre-COVID-19 expectation



Source: National Grid ESO (https://www.nationalgrideso.com/research-publications/winter-outlook)

Gas Consumption

D.31 During the initial phase of lockdown (March to mid-May), National Transmission System gas demand was reduced significantly (between 6-11%) when compared to weather corrected seasonal normal levels. As lockdown restrictions were eased this reduction decreased to 2% below seasonal normal levels.[79]

Implications for Modelling Energy Demand

D.32 Historically, energy demand in aggregate influenced infrastructure need which ensured supply matched peak demands, which was driven by structural factors such as seasonal, weekly and within day variations.

D.33 In the UK, there are clear long-term trends in energy demand and lower energy consumption per capita, driven by decarbonisation, greater energy efficiency and the emergence of advanced technologies. As a result, the UK's energy system is undergoing a period of significant and continuous change as fossil fuels are eliminated in order to respond to climate change. Importantly, energy consumers are becoming smarter as they make more informed choices about how and when they consume energy, and even shifting to becoming prosumers – who produce and store energy – themselves.

D.34 For the residential sector, electrification is likely to play a big role, particularly for cars and heating, with demand likely to become smarter, with technologies such as electric vehicles

[79] https://www.nationalgrid.com/uk/gas-transmission/insight-and-innovation/winter--outlook

and battery storage. Such technologies are likely to help to flatten peaks in energy demand within day, between weekdays and weekends, and between seasons.

D.35 Evidence to date from the first lockdown in 2020 during the COVID-19 pandemic can be summarised as follows:

- Total energy consumption reduced by almost a fifth between Q3 2019 and Q3 2020, although the permeance of this fall is uncertain given the time of year when the weather was relatively warm.
- There has been a shift in demand from non-households to households and from urban to suburban areas, with service sector consumption falling by 7.8% and industrial sector consumption by 8.4%, whilst domestic consumption increased by 2.5% over the same period.
- Within day electricity consumption by households changed due lockdown restrictions imposing working from home and home schooling, causing morning peaks in demand to flatten as activity was spread throughout the day. Shifts to new working patterns with a greater emphasis on working from home may result in permanent changes in household energy demand.
- Overall, the permanence of changes are uncertain. As restrictions eased over the course of 2020 demand returned to around 5% below pre-Covid levels, with some indications that demand was returning to expected levels as restrictions were further eased, highlighting that the pandemic’s impact could be temporary.
- Further evidence on the impacts of lockdowns on energy consumption will be provided once data is published by the government covering the lockdowns since Q4 2020.

E Water & Waste Water

Introduction

E.1 This Appendix considers the impact of the COVID-19 pandemic on the demand for water and the generation of wastewater and examines the implications for the modelling of that demand. It provides an introduction to the sector and considers the components of demand and the key drivers behind that demand, before looking at historical levels of demand and various projections for future demand. Evidence of the COVID-19 pandemic's impact on demand is summarised and, in light of that evidence, our initial thoughts on an approach to the modelling of future water demand are developed.

E.2 In England and Wales, water and sewage services are provided to household and non-household consumers by 32 privately-owned companies; the state-owned Scottish Water and Northern Ireland Water provides these services in Scotland and Northern Ireland respectively. The companies (generally) have geographic monopolies which are broadly based on river catchment areas. Untreated water is obtained from lakes, reservoirs, rivers or underground sources, from where it is pumped to water treatment plants. Following final treatment, the water leaves the treatment works and is stored in covered reservoirs, from where it is pumped to consumers through a network of pipes and pumping stations.

E.3 Sewage is generated by residential, institutional, commercial and industrial establishments and may also include stormwater runoff and urban runoff. Combined sewer systems (which are typical in the UK) are designed to accommodate all these wastewaters. However, as the COVID-19 pandemic cannot affect stormwater, this Appendix only considers wastewater generated by residential, institutional, commercial and industrial establishments, the volume of which is considered to be a function of water demand.

Key Metrics

E.4 Key characteristics[80] of water demand and wastewater generation in England and Wales can be summarised as follows:

- just over 26 million household and business properties connected to the public water supply network;
- demand for water in England and Wales was about 14 billion litres per day,[81]
- people use, on average, 142 litres per person each day. However, consumption ranges from 127 litres per person per day for Southern Water to 160 litres per person per day for Welsh Water; this has increased each year since 2014-15;

[80] Source: https://discoverwater.co.uk/

[81] 2018, https://www.nao.org.uk/wp-content/uploads/2020/03/Water-supply-and-demand-management-Summary.pdf

- Metering makes a difference to consumption: customers with water meters use an average of 129 litres per person per day (range of 113-150 litres per person per day) compared to 171 litres per person per day for non-metered customers (range of 133-284 litres per person per day);
- 2,954 million litres of water leaked each day from the 346,455 km of water pipes (mains) owned by water companies, an average of 112 litres per property per day (range of 68-152 litres per property per day);
- Over 624,200 km of sewers collect over 11 billion litres of wastewater per day from homes, municipal, commercial and industrial premises and rainwater run-off from roads and other impermeable surfaces.
- The UK's sewerage undertakers provide services to around 96% of the population.

E.5 In Scotland:[82]

- Scottish Water operates 237 water treatment works and delivers 1.44 billion litres of drinking water per day to some 2.56 million households and 152,806 business premises across Scotland;
- Scottish Water operates just over 1,800 wastewater treatment works and removes 983 million litres of wastewater per day;
- It manages 30,400 miles of water pipes and 33,655 miles of sewer pipes;
- Each person uses approximately 150 litres of water a day;
- Leakage from the Scottish Water networks fell to below 470 million litres per day In 2019/20, an all-time low.

E.6 In Northern Ireland:[83]

- Approximately 560 million litres per day of drinking water are delivered to about 840,000 households and businesses;
- About 330 million litres of wastewater per day are collected from some 669,000 households and organisations connected to the sewerage system;
- There are 23 water treatment works and 26,700 kilometres of water mains, as well as 15,600 kilometres of sewers and 1,030 wastewater treatment works;
- The average person uses about 150 litres of water a day;
- About 25% of drinking water is lost to leakage.

E.7 It has been estimated[84] that about 93% of total water consumption is used indoors while only 7% is used outdoors. For planning purposes, the proportion of water consumption that is returned to the sewer network is generally put[85] at between 90% and 95% (this proportion will vary from location to location depending on the characteristics of local water consumers).

E.8 The distribution of residential water consumption is shown in Figure E.1.

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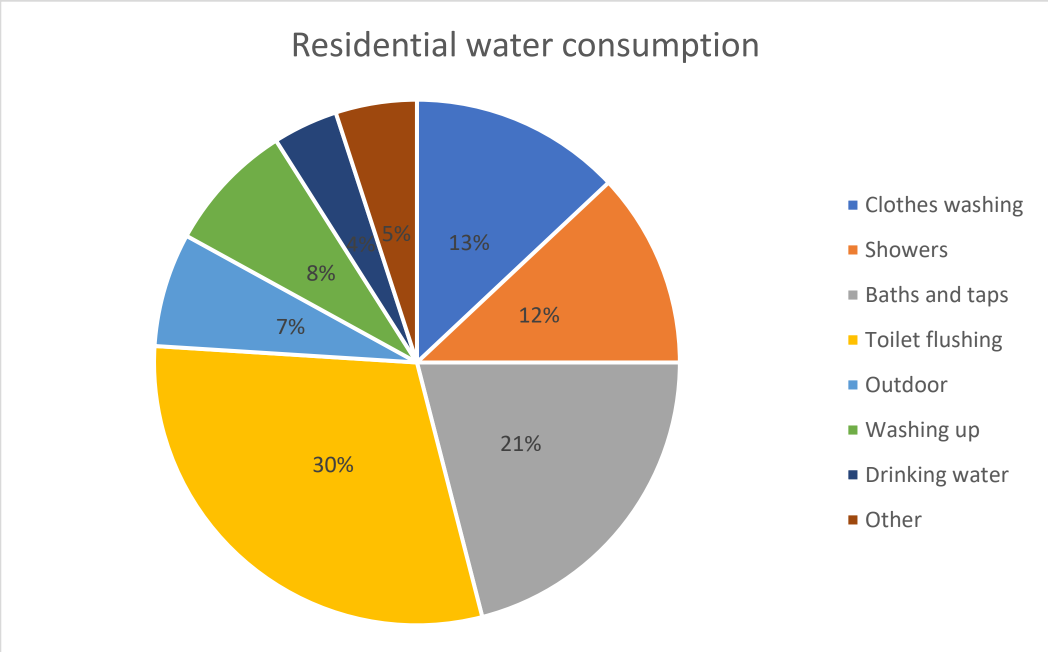
[82] Source: Various Scottish Water Reports (at https://www.scottishwater.co.uk/)

[83] Source: Various Northern Ireland Water Reports (at https://www.niwater.com/home/)

[84] **https://www.wte-ltd.co.uk/wastewater-amounts-in-the-home.html**

[85] CIWEM UDG Code of Practice for the Hydraulic Modelling of Urban Drainage Systems 2017

Figure E.1: Residential water consumption by use (% share)



Factors Driving Demand

E.9 The process of forecasting demand for water is made up of a number of steps which cover the key factors driving the level of demand:

- Size of the population, forecasts for which are generally based on local authority plans;
- Per capita consumption (PCC), which is influenced by a number of factors:
  – The proportion of households that are metered: It is estimated[86] that metering can potentially reduce consumption by between 10% and 15%, which will significantly reduce PCC. The impact of this on aggregate demand will depend on water companies' metering strategies.
  – Demographic, socio-economic variables and cultural and religious practices.
  – Tariff structure or water price – which are also recognised as key influences on the level of water consumption.
  – Technology: the improving efficiency of water fixtures and fittings such as toilets, dish washers and washing machines. For example, in England and Wales, toilet flushing is the component of PCC that is significantly higher than in other countries. Fitting older cisterns with variable flush mechanisms could be used to reduce domestic consumption.
  – Regulations: Changes in building regulations could increase the water efficiency of new housing.
- Changes in non-household (i.e. business, commercial and industrial) consumption: local authority plans generally provide the basis for water companies' forecasts of non-household demand (most non-household demand is measured) – these take account of the different compositions of such demand across companies' Water Resource Zones (WRZs).

[86] Environment Agency - International comparisons of domestic per capita consumption, 2008.

- The level of leakage: in part influenced by water companies' leakage reduction targets. Defra has set annual targets for water companies and longer-term targets to reduce leakage by a third by 2030 and by half by 2050. Ofwat expects leakage to fall by 16% between 2020 and 2025.
- Other: including water companies' own use of water (for operational purposes) and unbilled water (water used legally or illegally without charge).

E.10 Water companies generate demand projections for each of their WRZs[87] – there are some 70 WRZs in England and Wales which vary in size from 5,000 to 8 million people with demand of between 1.4 Ml/d and 2,070 Ml/d.[88]

E.11 The weather is an important influence on demand. For example, customers will use more water for activities such as garden watering or filling paddling pools in hot weather, while cold weather can cause pipes to contract and leak, increasing leakage. However, the impact of weather on demand is outside the scope of this Appendix.

E.12 As stated previously, the volume of wastewater generated is a function of the demand for water.

Historical Trends in Demand

E.13 The quality of data on the use of public water supply is considered[89] variable, and requires gap filling and estimation to provide national picture. There are many stakeholder relationships as data is held by individual companies and the collation of data is a lengthy and complex process. In contrast, data on freshwater resources is considered good, with data on net abstraction from those resources not as good.[90] Nevertheless, in order to show historical trends in demand for water, it is considered appropriate to use estimated abstractions as a proxy.

E.14 Estimated abstractions for public water supplies from 2000 to 2017 are shown in Figure E.2.

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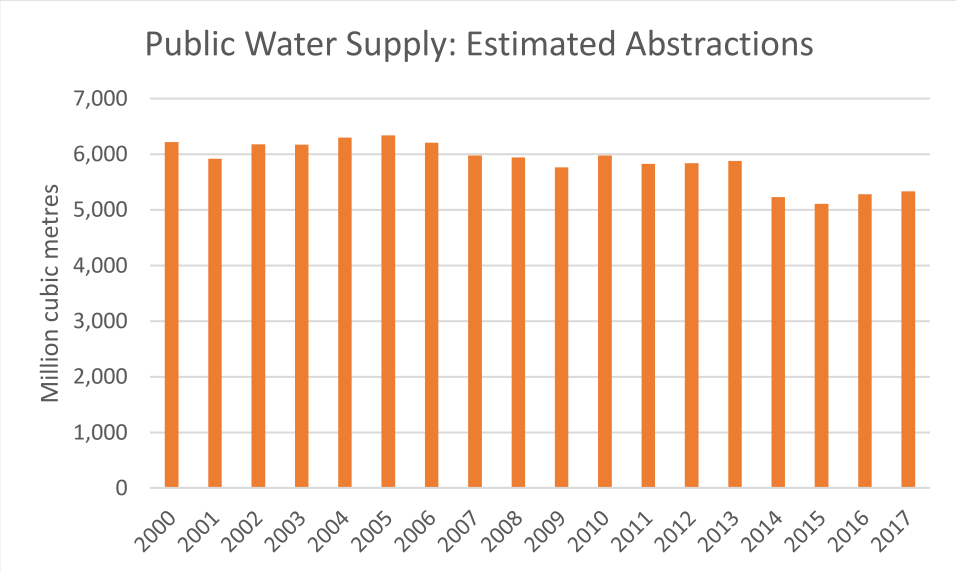
[87] Defined as the largest area of a water company's supply system where all customers have the same supply risk.

[88] Environment Agency, Meeting our future water needs: a national framework for water resources, March 2020

[89] Defra – Water Statistics in the UK, R&D Technical Report WT1509, March 2013

[90] Abstraction is the removal of water resources, permanently or temporarily, from rivers, lakes, canals, reservoirs or from underground strata.

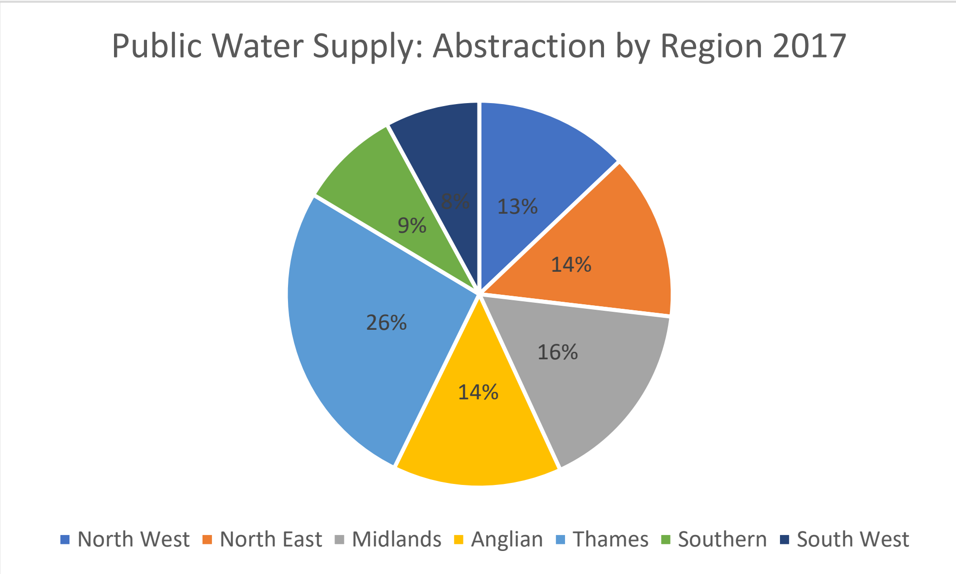
Figure E.2: Public Water Supply: Estimated Abstractions



E.15 Although abstractions increased in 2016 and 2017 from the low seen in 2015, they were still some 16% below the peak seen in 2005.

E.16 The geographic distribution of abstraction for public water supply in 2017 is shown in Figure E.3.

Figure E.3: : Public Water Supply: Abstractions by Region



E.17 As could be expected, the Thames region is the main source of demand, accounting for just over a quarter of the total.

E.18 The generation of wastewater will have followed the same patterns as those for water.

Forecasts for Future Demand

E.19 All water companies are required to develop Water Resource Management Plans (WRMP) which are underpinned by water demand forecasts which must cover a period of at least 25 years – the most recent WRMPs were produced in 2019. WRMPs are specific to the geographic areas that the individual companies serve and are based on a company's WRZs.

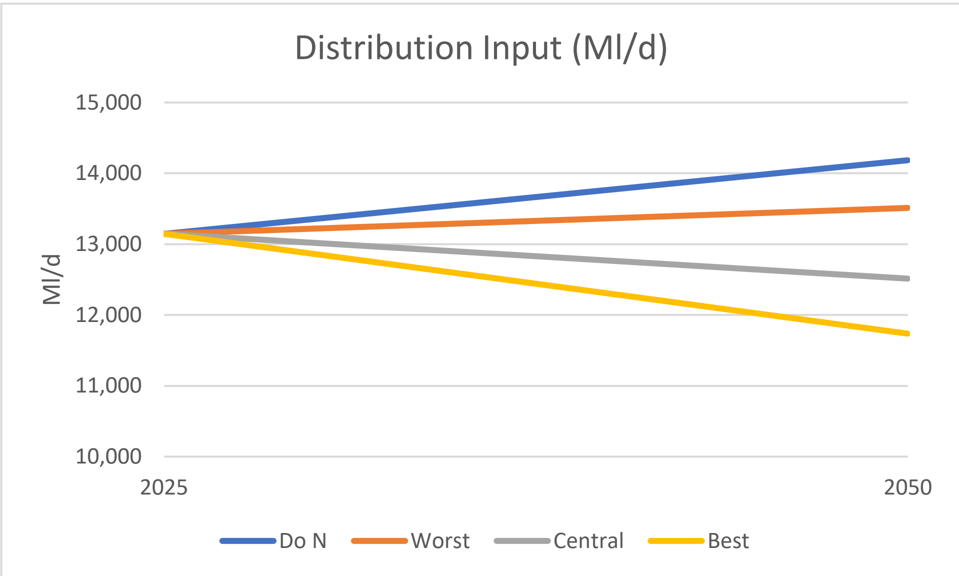
E.20 Based on water companies' 2019 WRMPs, and as part of its "Water resources national framework", the Environment Agency developed a (not publicly available) national water resources supply demand model which covered the whole of the country. The detailed modelling was undertaken at the Water Resource Zone level, with results produced at a regional level. The model was aimed at providing *a national and regional picture of the future challenges to public water supply.*

E.21 From a baseline of 2025, four scenarios were developed as part of the modelling exercise:

- The "do nothing" options predicted the water situation in 2050 if no new options were implemented either to reduce consumption or leakage or to increase supply through developing new options;
- Best case scenario: household PCC of 110 l/h/d; 4% reduction in non-household demand by 2050; 50% reduction in leakage from 2017/18;
- Central case scenario: household PCC of 118 l/h/d; no reduction in non-household demand by 2050; reduction in leakage as set out in the companies' 2019 WRMPs;
- Worst case scenario: household PCC of 127 l/h/d; no reduction in non-household demand by 2050; 30% reduction in leakage from 2017/18.

E.22 Results for the four scenarios are shown in Figure E.4.

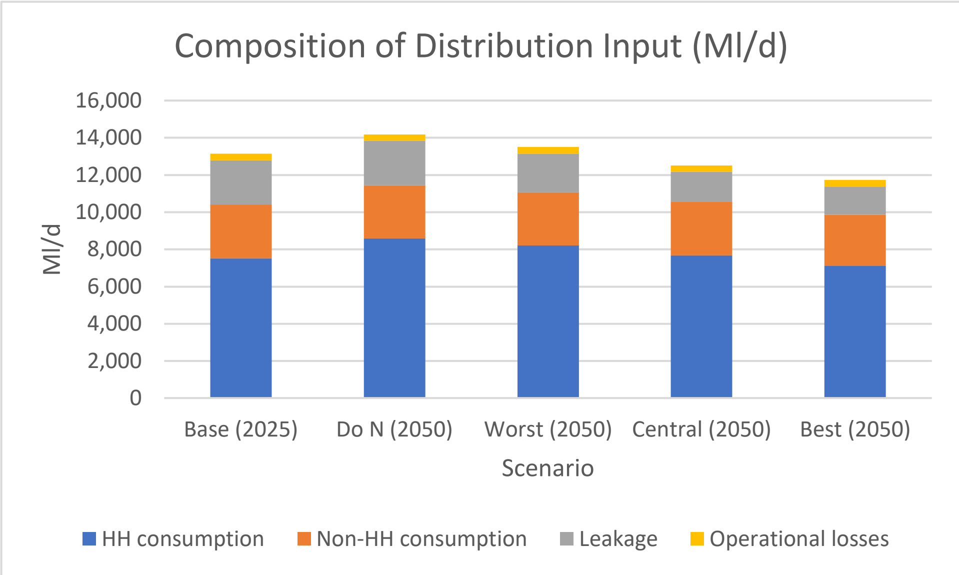
Figure E.4: Distribution Input under the four scenarios



E.23 In these scenarios, the volume of water required for distribution in 2050 ranges from 10.7% less to 7.9% more than in 2025.

E.24 The composition of Distribution Input under each of these scenarios is shown in Figure E.5.

Figure E.5: Composition of Distribution Input



E.25 In the best-case scenario (and compared with the base), the share of household consumption in total distribution input increases from 57% to 61%, while that of leakage falls from 18% to 13%.

E.26 According to the NAO,[91] total water supply is forecast to decrease by 7% by 2045 as a result of climate change and the need to reduce abstraction to restore sustainability. In aggregate, water companies' WRMPs show that total demand would start to exceed supply in 2034-35. In addition, it is estimated that demand for water in England will exceed supply by between 1.1 billion and 3.1 billion litres per day by the 2050s, depending on the extent of climate change and population growth. With low-cost options for increasing water supply running out, the NAO argues that reducing demand is essential to prevent water shortages.

E.27 This position has been reinforced by the House of Commons Public Accounts Committee[92] which considered that it is "wholly unacceptable that over 3 billion litres are wasted every day through leakage, with no improvement in the last 20 years". It continued "we are unconvinced by Ofwat's hope that water companies will 'surprise themselves' at what they can achieve and call on the Department and Ofwat to be more proactive in ensuring companies meet leakage targets".

E.28 The volume of wastewater generated by households and non-households will follow respective water consumption patterns. However, forecasts for the volume of wastewater treated also need to take account of urban surface runoff (which may be problematic at times of severe storms and flooding) – the total volume will affect both network size and capacity requirements. Meanwhile, meeting environmental standards will increase wastewater treatment demand since there is a limit to the capacity of receiving waters in the environment to assimilate the waste for a given effluent standard.

[91] National Audit Office Report – Water supply and demand management, 11 June 2020.

[92] House of Commons Public Accounts Committee - Water supply and demand management – 10 July 2020.

Observed Impacts of the COVID-19 Pandemic on Demand

E.29 There have been various studies, both in the UK and elsewhere, into changes in water demand as a result of the lockdowns imposed in response to the COVID-19 pandemic.

E.30 Analysis of water consumption patterns in the city of Karlsruhe, Germany found[93]:

- the demand peak shifted from around 7.10 am (pre-lockdown) to around 9.40 am (under lockdown);
- with more people staying at home, water consumption flattened out over the course of the day.

E.31 UK data, based on consumption from about 200,000 households and some 1,000 non-households,[94] found:

- the morning peak started later in the day for households;
- household peak daily consumption at the end of May 2020 was about 35% higher than it was pre-lockdown, and the evening peak was often higher than the morning peak, but this may be more attributable to the warm weather at the time;
- non-household consumption virtually disappeared during the lockdown.

E.32 The charges were attributed to a number of factors:

- the changes in behaviour from working at home and not needing to get children up and ready for school in the mornings;
- increased occupancy during the day (for example, older children returning home when colleges and universities closed);
- less movement of people between areas (people not going to work and not going away on holiday);
- changes in water use, such as more handwashing;
- the huge reduction in consumption from the hospitality, entertainment and retail sectors.

E.33 A comparison[95] of water use before lockdown (February to early-March) and at the beginning of lockdown (late-March to early-April) found:

- most water companies saw an increase in average water consumption during lockdown;
- companies covering predominantly suburban areas saw the most noticeable increase, while companies operating in city areas saw a reduction in water use; and
- differences between weekday and weekend water consumption largely disappeared.

E.34 A further study[96] (based upon a combination of quantitative evidence of changes in water demand, a rapid evidence assessment of news and other articles, and six focus group discussions) found that, as people spend more time at home, water consumption has changed

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[93] Source: **https://www.aquatechtrade.com/news/utilities/covid-19-lockdowns-impact-water-consumption/**

[94] Source: https://www.artesia-consulting.co.uk/blog/New Waterwise article! The effect of the coronavirus lockdown on water use

[95] Source: **https://blog.metoffice.gov.uk/2020/07/14/helping-to-forecast-water-demand-during-covid-19/**

[96] Understanding changes in domestic water consumption associated with COVID-19 in England and Wales, Artesia Consulting and University of Manchester, November 2020

as a result of changes in personal hygiene practices (e.g. increased handwashing, washing of clothes, or showering aimed at minimising risk of infection) as well as changes in other water use (such as gardening, filling paddling pools and cooking).

E.35 Focus group participants expected their new water use patterns to persist (i.e. increased cooking, drinking, flushing the toilet, gardening; reduced laundry; changing rhythms of showering and increased use of baths for leisure). They expressed their desire to maintain some leisure uses of water that have emerged (i.e. bathing) or increased (i.e. gardening and growing vegetables) since the lockdown even when they were conscious of the increased water usage associated to these activities.

E.36 As a result of customers spending more time at home and less time in non-household venues, a further study[97] found:

- An increase in household consumption and in PCC – almost all companies experienced a significant increase in household consumption and PCC over the April-July 2020 period, driven by a combination of the hot weather and the restrictions caused by COVID-19.
- Reflecting the location of household and non-household consumption, the location of demand has changed.
- A decrease in non-household consumption – all companies that provided data experienced a significant reduction in non-household water consumption over the April-July 2020 period. Non-household customers in the 0.5-50Ml per year usage category (representing relatively low usage customers such as high street retailers) saw the biggest reduction.

E.37 More research[98] found that the effect of the COVID-19 pandemic on total water demand varied from community to community. Key factors are both the relative proportion of residential and non-residential water uses and the makeup of the non-residential sectors in the community. Most communities – including larger metropolitan systems in Boston (Massachusetts), Pittsburgh (Pennsylvania), and Austin (Texas) – experienced a reduction in total demand. However, more residential communities experienced either modest increases in total demand or the smallest decreases.

E.38 While the net change in water demand was relatively modest for most systems, changes within a water system can be much more dramatic. The Cape Fear Public Utility Authority in North Carolina reported that while demand across its service area was down only 3% in April compared to the previous year, impacts on its three major subsystems were much larger. Its Sweeney Treatment Plant – which provides much of the water to the community and serves a mix of residential, commercial, industrial, and institutional users – experienced a 9% reduction in demand. In contrast, water demand in the two smaller systems that largely serve residential areas increased by 25% and 36%.

Implications for Modelling Water Demand by NIC Scenario

E.39 The five NIC scenarios are defined by the extent of the impact (high, medium and low) of the COVID-19 pandemic on four key characteristics:

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[97] Frontier Economics - Economic Impacts of Covid-19 on the Water Sector, Final Report, December 2020.

[98] Pacific Institute - Water and the COVID-19 Pandemic: Impacts on Municipal Water Demand, July 2020.

- Working from Home: inclination of people and businesses (i.e. employers and employees) to adopt flexible working and/or homeworking;
- Social Wariness: people being more cautious to participate in gatherings which involve being in close proximity to others;
- Dispersal from Cities: inclination of people and businesses to locate in densely populated areas, versus having more space in less densely populated areas. This covers suburbanisation (desire to move out of cities to suburbs and more rural areas), regionalisation (reduced population density and access to open spaces e.g. natural beauty) or combination of these; and
- Use of Virtual Tools: potential uptake of online and virtual activities in social, leisure, learning and consuming (including public services).

E.40 The manner in which the five scenarios have been defined is summarised in Table E.1.

Table E.1: Impact of scenarios on key characteristics

	Key Characteristic			
Scenario	Working from Home	Social Wariness	Dispersal from Cities	Use of Virtual Tools
1: Reversion and reaction	L	L	L	L
2: A more flexible future	M	L	H	M
3: Low social contact urban living	L	H	L	H
4: Social cities	H	L	L	M
5: Virtual local reality	H	H	H	H
Note: H = High, M = Medium, L = Low				

E.41 Evidence to date on the impact of the COVID-19 pandemic on water and wastewater demand can be summarised as follows:

- The impact on total demand is unclear;
- There has been a shift in the source of demand (from non-households to households);
- There has been a shift in the location of that demand (from city centres to suburbs);
- Morning peak demand has shifted to about two hours later.

E.42 The implications for modelling water and wastewater demand under the five NIC scenario can be summarised as follows:

- Increased household demand may be reflected in an increase in PCC. However, with the impact of the COVID-19 pandemic on aggregate demand unclear, this could be offset by a reduction in per-unit non-household demand.
- The importance of these changes will depend on the degree of the geographic granularity with which that demand is modelled. Modern, centralised, water infrastructures are considered to be quite rigid systems which do not adapt well to sudden changes – the infrastructure may, therefore, not be able to accommodate a shift in demand to suburban

areas. This will not be seen if modelled at the national or regional level but will be more important at the level of the WRZ.[99]

[99] NISMOD operates at the level of the WRZ. Water companies also report PCC at the level of the WRZ.

F Review of Models

Introduction

F.1 As part of this work, Steer was asked to consider how the NIC's scenarios could be assessed in greater detail using extant transport models.

F.2 There are three broad categories of models that can be used to model in detail the NIC's scenarios. These are:

1. the Department for Transport's National Transport Model and associated National Trip End Model, which are the models used to produce its Road Traffic Forecasts. These have a national scale
2. Land Use Transport Interaction models with a sub-national focus (which could be a region (e.g. North of England), a conurbation (e.g. Greater London) or an administrative area (e.g. county/district)
3. Fixed land use transport models, of which there are many across the country with scales ranging from regional to local and with different levels of model detail.

F.3 Models in the transport sector tend to be complex and take substantial time and money to develop. Most are also developed within the context of DfT's Transport Assessment Guidance (TAG), which sets out expectations for how data is used, and how models are structured, how they are calibrated and validated, as well as criteria for what is considered to be acceptable model performance.

F.4 To model the post-Covid scenarios appropriately there is a need to consider both explanatory variables and the parameter values that determine how models respond to changes to those explanatory variables. To illustrate this second point, almost all land use transport interaction models or transport models will assume that all other things being equal there is no change over time in how a model responds to the relative attractiveness of urban public transport vis-à-vis car. In a post-Covid world, this may or may not be the case and it could potentially be useful to use scenarios to explore the potential impact of a change in modal preferences.

F.5 While there are many models, there is a high degree of commonality with both the explanatory variables that they use as well as the formulation of the model and, because of this, the set of parameters that they use. However, parameter values vary from model to model reflecting the different geographic scales models cover, local socio-economic characteristics, the quality and coverage of the available data used to build the models and differences in model structure within the overall TAG context.

F.6 The adopted approach has been to take a small sample of models from each category and review the set of explanatory variables and parameters that they use. Five models have been considered:

- the DfT's National Transport Model/National Trip End Model;

- two Land Use Transport Interaction (LUTI) models (one each from the two principal classes of models in use, which are the System Dynamics-based Urban/Regional Dynamic Model and models built using DELTA, which is a neo-classical equilibrium model);
- Two fixed land-use models, one of which is a multi-modal Variable Demand Model and the other of which is focussed on highways.

National Transport Model

Model context

F.7 This section summarises the purpose and context of the National Trip End Model (NTEM) and National Transport Model (NTM). For this review, the principal documents consulted are:

- DfT (2016) *TAG Supplementary Guidance NTEM Sub-Models*
- DfT (2020) *National Transport Model - Analytical Review*
- WSP (2020) *National Transport Model Version 2r: Overview of Model Structure and Update To 2015*

F.8 While the text here has been prepared by Steer, a draft was shared with DfT officials for comment. This said, the following text should not be taken to represent the Department's position on the functionality of the two models reviewed or the potential use of NTEM and NTM to explore the NIC's scenarios.

Owner

F.9 Both NTEM and NTM are Department for Transport (DfT) models.

Purpose

F.10 NTEM is integral to DfT's Transport Assessment Guidance (TAG) suite of guidance documents and supporting tools. Outputs from NTEM are the starting point for the development of future year forecasts produced by models that are developed with regard to TAG (which includes models for any transport intervention seeking public sector funding). To this end, NTEM produces estimates of person travel by all modes (including walk and cycle) for each of 7,700 zones that make up Great Britain.

F.11 NTM is used to produce projections of traffic on different types of road by different vehicles types in different geographic areas (illustrated in Figure F.1). Its purpose is to:

- Produce evidence-based forecasts that represent the Department's best estimate of the future direction of the main road transport indicators such as road traffic, congestion and vehicle emissions;
- Explore variations of road traffic demand, including uncertainty around how it may evolve, to influence policy and strategy development;
- Be a policy and scenario testing tool;
- Inform the development of policy. Outputs of NTM underpin the DfT's 2018 Road Traffic Forecasts.[100]

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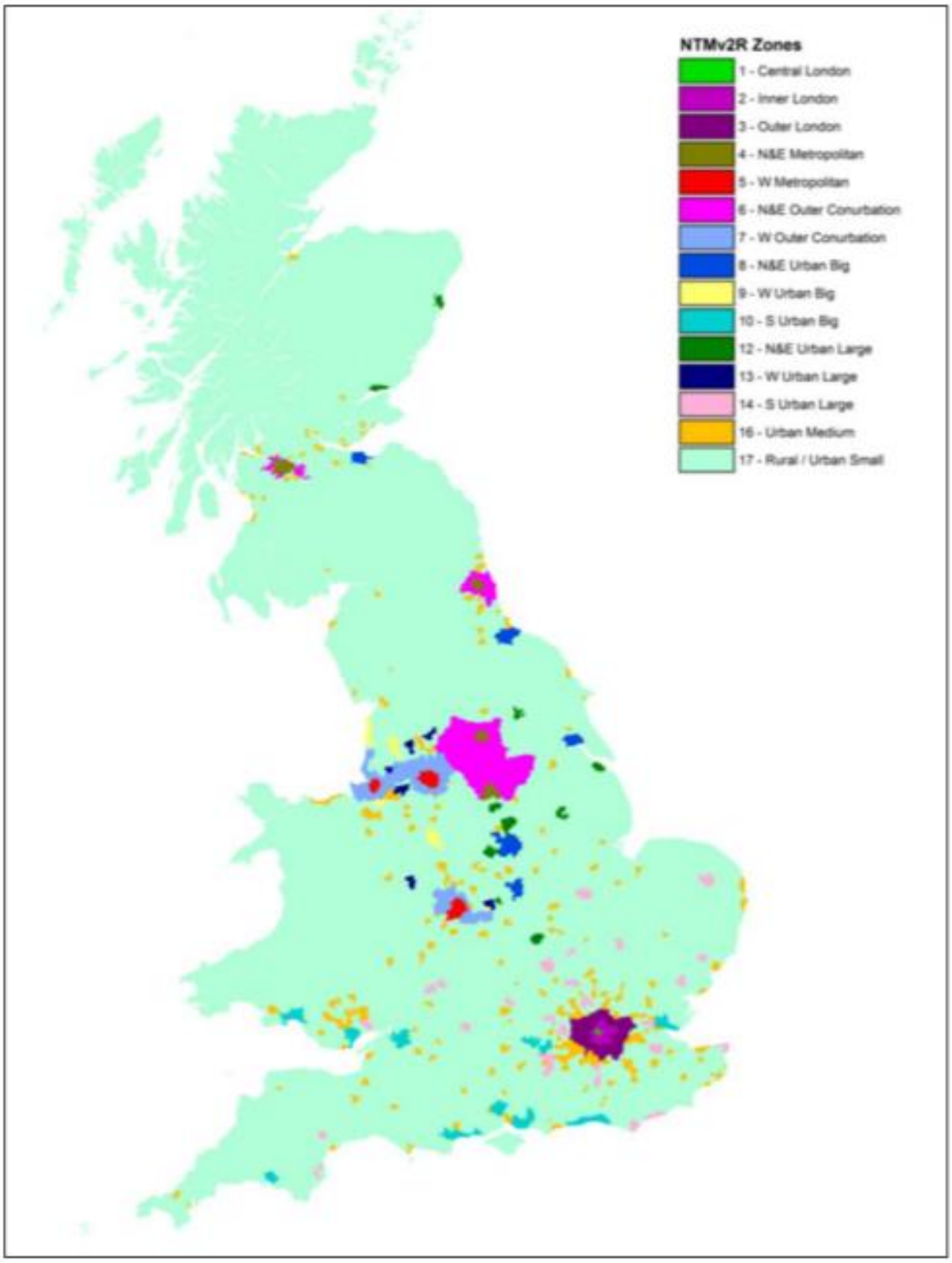
100 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/873929/road-traffic-forecasts-2018-document.pdf

Figure F.1: NTM – Geographic Coverage



Source: DfT (2020) *National Transport Model - Analytical Review*

Scope

F.12 NTEM and NTM cover Great Britain but not Northern Ireland. Currently, NTEM and NTM forecast transport demand up to 2050

Inputs

F.13 The NTEM uses as inputs:

- Forecasts of car ownership, which are outputs of the DfT's car ownership forecasting model (NATCOP);

- Tables of trip rates, mode split and time period profiles derived from National Travel Survey (NTS) data;
- Forecast year population and employment levels by zone.

F.14 Inputs to NTM include:

- Travel demand inputs (trip ends) – trip productions and attractions by zone. These are sourced from NTEM;
- Travel characteristics (i.e. generalised cost components) by mode (car, bus, rail, walk and cycle) for different combinations of trip purpose, trip length (distance band) and production/attraction zones (area types);
- Traffic growth for bus, LGVs and HGVs (from external models);
- Description of road network;
- Base year traffic data;
- Speed flow curves;
- Emission curves.

Outputs

F.15 Outputs of NTEM are trip productions and attractions by year by zone.

F.16 Outputs from NTEM are available via TEMPro (Trip End Model Presentation Program), which is readily available to transport analysts.

F.17 Outputs from NTM are:

- Average daily trips, disaggregated by mode, journey purpose, origin and destination zone type and length (by distance band);
- Traffic (vehicle km) and its speed on the road network disaggregated by region, area type, road type, vehicle type (including journey purpose for cars) and time period (within a week).

Limitations

F.18 The primary purpose of NTM is to produce estimates of future road traffic and associated impacts such as congestion and emissions. While NTM produces forecasts public transport, the Department maintains separate models to forecast rail demand. When looking at LGV and HGV traffic it may be more appropriate to use the Department's LGV forecasting model and the Great Britain Freight Model (GBFM) for HGVs.

Development

F.19 This review has focussed on the version of NTM that underpins the DfT's 2018 Road Traffic Forecasts. This is known as NTM v2R, which is NTM v2 re-based to 2015. DfT has developed NTM v5, which has greater spatial and network detail than NTM v2R. This later version of the model has yet to be used to underpin any published DfT projections of road traffic.

Model Functionality

F.20 NTEM produces trip end projections by:

- Estimating trip productions for each zone by multiplying zonal characteristics (segmented population) by trip rates derived from the National Travel Survey (NTS);
- Splitting these productions into the modelled time periods and by mode of travel;

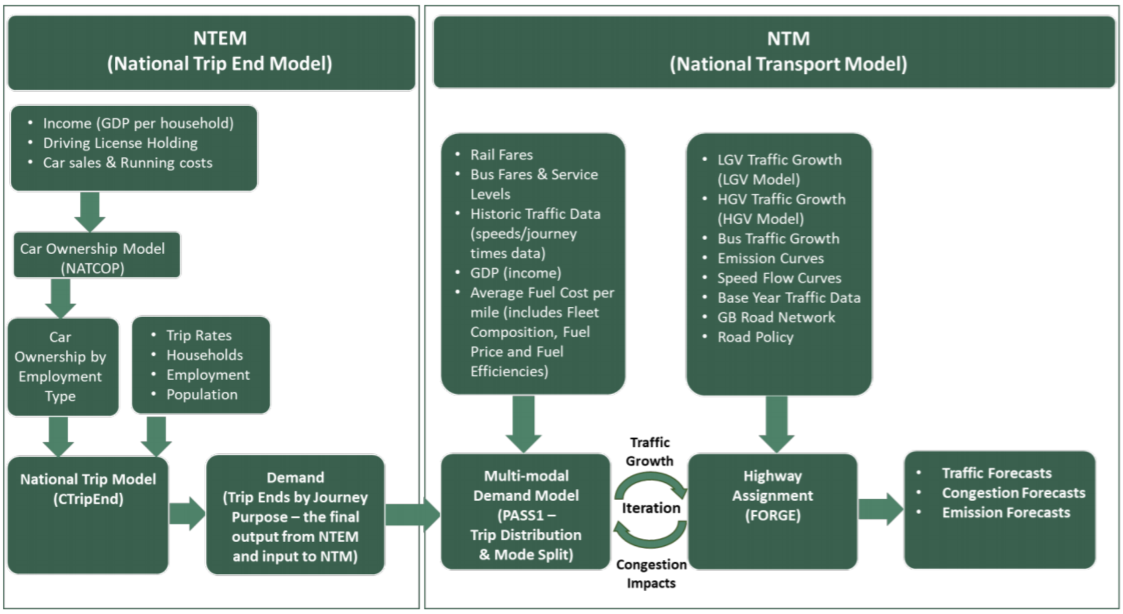
- Estimation of trip attractions by multiplying zonal characteristics (segmented employment) by trip attraction rates;
- Splitting these attractions into the modelled time periods and by mode of travel;
- Undertaking a process to ensure that productions and attractions balance.

F.21 NTM comprises three main components:

i. A traffic database providing the base year traffic conditions by road type, area type and sub region;
ii. A demand model for forecasting personal travel demand by purpose, mode and traveller type (PASS1);
iii. A statistical traffic forecasting tool (FORGE) which allocates forecast growth in road vehicle travel to the available capacity.

F.22 The structure of the NTEM and NTM models and how they relate to each other is shown in Figure F.2.

Figure F.2: NTEM and NTM Model Structure



Source: DfT (2020) *National Transport Model - Analytical Review*

Assignment

F.23 The FORGE component of NTM is responsible for assignment. In the reviewed version of NTM (v2R), the model does not produce flows on particular road links for different time periods. Rather, it produces aggregate projections of traffic for different types of links in the model's different geographic areas.

Other Considerations

F.24 The performance of NTM has been assessed by a 'backcasting' exercise. In essence, a backcast uses an established model to produce projections of outputs (in this case traffic) for years before the base year and compares these with observed data. The Department's view is that the backcasting work "indicates the good quality of the National Transport Model".[101]

Scenario modelling

Overview

F.25 NTM has previously been used for scenario modelling. For example, a number of alternative scenarios were reported as part of the DfT's 2018 Road Traffic Forecasts. In principle, there is no reasons why the NTS-derived trip rates and future distributions of population and employment within NTEM could not be altered to capture the potential impacts of the NIC's scenarios on future trip making. The outputs of the adjusted NTEM could then be used passed onto NTM, or alternatively used as inputs into other TAG-consistent models (such as TfL's MoTIoN or Birmingham City Council's mode, both of which have also been reviewed).

F.26 As noted previously, NTM is most suited to looking at impacts on the road network. Impacts on rail demand may be better examined using the DfT's rail forecasting models.

Inputs

F.27 Within the NTEM/NTM suite the following could be altered to model the NIC's scenarios:

- The segmented population and employment on different zones – this could be altering the splits between segments for different scenarios, as well as the total population and employment in different zones;
- The production and attraction trip rates, for example to represent a greater share of people working form home or lower retail activity;
- Coefficients in the road/public transport utilities, to represent changing preferences for one mode over another.

Outputs

F.28 For each scenario, NTM would produce projections of road traffic by road type, time period and geographic area, along with projections of congestion and emissions.

Limitations

F.29 Outputs from NTEM are used by models developed within the DfT's TAG framework. NTM is used both DfT to inform policy development. Both models therefore have provenance. NTM has been subject to detailed review and reports of this work are published by DfT and available on its website.[102]

F.30 As already noted, NTM is best suited to forecasting road traffic. The DfT maintains other models rail forecasting.

Development

F.31 This review has focussed on NTM v2R. It is possible that NTM v5 may offer further insights. However, NTM v5 has not yet been used to support analysis published by DfT.

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[101] Para 4.101 DfT (2020) *National Transport Model - Analytical Review*

[102] See: https://www.gov.uk/government/collections/transport-appraisal-and-modelling-tools

Conclusion

Assessment

F.32 The NTEM/NTM suite could provide a valuable tool for assessing the impacts of the NIC's scenarios on road traffic. NTEM could also provide outputs for use in more spatially disaggregate models such as the ones reviewed later in this Appendix.

Next steps

F.33 Engagement would be needed with the Transport Appraisal and Strategic Modelling (TASM) division at DfT to explore further the practicality of using NTM to explore the impacts of the NIC's scenarios and how this fits with their wider work programme for the development and application of NTM.

South East Economy and Land Use Model (SEELUM)

F.34 This section summarises the purpose and context of the South East Economy and Land Use Model (SEELUM).

Owner

F.35 The model is owned by Transport for the South East (TfSE) and has been used to help inform the development of its transport strategy.

Purpose

F.36 SEELUM is a transport and land use model that simulates the interaction of transport, people, employers and land-use over periods of time. It is a customised application of Steer's Urban Dynamic Model (UDM), which was originally developed over fifteen years ago to explore the relationship between transport and economic activity and regeneration. The UDM has been applied widely in the UK, including across the whole of the North of England (for Transport for the North), West Yorkshire, Leeds City Region, Merseyside, Humberside, North East Scotland, and the Oxford to Cambridge corridor.

F.37 The UDM's primary use is to test how investment in transport, sometimes coupled with changes to land-use policy, will affect the economic performance of a region, city or urban area. It does this principally by simulating how changes in patterns of connectivity and access affect how attractive different locations are for employers and/or households to locate in, how they respond, and what the consequences are. For example, if travel costs rise in a particular area (say, due to an exogenous input), depending on the other options available, people may change their mode of travel, change where they live or change where they work. In the extreme, if there are no other viable options to access work, people can become unemployed. Similarly, businesses can relocate to an area if transport costs reduce, increasing their accessibility to the potential workforce.

Scope

F.38 The core study area (see Figure F.3) is that which is covered by the TfSE area, namely the counties of:

- Berkshire;
- Hampshire;
- Surrey;
- West Sussex;

- East Sussex;
- Kent.

Figure F.3: The Transport for the South East area (source: transportforthesoutheast.org.uk)

F.39 The core study area is divided into 167 'internal' zones. The study area zones have been defined to capture key inter-district and intra-district (or hinterland to centre) transport flows to/from key urban centres, railway stations, seaports and airport. Zones were based on the disaggregation of Local Authority Districts into groups of Middle Super Output Areas (MSOAs). This approach means that model outputs can be presented at both the zone level and district level.

F.40 The area outside of the study area has been divided into 38 'external' zones. These zones are based on aggregations of districts in the regions of England (North East, North West, East, East Midlands, West Midlands, London, South West), Scotland, and Wales.

F.41 The SEELUM model is used for conducting scenario tests, beginning from 2018. The model is run for thirty-two years to provide forecasts up to 2050.

Inputs

F.42 SEELUM simulates the interaction of transport, people, employers and land-use over time. The start year – or base year – for those simulations is 2018. The model is initialised for a base year of 2018 by providing it with information about the locations of the **population and households**, **businesses and employers**, and the **travel costs** between them. All of this data was obtained from a number of existing data sources; this section describes how that data was assembled.

Household data

F.43 The model was initialised with the following information about **households** in each zone:

- The number of households, split by category;
- The average number of people, split by skill category, for each type of household; and
- The number of premises, by type, needed to accommodate the households.

F.44 The model requires information on the number of households, categorised by type and by zone. Household types in SEELUM are based on the NS-SeC (National Statistics – Socio-economic Classification) used in the Census. Data on the number of households by MSOA and by NS-SeC was obtained from Nomis. The data was then converted to the model's zoning system and uplifted from 2011 to 2018 using NTEM forecasts (from TEMPRO 7.2) for growth in households. The data was then aggregated to the SEELUM household categories.

F.45 Population itself is not an input to SEELUM; it is instead calculated within the model using the number of households and what is referred to as the 'household structure table'. This is a matrix that, when multiplied with the households table above, produces a table of population, by skill type, in every zone. Skill types in SEELUM are based on census occupation data. There are nine occupation categories in the census. These have been aggregated to three skill categories in SEELUM. The total population is made up of the population in these skill categories, plus students and people of non-working age.

F.46 The model requires information on the Economic Activity Rate (EAR) of the population. EAR is the fraction of people of working age within each skill category who are economically active, meaning they are either in work or available for work. The model applies the activity rate to the population of working age in each zone to calculate the workforce in each zone. 'Working age' is defined as people who are aged 16 to 64. 'Economically Active' people are those that are either in work or seeking work. Census data provides the total number of people and the numbers that are economically active. From this, the proportion that is economically active can be derived.

F.47 The model requires data on the number of housing units by type per zone. Data on housing unit types is available from the 2011 census. Five categories of housing unit were used for the model; the total numbers of units in each zone were scaled up to 2018 using the NTEM growth in households between 2011 and 2018.

F.48 The table below provides a summary of the data sources used thus far for the households and housing model inputs.

Table F.1: Summary of households and housing data sources

Model Requirement	Source	Year
Table of households, by type, by zone	Census data on number of households by NS-SeC by MSOA	2011 uplifted to 2018
Household structure table that relates household type to skill type	Census data on Number of people in each occupation by MSOA Number of households by NS-SeC by MSOA	2011 uplifted to 2018
Table of economic activity rate, by skill type, by zone	Census data on Population of Working Age by MSOA Economic Activity by MSOA	2011 uplifted to 2018
Workers check	NTEM number of workers by MSOA	2018
Table of the number housing units, by unit type, by zone	Census data on number of housing units by type, by MSOA	2011 uplifted to 2018
Housing preference table that relates housing type to household type	Census data on Number of housing units by type, by MSOA	2011 uplifted to 2018

Model Requirement	Source	Year
	Number of households by NS-SeC by MSOA	

Business data

F.49 The model was initialised with the following information about **employers** in each zone in 2018:

- The number of employers, split by employer category;
- The average number of employees, split by skill category, for each type of employer; and
- The number of premises, by type, needed to accommodate the employers.

F.50 The model requires data on the number of businesses and other employers by type, by zone. Businesses in the model are grouped into nine categories derived from the Standard Industrial Classification of Economic Activities (SIC) 2007 codes. The number of businesses by type in 2018 in each zone were taken from the UK Business Count data on the Nomis website

F.51 The employer structure table provides the model with the average number of jobs per business, by business type and skill type. It is used in conjunction with the table of businesses by type, to calculate the number of jobs, by skill type, by zone. The table was created using a combination of the census and UK Business Counts data from the Nomis website.

F.52 Skill types in the model are based on occupations. The census provides a table of the number of employees by occupation and SIC 2007 code for 2011. This data was uplifted to 2018 using NTEM growth in workers and aggregated to the SEELUM business and skill types. Each cell in the table was then divided by the total number of businesses in that business type to give the average employees per business by business type and skill type.

F.53 The number of jobs is calculated in the model as a function of the number of businesses and the employer structure table. The number of businesses in each zone was therefore adjusted so that the model calculates the same number of jobs in 2018 as reported in NTEM (obtained from TEMPRO 7.2) for the same year.

F.54 The number of business premises in each zone was estimated using the number of businesses per zone and the premises preference table. The values in the table are assumptions made by Steer, on the basis of reasonable assumptions about the scope for re-use of types of building.

F.55 The table below provides a summary of the data sources used thus far for the business and business unit model inputs.

Table F.2: Summary of businesses and business units data sources

Model Requirement	Source	Year
Number of employers, by business category, by zone	• UK Business Count data on number of businesses by SIC 2007 by MSOA	2018
Employer structure table that relates type of business to number of jobs, by business, by skill type	• UK Business Count data on number of businesses by SIC 2007 by MSOA • Census data on number of employees by occupation and SIC 2007 code by MSOA	2018 2011 uplifted to 2018
Jobs check	• NTEM number of jobs by MSOA • Census data on number of people in employment	2018 2011 uplifted to2018
Business units by business type by zone	• UK Business Count data on number of businesses by SIC 2007 by MSOA	2018

Transport data

F.56 For the model to estimate how and where trips are made in the South East, it needs to know the cost of travel within and between the zones, in terms of time and money.

F.57 SEELUM has two internal multi-modal transport models, one for peak and one for off-peak. Each model represents four modes: highways, rail, bus and walk/cycle.

F.58 The model's transport cost inputs consist of matrices of travel times, and (where applicable) fares, between each pair of zones in the model. For the major rail and road corridors, an internal strategic network model is included that can vary travel times with the volume of trips using the corridor. For road, this represents delays caused by congestion, and for rail, it represents the discomfort of crowding.

F.59 SEELUM models peak and off-peak travel and so rail and road costs are provided separately for peak and off-peak travel periods. Each transport mode has its own matrix of transport costs, which have been calculated to and from the population-weighted centroid of each zone. Where a separate mode is used to get to and/or from the main mode used for a journey, the matrix also includes that additional travel time for access and egress. For example, the zone-to-zone travel costs in the rail matrix also include the cost to travel to/from the rail stations used. This means that there is only one travel cost per mode for each pair of zones for each period. Vehicle operating costs for cars are calculated by the model based on a matrix of distances within and between zones and a cost per kilometre.

Outputs

F.60 The model generates a set of outputs allowing detailed examination of how and why conditions change in the simulated area. Detailed reports are available on:

- Travel patterns, volumes and mode shares;
- Changes in land-use in each zone (i.e. the number of housing units and number of employment premises (business space));
- Changes in households, population and the workforce in each zone;
- Changes in employment (jobs filled) in each zone and the unemployment rates;
- Changes on CO_2 emissions from transport activity;

- Time savings benefits for appraisal, and the wider economic impacts on productivity and agglomeration.

F.61 Key high-level metrics usually reported on when comparing scenarios include:

- Travel patterns, volumes and mode shares;
- Jobs filled;
- Population;
- Gross Value Added (GVA).

Limitations

F.62 SEELUM is a strategic model of the South East, designed to show how transport interacts with where people live and work, and also with 'land-use', meaning what gets built, and where. Its primary role is to show how large-scale, transformative, and integrated investment can reshape the South East's economy.

F.63 While SEELUM includes a multi-modal transport model, its role is not to replicate or replace existing detailed transport models available to TfSE, but to increase the range of analysis and scenario testing available to TfSE, and thereby increase confidence in the investment cases they can present.

Development

F.64 SEELUM does not follow a conventional version number approach (this may change in the future), as such it is under continuous development and improvement. The latest area of development being focused on includes the incorporation of DfT-sourced freight movement data into the model. Prior to this, SEELUM had been used to simulate scenarios, based on different assumptions, about how COVID-19 pandemic may develop and the resulting implications over the short-term.

Model functionality

F.65 This section describes how the SEELUM model functions.

Demand

F.66 The UDM is a simulation of how an urban area evolves over time. It looks at how house builders and property developers provide new infrastructure, the inward and outward migration of households, and the start-up and closure of businesses. It includes internal models of highways, bus and rail services, walk and cycle, all connecting places together and influencing their relative advantages as places to live or work. It can incorporate planned land-use changes and investment in transport infrastructure or services.

Assignment

F.67 The UDM is a simulation, which means that it attempts to replicate events in the real world using simplified representations of how people perceive their circumstances and decide how to react. It is also dynamic, which means it is concerned with how events unfold through time: as its internal clock rolls forward it calculates, step by step, how conditions change and how people respond. It does this for everything encompassed by the model, at every time step, simultaneously.

F.68 It can do this because it is built using System Dynamics, which is a type of computer simulation designed to handle complicated systems with many factors interacting over time. System

Dynamics provides the language and tools to describe such systems and then simulate their behaviour.

F.69 A guiding principle of a model of this type is that all the mechanisms in it should have real-world counterparts; it is an attempt to describe what really happens. The UDM does this drawing on a wide pool of research by transport researchers and others. Its internal structure tells a story of how an urban area and the people in it behave, based on evidence and research.

F.70 Despite applying innovative technology for a transport model, the UDM does in fact borrow a lot from established transport modelling techniques. It includes network models that will be familiar to transport modelers, while choice processes are handled using the same nested logit models that are used widely in the field. The difference is that these models are put to work in a dynamic framework that links them to a broader set of processes such as migration and business start-ups.

Other Observations

F.71 The Calibration process was undertaken in two stages:

- **Stage 1**, known as 'Dynamics off', uses a version of the model in which all the population and employer numbers are held fixed (i.e. the dynamic relationships are not active), in order to build a travel-to-work (TTW) trip matrix. Calibration at this stage is to ensure that:
  - TTW matrices and mode shares produced by SEELUM match the trip distribution and mode shares in 2011 Census data (uplifted to 2018); and
  - Trip volumes and mode shares for other trip purposes match data taken from NTEM.
- **Stage 2**, known as the 'Stabilise run', takes the synthesised TTW trip matrix and allows all the internal dynamics to run to a position of equilibrium or near-equilibrium. Calibration at this stage is to ensure that the model is stable in terms of employers and households when the dynamic functionality is turned on.

F.72 This process is used because the model creates its own TTW matrix, given the base year disposition of households (and workforce), employers and the transport networks. In stage 1, it begins with everyone unemployed, and lets employers recruit a workforce. This method of building the TTW matrix will not work if numbers of households or employers are also allowed to vary at the same time.

F.73 Stage 2 then checks that the model is stable when given the TTW matrix and while allowing all the other dynamics to operate. The main test is that the model does not shift numbers of employers or households very far, if at all, from the initial input values given to it (the implicit assumption being that the economy of the South East is currently in near-equilibrium).

F.74 The end-point of the stabilise run then becomes the starting point for all subsequent runs of the model (using the 'Scenarios' model).

Scenario modelling

Overview

F.75 The UDM is a simulation of how transport, population, land use and infrastructure interact together over long periods of time. Due to its iterative timestep nature and the changing dynamics the model is appropriate for use when attempting to understand the implications of different COVID related scenarios and searching for the most effective ways of alleviating their worst impacts.

Inputs

F.76 The following parameters have been identified as areas where adjustments could be made and/or further developed to assist in the modelling of the five scenarios developed by the National Infrastructure Commission:

- Percentage of staff that can/would be expected to work from home
- The employment catchment area applied to businesses
- The capacity on transport systems
- The capacity on business space use
- Adjustments to retail expenditure habits
- Adjustments to office property values

F.77 Development of each of these would require interpretation of the NIC's scenarios and the development of a more spatially disaggregated assessment of what these may mean for the future (limits on the) location of population and employment.

Outputs

F.78 The model currently provides a number of KPIs numerically and via time series graphs. A list of the most relevant KPIs has been set out earlier.

Limitations

F.79 SEELUM takes the consequences of the virus, such as social distancing, as inputs and demonstrates their effects on some aspects of this region. Therefore, it should be understood that the changes illustrated by the model outputs which vary based on Scenario tested as a result of the assumed inputs used. The availability and appropriateness of data to infer the required input adjustments should be highlighted as areas of potential constraint and limitation.

Development

F.80 Generally, model applications such as SEELUM have been subject to incremental development with its functionality increased and extended to respond to new and emerging questions. In principle, there is no reason why SEELUM could not be adapted to represent better the NIC's scenarios.

Conclusion

Assessment

F.81 The model is a potentially useful tool to assess the impacts of NIC's scenarios at a regional scale. Given SEELUM's geographic focus it may be particularly helpful to consider the impacts of greater homeworking supporting and facilitating migration of parts of the population from London.

Next steps

F.82 Transport for the South East would need to give permission for the model to be used. The model is not available on an open access basis or licence basis and arrangements would need to be put in place for TfSE's consultants to run the model.

Other LUTI Model

Owner

F.83 The London Land-use and Transport Interaction Model (LonLUTI) model is owned by Transport for London (TfL) and has been developed for TfL by David Simmonds Consultancy (DSC).The review set out here has been developed by reference to a number of TfL and developer documents.[103]

Purpose

F.84 The purpose of LonLUTI is to assess the land-use impact of transport schemes and provide analysis of the demographic, economic and transport outcomes of land-use proposals. The term 'land-use' in this context refers mainly to activities that use space and in particular, where people live and work.

Scope

F.85 LonLUTI covers London as well as the East of England and the South East. There are 338 zones in the model, of which 297 internal zones cover Inner London (45 zones), Outer London (75 zones), East of England (69 zones), South East of England (108), and 41 external zones which cover major airports and ports in London-East-South East Regions (15 zones) and other external zones (26 zones) which cover the rest of the UK. The model's geographic coverage is shown in Figure F.4.

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[103] Sources:

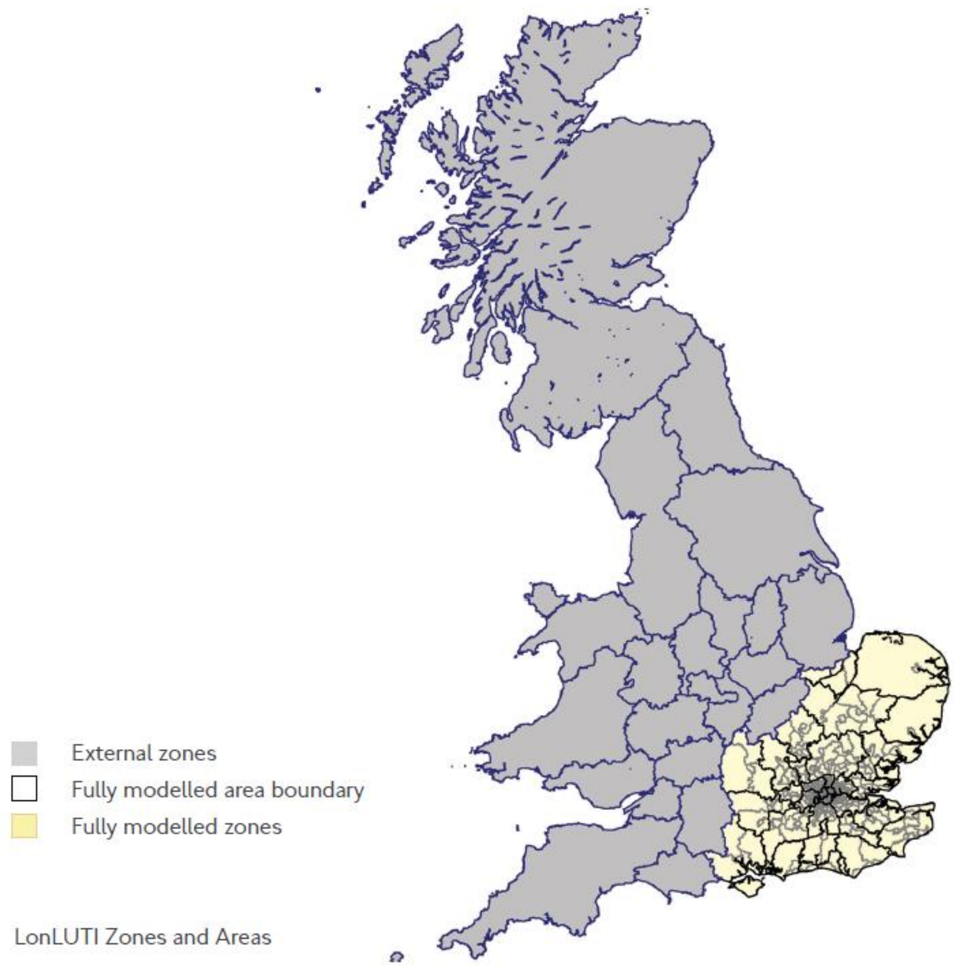
Feldman O (2010) *et al*. *Land Use/Transport Interaction Modelling of London*, 12th WCTR, July 11-15, 2010 – Lisbon, Portugal

Simmonds, D C (2017): *The DELTA Models and their Applications*. Paper based on earlier presentations to the Applied Urban Modelling Symposia, Cambridge, updated and extended.

TfL (2014) *The London Land-Use and Transport Interaction Model* (LonLUTI)

TfL (2020) *London's Strategic Transport Models*

Figure F.4: LonLUTI Geographic Coverage



Source: TfL (2014)

F.86 The model base year is 2011. Future year land-use outputs are available in annual increments, whereas transport outputs are available in five-year steps from 2021 to 2041. The transport model years include up-to-date plans for infrastructure schemes.

F.87 LonLUTI represents average hourly conditions for three key time periods during the day:

- AM Peak (07:00–10:00)
- Inter Peak (10:00–16:00)
- PM Peak (16:00–19:00)

Model functionality

F.88 The model consists of four components:

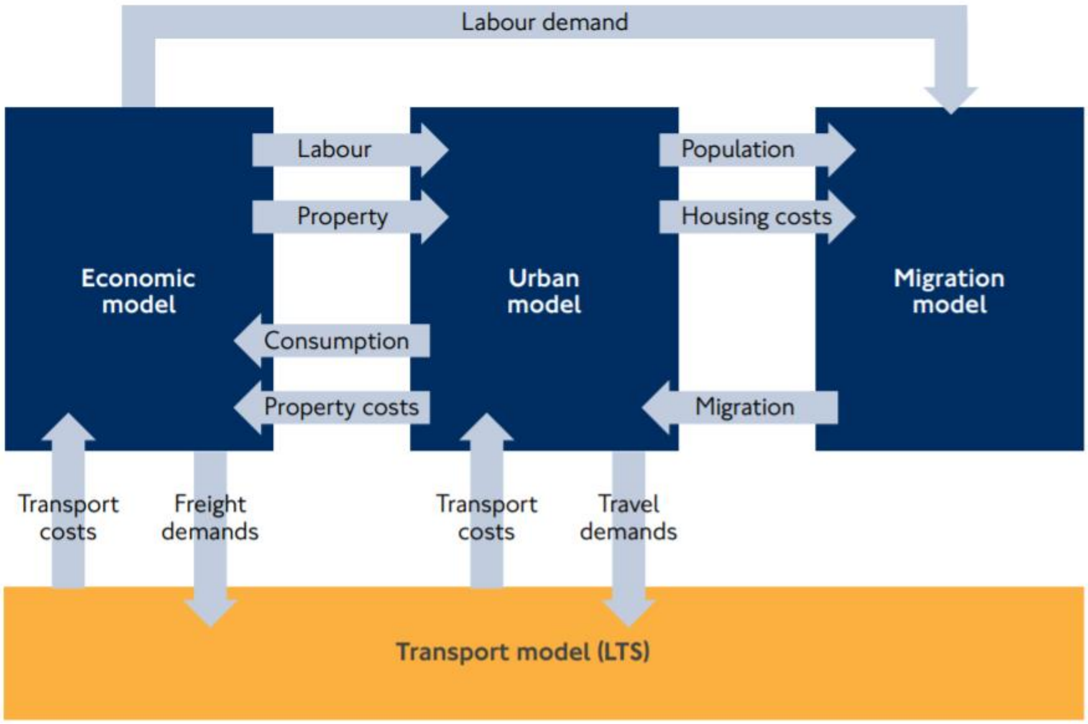
- London Transportation Studies (LTS) model forecasts travel by highway and public transport using demand inputs from the economic and urban models. In doing so, it estimates the time and cost of travel between locations, allowing for congestion and crowding effects.
- The economic model predicts the growth (or decline) of sectors of the economy in each of the areas modelled. The predictions by sector and area are influenced by transport costs

from LTS, and consumer demand for goods and services, with property costs from the urban model.

- The urban model predicts the location of households and jobs which are influenced by the supply of floorspace, accessibility and environmental variables. Households are influenced by access to workplaces and services. Jobs are influenced by access to potential workers and customers.
- The migration model predicts migration between regions in the model (movement within each region is predicted in the urban model). The inputs to this model include job opportunities and housing costs from the urban model.

F.89 The model's structure is illustrated in Figure F.5 below.

Figure F.5: LonLUTI Structure



Source: TfL (2020) *London's Strategic Transport Models*

Inputs

F.90 As described above, LonLUTI has four component models. These are a transport model, which is LTS, a model of the economy in the modelled area, an urban model that considers land use and a migration model, that considers movement of population.

F.91 A description of the road and public transport network for the base and all future forecast years is an input to LTS, which produces generalised costs by purpose between each production and attraction pair for car, a combined public transport/active mode and for goods vehicles. These are passed to the economic and urban sub-models. Costs representing the more spatially disaggregate LTS zone to zone movements are trip-weighted and converted the LonLUTI system.

F.92 The economic model forecasts the growth (or decline) of the sectors of the economy in each of ten economic sectors. Its inputs include forecasts of overall growth in output and productivity. The forecasts by sector and area are influenced by costs of transport (from the transport model), consumer demand for goods and services (from the urban model), and commercial rents (from the urban model). Forecast changes in employment by sector and area are passed to the urban model.

F.93 Inputs to the urban model include a description of the existing land uses in each zone, as well as the capacity of each zone to accommodate additional land use development. There are nine modelled 'floorspace' categories including housing, retail and office. Housing floorspace is sub-divided into detached, semi-detached, terraced and flats for both occupied and vacant dwellings. For future years, the land available for development represent planning policy.

F.94 Inputs to the migration model include job opportunities and housing costs, which are outputs from urban model.

Outputs

F.95 Outputs include total population and the number of households, children, resident workers, non-working adults, retired people and jobs.

F.96 The model can also produce more detailed outputs by zone and individual activity, for example, number of jobs or households by a particular type of land-use. Total floorspace by land-use type in each zone and for each year can also be extracted, as well as greenfield and brownfield development floorspace, floorspace rent, permissible development floorspace, occupied and vacant floorspace, occupied floorspace density, quality of floorspace, and floorspace redevelopments and intensifications.

Limitations

F.97 The model is highly complex with numerous interactions between different elements of the model, so it may be challenging to interpret the results, or in scenario testing to 'fix' elements of the model to represent particular characteristics of a scenario.

F.98 Developing a set of inputs that represent the land use consequences of each scenario could be a demanding task which may limit its usefulness for examining the NIC scenarios.

F.99 The model run time are likely to be a practical constrain on how many tests could be considered. This also creates a need for model tests to be well thought through and defined before the model is run.

Development

F.100 The transport model element of LonLUTI is LTS, the predecessor of MoTiON (also reviewed in this Appendix). It is understood that in 2021 TfL intends to replace the link with LTS with a link to MoTiON.

Other Observations

F.101 Like many comparable models, LonLUTI has been developed over many years. The first version of LonLUTI was developed in 2008 and itself was the development of an earlier model (LASER). This earlier version was subsequently superseded by a model which linked to a later version of LTS, which in turn was further developed informed by data from the 2011 Census. Further developments have been made since then, although it is understood that the principal data source in the 2011 Census, and for forecasting, the Greater London Authority's land use strategy.

Scenario Modelling

Overview

F.102 In principle, as a Land Use Transport Interaction (LUTI) model LonLUTI offer the functionality to explore the transport and land use impacts of the full range of the NIC's scenarios. The model is highly segmented socio-economically and so offers the potential to consider the impacts of different segments of the population responding in different ways to post-pandemic stimuli and having different behavioural responses. As a LUTI model, it also allows feedbacks to be considered. For example, a migration of those socio-economic groups who can work from home from (say) inner London to outer London would in the model lead to a drop in the relative house prices in the areas where people have migrated from, which in turn would make these areas more attractive to different segments of the population.

F.103 LonLUTI is, however, complex and undertaking a programme of work would be a major undertaking requiring specialist resources.

Inputs

F.104 Inputs to the model that could be adjusted to reflect different futures include:

- Overall growth in output/productivity;
- Supply of existing floorspace;
- Land available for (re)development for different property types by zone;
- Coefficients that represent the attractiveness of different areas for different activities by different segments of the population (e.g. the attractiveness of a zone as a residential or employment location);
- Coefficients that represent the attractiveness of a zone as a place for businesses to locate;
- Coefficients that represent how the local economy functions;
- Via LTS, by adjusting parameters in the equations that calculate modal utility, the relative attractiveness of different modes.

Outputs

F.105 As set out above, the model can produce highly segmented outputs on land-use and transport at a zonal level. These could be used to compare the localised impacts of scenarios both with each other and with a counterfactual.

Limitations

F.106 The model is highly complex and takes a long time to run.

F.107 The parameters within the model have each been calibrated against observed data. Any adjustment to the parameters would be judgemental, even if informed by the experience of the modelling team.

Development

F.108 As already noted, TfL has stated its intention to replace the LTS element of LonLUTI with MoTiON. Given the complexity of LonLUTI, if it were to be used to look at the NIC scenarios it is suggested that the focus be on the development of the input parameters and potential changes to model coefficients rather than model development.

Conclusion

Assessment

F.109 In principle, LonLUTI could be used to explore the localised impacts of the NIC's five scenarios. This would be done by adjusting both model inputs as well as model coefficients. To avoid potentially implausible results, this would need to be done judiciously.

Next steps

F.110 The land-use model element of LonLUTI uses the DELTA package developed by David Simmonds Consultancy. Operating LonLUTI requires skills and experience in DELTA and Cube, and a good understanding of LonLUTI's methodology, model assumptions, data preparation and interpretation of results. In practice, the resources available to apply LonLUTI are limited and it could only be taken forward to model the NIC scenarios with the cooperation and on-going engagement of TfL.

Model of Travel in London (MoTiON)

Owner

F.111 Transport for London (TfL) own this model.

Purpose

F.112 Model of Travel in London (MoTiON) is a multi-modal strategic transport model of London and the surrounding area. It is an improved version of LTS (the longstanding demand model for London), with additional functionality and more detail. MoTiON can model how many trips there are likely to be, their origins and destinations and their modes of transport. It imitates the impact of changing demographics in potential future scenarios, for example helping TfL plan for an ageing population, or to reflect the positive impact of urban regeneration.

F.113 MoTiON uses five demand modules to forecast trip change and mode shift. It works in four stages, as shown in the illustration, with all stages carried out in the demand model and the fourth incorporating the strategic assignment models: Highway Assignment Models (HAMs, in SATURN), public transport (Railplan, in Emme) and cycling (Cynemon, in Cube). The transport modes modelled are car driver, car passenger, Private Hire Vehicles (PHV), public transport, cycling and walking. MoTiON also models light goods vehicles, other goods vehicles, coaches and taxis.

F.114 MoTiON can be used to explore measures that may affect cycling propensity, bus propensity, the opportunity and challenge of CAVs and new private and shared mobility, and has a London population synthesiser. MoTiON outputs can be used to develop business cases and as inputs into economic appraisal.[104]

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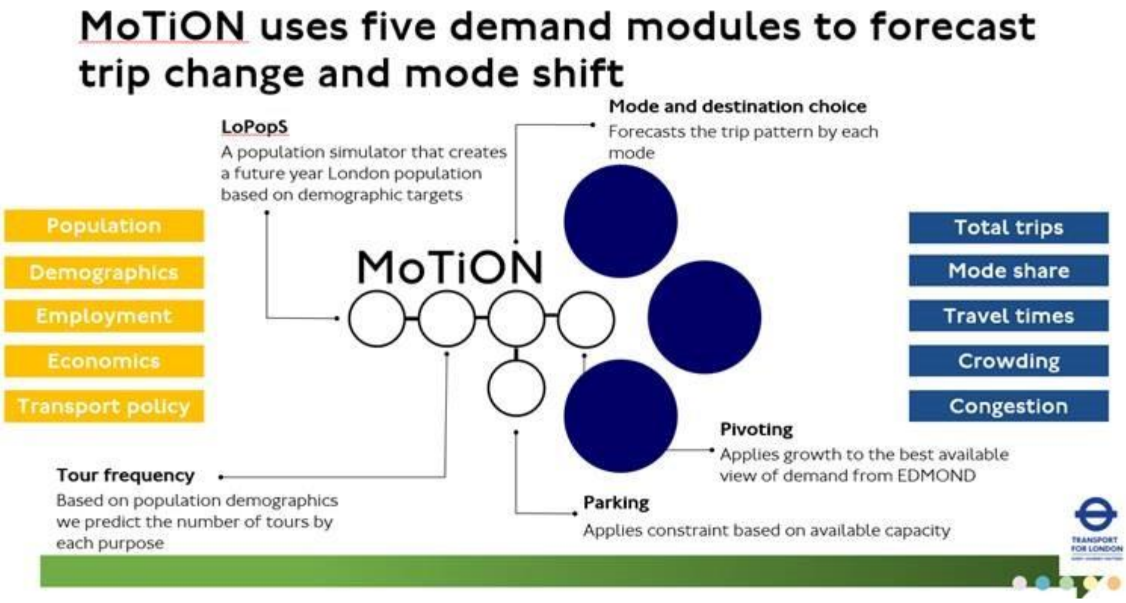
[104] http://content.tfl.gov.uk/londons-strategic-transport-models.pdf

Figure F.6: MoTiON Overview



Scope

F.115 MoTiON models London and the surrounding area. It forecasts trips for a typical 24-hour weekday and provides information on average conditions for three time periods: AM Peak (07:00-10:00), Inter Peak (10:00-16:00) and PM Peak (16:00-19:00)

Inputs

F.116 Parameters for input into MoTiON include

- Land use – households, employment, retail floor space, numbers of education places etc.;
- Population information – age, gender, work status, income, car ownership;
- Transport networks - highway, public transport and cycling;
- Behavioural parameters – mode preferences, propensity to travel etc.;
- Parking information;
- Calibrated 2016 base year matrices – developed from data sources including household surveys, mobile phone data, Oyster Card data, traffic and passenger counts.

Outputs

F.117 Outputs of the model include total trips, mode share, travel times, crowding and congestion. The network models can be used to display flows on different parts of the network and areas of congestion (e.g. average delay, queuing, demand versus capacity) or crowding.

Limitations

F.118 The model is highly complex with numerous interactions between different elements of the model, so it may be challenging to interpret the results, or in scenario testing to 'fix' elements of the model to represent particular characteristics of a scenario.

F.119 Changes in demographics and land uses are an input to the model and are not forecast as part of the model run.

F.120 The model takes up to 4-5 days to run, so there is considerable elapsed time waiting for results. This also creates a need for model tests to be well thought through and defined before the model is run.

Development

F.121 MoTiON is a new model launched in December 2020. There are likely to be further updates as the model starts to be applied on more projects, however these are likely to be small incremental changes in the short to medium term.

Model functionality

F.122 This section describes how the MoTiON model functions.

Demand

F.123 *MoTiON* forecasts demand through the following steps:

- LoPops – a population simulator creates a future year London population by area based on demographic targets;
- Tour frequency – based on population demographics the model predicts the number of tours by different journey purposes;
- Mode and destination choice – forecasts trips by mode and distributes them to destinations based on the relative attractiveness of each mode and the locations of different land uses;
- Pivoting – the model is an absolute demand model applied incrementally. This means that base year demand matrices calibrated against observed data are maintained where appropriate, through a pivoting process.
- Assignment and Parking Models – time, distance and cost information is extracted from the assignment (Highway, PT, cycling models) and parking model to feed into the frequency, mode and destination models.

F.124 The model forecasts trips for a typical 24-hour weekday and provides information on average conditions for three time periods: AM Peak (07:00-10:00), Inter Peak (10:00-16:00) and PM Peak (16:00-19:00).

Segmentation

F.125 The demand model has a high degree of segmentation. The goal is to capture the effect of different demand drivers on transport behaviour such as higher income driving, increased rail use and cycling, or that gender is found to influence modal preference. The segmentation includes:

- Demographics – gender, income, age, household structure, car availability, disability, employment status, population density;
- Trip Purpose – commute, Business, Education, Shopping, Escort, Other.

F.126 The forecast demand is assigned to infrastructure using three different assignment models, namely

- HAM (Highway Assignment Model) – a detailed model in the SATURN software which includes junction simulation. The demand is segmented by Car Other (including commute), Car Business, Taxi, PHV, LGV and OGV (with buses included as fixed demand segment);

- Railplan – a public transport assignment model in EMME software including all bus, rail and underground services in London;
- Cynemon – a cycling model including different cycling infrastructure.

F.127 The demand model includes forecasts of walk trips, but these are not assigned to a specific walk model (other than access to PT services within Railplan).

Other Observations

F.128 The model has been developed following significant data analysis including:

- Mobile Phone Data (for origin/ destination patterns);
- London Transport Demand Survey (LTDS) a large scale household survey carried out by TfL;
- Oyster Card data.

F.129 The network models have been calibrated against observed traffic and passenger counts including use of matrix estimation techniques to adjust the demand based on the observations. Real time journey time data is used to calibrate the network to ensure the network costs reflect real time conditions.

F.130 Capacity constraints are modelled as follows:

- Demographic, land use and tour trip rate assumptions limit total growth.
- The highway and public transport models model capacity which affects routeing within the assignment models. The associated journey times or perceived delays are also fed back to the demand model so that trip frequency, mode and destination choice reflects the capacity constrained journey times. The model runs through several loops until an acceptable level of convergence is achieved (i.e. changes in demand forecasts would be minimal with an extra iteration of the model):

F.131 The highway model includes junction simulation where flows (during the modelled hour) cannot exceed capacity and includes the impact of queueing traffic.

F.132 The public transport model includes crowding where a perceived additional travel time is added to lines that exceed certain capacity thresholds.

Scenario modelling

Overview

F.133 The model contains a detailed segmentation of the population and land uses, behavioural parameters, and detailed network models for different modes. It has been constructed to be able to test different scenarios for the future of London, and therefore has significant functionality for testing NIC's future scenarios. Indeed, TfL has already used MoTiON to forecast post-COVID travel return for different segments of the population (although this is over the short term).

Inputs

F.134 The inputs to MoTiON can be updated to reflect the five NIC scenarios, however it should be noted that the expected outcomes would be an output of the model runs. Inputs to the model that could be adjusted to reflect different futures include:

- Population and employment assumptions by area;
- Land use assumptions by area;

- Economic growth;
- Trip rates by journey purpose;
- Assumptions on average trip distance/ time travelled;
- Modal preferences;
- Car ownership;
- Adjustments to the network assumptions such as reduced highway capacity to reflect improved pedestrian or cycling facilities, or a reduction in PT capacity or service levels.

F.135 Moving from the broad definition of the NIC's scenarios to be able to model them using MoTiON will require some further work to develop a full set of input parameters. This will particularly be the case for geographically disaggregated inputs including population and employment assumptions. In essence, what would be needed is a detailed spatially disaggregated definition of each scenario.

Outputs

F.136 For each scenario, outputs would include:

- Number of trips by journey purpose;
- Number of trips by mode;
- Change in trips by time period;
- Distribution of trips across the model area to show changes in trip generation and attraction;
- Change in journey distance and time travelled;
- Assignment models would show the change in network usage by scenario and the impact on network conditions (e.g. delays or crowding).

F.137 Detailed analysis on the impacts of the assumptions on different population demographics such as students, gender, blue or white collar and low or high income can also be carried out.

Limitations

F.138 The model is highly complex and takes a long time to run.

F.139 The model parameters have been calibrated to non-Covid conditions so extreme changes to the behavioural parameters could lead to implausible results. Adjusting these parameters to capture post-Covid scenarios where behaviour changes would be a non-trivial task, in part because parameters are functionally related. The model run times militate against a trial and error approach to parameter adjustment.

Development

F.140 The model functionality is already very detailed. Additional adjustments could be made to the network assignment matrices to test additional fixed assumptions above what comes out of the VDM.

Conclusion

Assessment

F.141 The detailed segmentation of demographics, journey purposes and modal detail means that MoTiON can be used to test the NIC's five scenarios. It should be noted that the model would need to be updated by adjusting model inputs, with the magnitude of the results potentially different than expected. Updates to the assignment model matrices could be done outside of the model with reference to data within MoTiON if required.

Next steps

F.142 To use the model, permission would be needed from TfL. Generally, TfL is keen for the model to be used as widely as possible, so this is likely to be granted. There is a fee for public sector body access, which is per annum and per project (there is generally some flexibility if the project extends for over one year).

F.143 Transport modellers with expertise in the software (CUBE, SATURN, EMME, Python) and understanding of the principles of demand modelling are required to run the model. In addition, TfL has an accreditation process so that only organisations/consultancies who have demonstrated they have the expertise to run the model are given access.

Birmingham City Model (BCM)

F.144 This section summarises the purpose and context of the Birmingham City Model.

Owner

F.145 The model is owned by Birmingham City Council.

Purpose

F.146 The BCM model is used to plan for future growth in Birmingham, by forecasting how it will affect the highway network, and to test highway interventions. To be consistent with other transport and land use planning in the region, background traffic growth is sourced from Transport for the West Midlands (TfWM) regional transport model, with BCM used by the Council to test the impacts of schemes it is developing.

Scope

F.147 The BCM model comprises of a highway network model in the SATURN software that covers the whole of the City of Birmingham with detailed junction coding. There is a small buffer area in the Wider West Midlands to include the Motorway Box. Model coverage has recently been extended as part of the Commonwealth Games and HS2 construction study.

F.148 The SATURN model is linked to a Variable Demand Model (VDM) in the CUBE software. The VDM includes frequency choice for purposes of Home Based (HB) Employers Business, HB Commute and NHB Employers Business, and NHB Other, and a Destination Choice model.

F.149 This demand model works with 12 hour Production-Attraction matrices. The highway network model consists of three highway models covering the following average hour periods: AM peak (07:30 – 09:30), Inter Peak (09:30 – 15:30), PM peak (15:30 – 19:00).

Inputs

F.150 Initial highway traffic growth is sourced from Transport for the West Midlands (TfWM) PRISM[105] model, which is a full demand model for the West Midlands that includes:

- Government assumption on demographic and employment changes (from TEMPRO).[106]
- West Midlands Combined Authority (WMCA) assumptions on where new development will be located.
- A demand model incorporating trip frequency, mode shift and distribution.

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[105] https://www.tfwm.org.uk/strategy/data-insight/transport-modelling/about-prism/

[106] https://www.gov.uk/government/publications/tempro-downloads

- A highway and public transport network model to feed the choice models.

F.151 The calibrated base year BCM SATURN matrices are updated based on PRISM growth to ensure that the trip patterns calibrated through matrix estimation on traffic counts are carried forward into the forecasts.

F.152 Future year runs are created by updating the base year highway network with committed network changes and run with the demand growth sources from PRISM. A 'Do Something' is then created with updated network assumptions as an input to the demand model. The costs from these runs are used as the input to the demand model.

F.153 The demand model choice model is calibrated using base year demand, with choice parameters for trip frequency and distribution sourced from Government TAG[107] guidance on building demand models and calibrated to be within elasticities also defined in TAG guidance.

Outputs

F.154 The model outputs are focused on changes in the highway network model:

- Changes in link flows, congestion hotspots, etc;
- Overall change in distance and time travelled;
- Change in demand by traffic zone, between sectors;
- The demand can also be interrogated to include changes by trip purpose.

Limitations

F.155 Key limitations:

- There is currently no public transport model;
- Growth sourced from the PRISM model with BCM used as a rebalancing tool for specific schemes;
- Transport demand is not directly linked to land uses and demographics, and therefore not easy to adjust land use demographic assumptions directly;
- Only 4 journey purposes are included.

Development

F.156 The model has been developed since 2018 with various extensions to the model for various studies over that time. The most recent extension to the network has been extending the model to be able to model the impact of HS2 construction.

F.157 A PT model has been developed, but issues with sourcing PT count data means the calibration has not been finalised.

Model functionality

F.158 This section describes how the BCM model functions (see Figure F.7). The demand model is an incremental pivot point demand model, with the future base model taking inputs from the PRISM model. The demand model forecasts changes, due to interventions on the highway network pivoting of the base demand. The demand model includes the following changes:

- Trip Frequency;
- Destination choice (or trip distribution);

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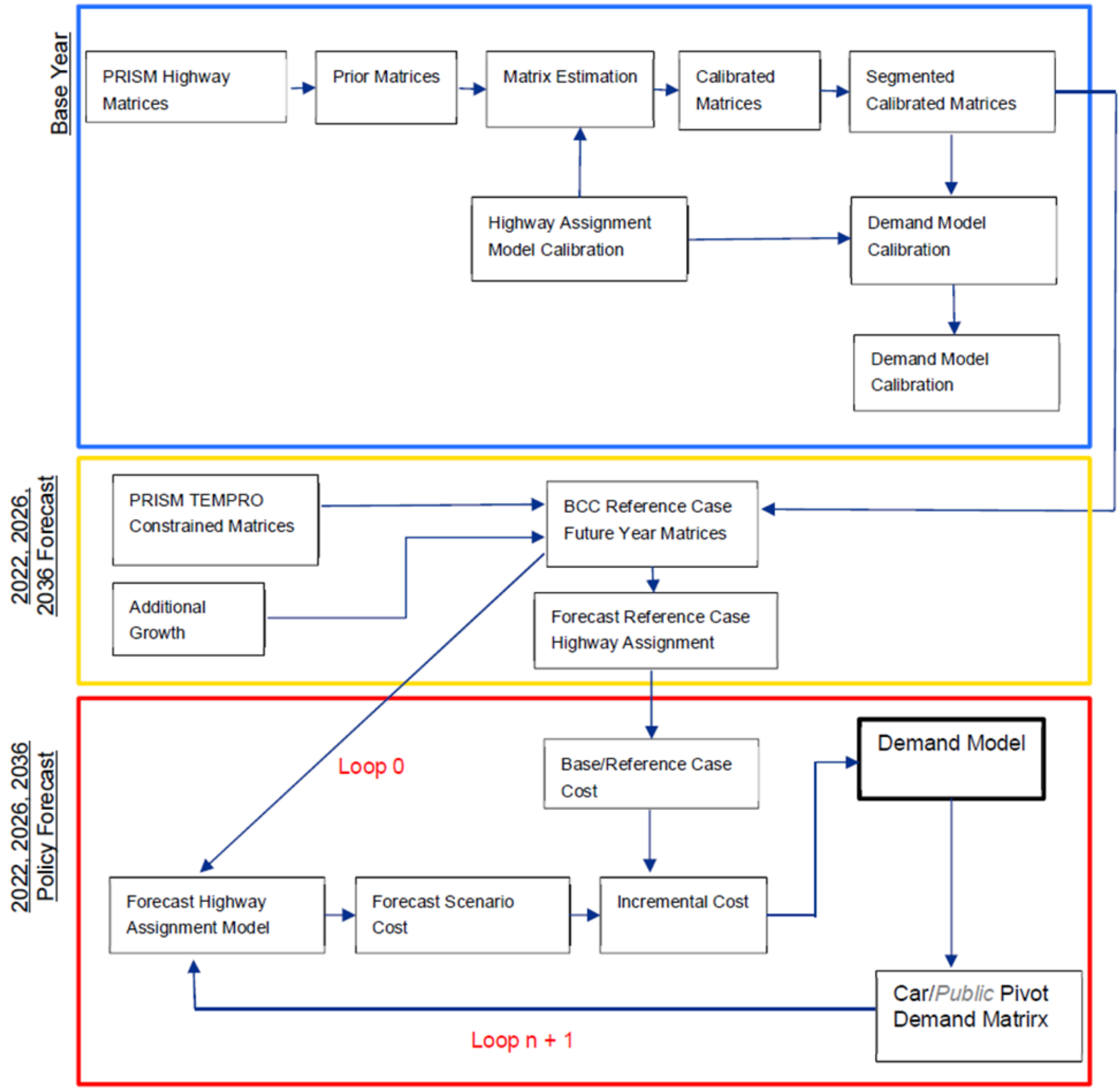
[107] https://www.gov.uk/government/publications/tag-unit-m2-1-variable-demand-modelling

- The following journey purposes are included:
  - Home Based Commute;
  - Home Base Employers Business
  - Non Home Based Other; and
  - Non Home Base Employers Business

Figure F.7: BCM Model Structure



F.159 Network costs (time, distance and toll) from the base model and test scenario are read into the model with trip frequency and destination updated accordingly.

F.160 The model demand covers a 12 hour average weekday with the network models covering average weekday for the following periods, AM peak (07:30 – 09:30), Inter Peak (09:30 – 15:30), PM peak (15:30 – 19:00).

Assignment

F.161 The model assigns origin destination demand matrices onto the SATURN highway network model with users taking the 'best' route through the network considering congestion.

F.162 The assignment model is segmented by:

- Car Other;
- Car Employers Business;
- LGV;
- HGV;
- Buses are included as fixed flows;
- The demand model includes the following car demand segments:
  - Home Based Commute;
  - Home Base Employers Business
  - Non Home Based Other; and
  - Non Home Base Employers Business

Other Observations

F.163 The prior base year demand matrices are sourced from the PRISM model, which has been developed from mobile phone data and a 'gravity model' to infill for unobserved trips (typically shorter distance trips not captured in the mobile phone data). The gravity model is developed using observed demographic and land use data and calibrated against household survey data on trip length distribution.

F.164 The demand is then refined using the BCM network models through a matrix estimation process that adjusts the demand using traffic counts. The network delays are calibrated against observed journey times sourced from GPS data.

F.165 Capacity constraint is modelled in the highway network using junction simulation modelling in the SATURN software, where flows (during the modelled hour) cannot exceed capacity and includes the impact of queueing traffic.

Scenario modelling

Overview

F.166 The scenarios specified by NIC would be best tested by adjusting the assignment model matrices rather than running the demand model. The VDM could be used to identify different journey purposes to help with the adjustment. Procedures would need to be developed to take the broad specification of the NIC scenarios and then develop the spatial detail that the BCM would require.

F.167 Assumptions on changes in trip patterns and distribution as discussed below could then be derived to adjust the future baseline.

Inputs

F.168 Trip matrices by vehicle class would be adjusted to reflect lower or highway car or freight usage, and any changes in trip distribution.

Outputs

F.169 Analysis of the SATURN network model would show changes in flow, congestion by area.

F.170 Zonal analysis would show how different areas of the City are generating more or less traffic.

F.171 Aggregate assessment of changes in distance/ time travelled to assess how the cities transport system would benefit/ suffer in different scenarios.

Limitations

F.172 The model is not linked directly to demographic land uses so additional work would be required to generate the changes to the model.

F.173 There is no public transport model so any reductions in PT attractiveness could not be directly modelled.

Development

F.174 The public transport model is close to completion so this could be included in future assessments.

Conclusion

Assessment

F.175 The model is a potentially useful tool to assess the impacts of NIC's scenarios on the city's highway network. The demand model cannot be used directly to forecast the impacts but there is information within it that would help to derive the changes to the demand matrices.

Next steps

F.176 Birmingham City Council would need to give permission for the model to be used. Generally, the City is keen for the model to be used widely and to support its development. Transport modellers with expertise in the software (CUBE and SATURN) and understanding of the principles of demand modelling are required to run the model.

G First National Infrastructure Assessment

Introduction

G.1 Previous modelling work[108] for the NIC that informed the first National Infrastructure Assessment (NIA1) established four drivers of infrastructure demand:

- Changes in the economy;
- Changes in population and demography;
- Changes in climate and environment;
- Changes in technology.

G.2 The purpose of this work has been to consider a fifth driver: changes in behaviours as a result of the pandemic.

G.3 There is uncertainty around each of the four drivers identified in NIA1 and the NIC adopted a scenario approach to help manage this uncertainty. To support the preparation of NIA1, each one of these drivers was subject to detailed consideration and the findings have been published on the NIC's website.[109] For each driver a central case scenario was established.

Changes in the Economy

G.4 For NIA1 three economic scenarios were considered: the Office for Budget Responsibility's (OBR's) then central case and then two alternative lower growth scenarios. At that time the OBR's central long term economic projection was for long run GDP growth per capita of 1.9% per year, on average. This suggested that by 2050 GDP per capita would be 74% larger than in 2020.

G.5 The OBR's forecasts are periodically updated. The OBR's most recent long term forecasts were published in March 2020 in its *Economic and Fiscal Outlook*. Shorter term projections were published in the July 2020 *Fiscal Sustainability Report* and then at the time of the March 2021 Budget.

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[108] NIC (October 2016) *Congestion, Capacity, Carbon: Priorities for National Infrastructure: Modelling Annex*

[109] NIC (March 2017) *Economic Growth and Demand for Infrastructure Services*

NIC (December 2016) *The Impact of Population Change and Demography on Future Infrastructure Demand*

NIC (June 2017) *The Impact of The Environment and Climate Change on Future Infrastructure Supply and Demand*

NIC (December 2016) *The Impact of Technological Change on Future Infrastructure Supply and Demand*

G.6 Before the pandemic the OBR had downrated its long term growth projection compared with the 2016 position. During the pandemic, the OBR has addressed short to medium term uncertainty by considering a number of scenarios. Its July projections has a central case scenario of the economy regaining its pre-virus peak by the end of 2022. In its central case the OBR's March 2021 *Economic and Fiscal Outlook* brings this forward to the start of Q2 2022, but with a medium-term impact of the economy being 3% smaller than its pre-pandemic trajectory.

Changes in Population and Demographic

G.7 For NIA1, the NIC adopted as its central case the ONS's 2014-based population projection, which was that the UK population would be 77.5 million people in 2050.

G.8 The ONS's 2018-based population projections were released in October 2019. These have a population forecast of 73.6 million in 2050 and 74.2 million in 2055. These projections were made before the Brexit deal, which may have long term impacts on the attractiveness of the UK for inward migration and do not take into account any long term impacts of the pandemic.

Changes in Climate and Environment

G.9 For NIA1 climate change scenarios were primarily used to consider alternative scenarios for the demand for water supply (reservoirs, etc.) and flood protection. Other responses to climate change, for example the move to electric vehicles, were considered as part of the technology theme (below).

Changes in Technology

G.10 Changes in technology have the potential to have a profound impact on the future demand for infrastructure. As the NIC has previously established, changes in technology can:

- Reduce the need to build new infrastructure;
- Create demand for additional infrastructure;
- Reduce demand for existing infrastructure;
- Create a need for new infrastructure and networks that do not currently exist.

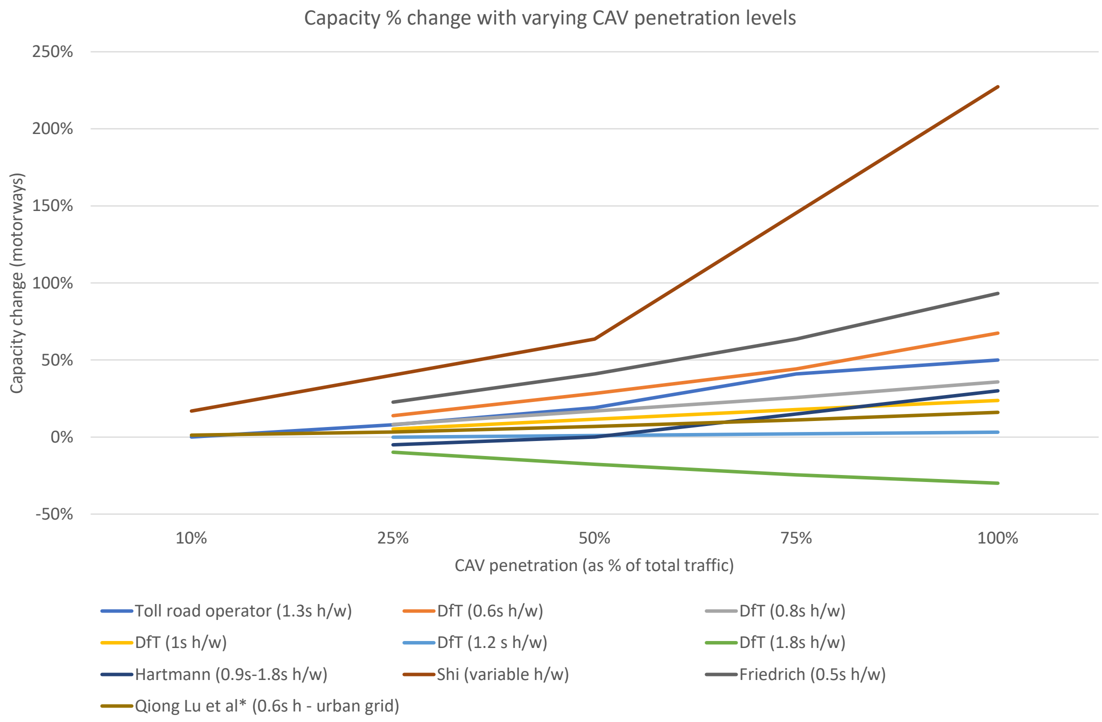
G.11 The table below is a simplification of Table 1 from the NIC's December 2016 report of the potential impacts of changes in technology, focussing on trends that could either reduce or increase demand for infrastructure. The original NIC work also considers changes in the cost of technology that in turn reduce the cost of infrastructure provision, the potential demand for new infrastructure networks and the potential redundancy of existing networks. Also, in the table we have focused on the table entries that we think are potentially most significant macro trends, that is those that can have a system wide effect rather than those that could have an impact on particular flows.

Table G.1: Technology and Potential Reductions and Increase in Demand for Infrastructure

Sector	Reduce demand for new infrastructure	Increase demand for new infrastructure
Transport	• Demand management (e.g. road user charging) • Connected Autonomous Vehicles • Advanced traffic management	• Electric vehicles reduce marginal costs • Connected Autonomous Vehicles • E-commerce (light goods vehicles)
Digital	• Technology change to increase capacity of existing networks	• New technology (e.g. 6G, 7G, etc) • New apps/devices
Energy	• Energy storage (better use of renewables) • Energy efficiency (devices, buildings) • Smart metering (consumers shift demand) • Smart network management	• New domestic devices • Cloud computing • Electric vehicles
Water & Wastewater	• Smart metering (consumers shift demand) • Improved preventative maintenance/leak detection	• Carbon Capture & Storage (CCS)
Waste	• Sharing economy • Greater penetration of recyclables	

G.12 In the transport sector Connected Autonomous Vehicles (CAVs) appear in both the 'reduce' and 'increase' demand columns. This reflects the considerable uncertainty around what the potential impact of CAVs will be and, indeed, whether they will have any impact at all. The graph below is from earlier work that Steer has undertaken bring together different projections for the impact of CAVs. This chart focusses on motorways, which is where potentially CAVs may have the greatest initial impact. On other types of roads the impact of CAVs is even more uncertain and there are further factors such as whether CAVs result in 'zombie mileage' (CAVs running around empty) that cancel out any capacity gains.

Figure G.1: Motorway Capacity Impacts of CAVs



Note: h/w = headway, the time gap between vehicles

G.13 For NIA1, the assumed central case was that new technologies are developed and made available at a steady pace similar to that observed in recent years. This means that:

- In the transport sector, there is not widespread adoption of Level 5 CAVs nor introduction of additional fiscal restraint on driving. Adoption of EVs continues as per the Government's trajectory to the cessation of sale of new petrol and diesel cars in 2030.
- In the digital sector, expansion of digital capacity will continue apace as will the demand for this capacity as more data intensive devices and apps come to market.
- In the energy sector, there will continue to be efficiency improvements but a growing economy will continue to create demand for new energy consuming devices. Commensurate with the increased market penetration of EVs, there will be additional domestic demand for electricity. Adoption of domestic solar panels and heat pumps, along with domestic energy storage will reduce demand for grid supplied power.
- In the water and wastewater sector there will be modest reductions in leakage but no significant changes in the per capita consumption of water.
- In the wate sector there will be greater penetration of recyclables, changing the waste mix.

Control Information

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