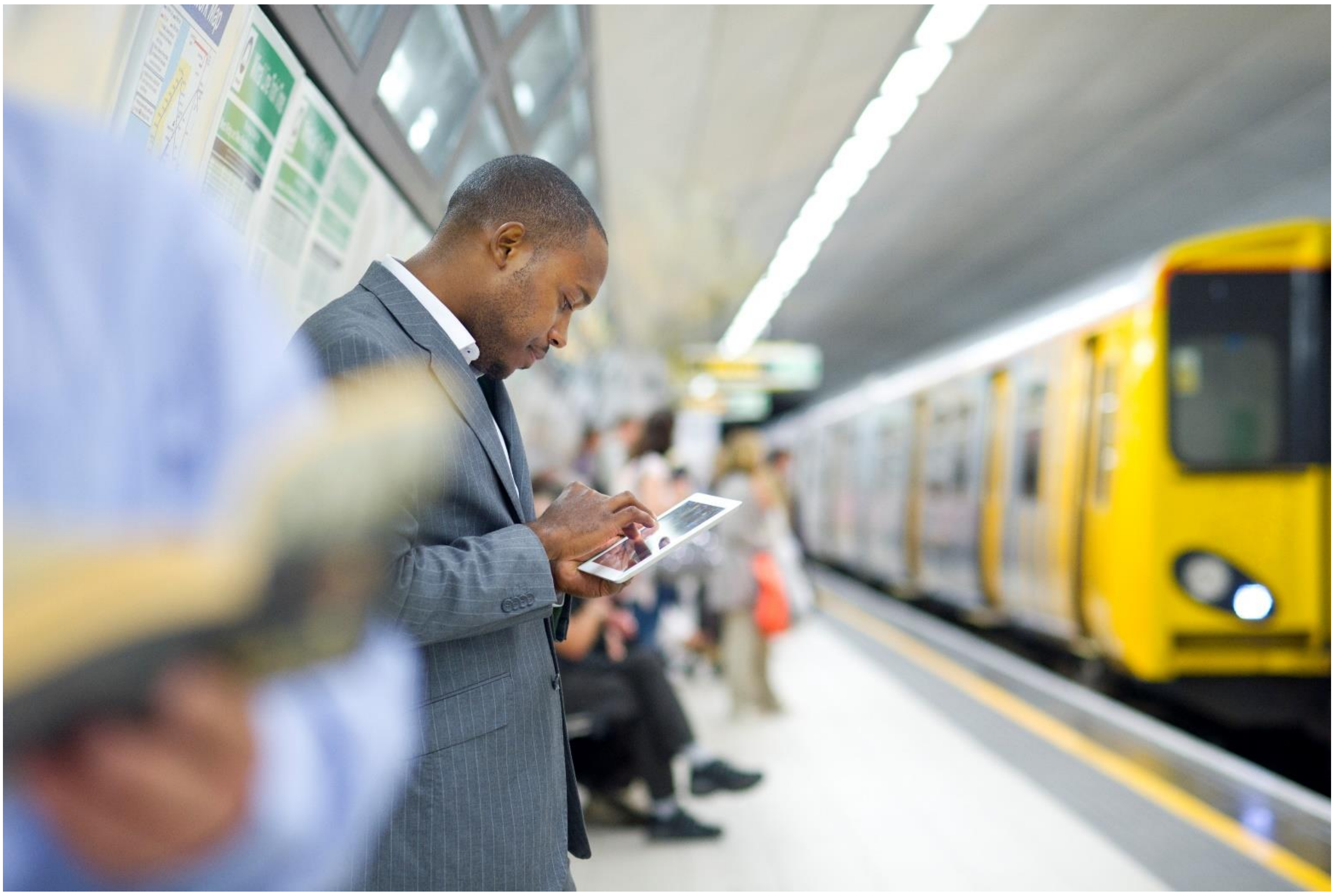
Report
March 2023

Urban Transport Capacity, Demand and Cost: Research Methodology



National Infrastructure Commission
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Urban Transport Capacity, Demand and Cost: Research Methodology

Prepared by:

Steer
14-21 Rushworth Street
London SE1 0RB

+44 20 7910 5000
www.steergroup.com

Prepared for:

National Infrastructure Commission
4th Floor, Finlaison House
15-17 Furnival Street
London
EC4A 1AB

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1 Introduction

Background and Purpose

1.1 This document sets out the technical approach and assumptions to the National Infrastructure Commission **Urban Transport Capacity, Demand and Cost** study.

1.2 The Main Report assesses the broad scale and type of requirement for new urban, city-centre transport capacity, and associated capital and operating costs, within England's largest cities by 2055, including the effects of:

- **different levels of employment growth,** and in particular the extent to which national employment growth in concentrated within city regions, and city centres, in future;
- **post-pandemic uncertainties, and their implications for travel patterns**, arising from:
  - a greater uptake of remote and hybrid working;
  - business centralisation;
  - household suburbanisation;
- the **emergence of new transport technologies**, such as connected and autonomous vehicles;
- **demand management of highway space**, including charging and physical measures.

1.3 This document outlines the methodology in further detail to the main report, and evidences the key assumptions that underpin the modelling and analysis.

Structure of this document

1.4 This document is structured as follows:

- **Chapter 2** describes the approach to the **baseline demand and capacity assessment**, which underpins the overall approach to assessing cities' future demand;
- **Chapter 3** describes how **each of the different uncertainties are considered in practice,** and how these are **combined** into a series of scenarios to produce an updated capacity and demand assessment, for each city;
- **Chapter 4** outlines the approach to **considering demand management**, including:
  - Assessing the potential impact of demand management on highway demand and mode shift to other modes in different contexts;
  - Assessing high-level capital and operating costs of different forms of demand management.
- **Chapter 5** outlines the **different investment approaches** for providing the capacity requirement in each city, and how their **capital and operating costs** of these approaches have been assessed.

2 Baseline Capacity, Demand and Network Utilisation

Introduction

2.1 This Chapter sets out our approach for assessing the current, and potential future, utilisation of the urban transport networks of England's largest 20 cities, and their ability to support future employment growth with a 'baseline', pre-pandemic set of planning assumptions. This refers to what would have been expected to occur if the COVID-19 pandemic, and the major changes to working practices it resulted in, did not occur.

2.2 This stage forms the basis for understanding the 'capacity gap' for each city – that is, the level of additional transport capacity required to support forecast, unconstrained city centre employment growth. It forms the overall framework to which the 'scenario effects' (which include the long-term impacts of the pandemic) are applied, as discussed in Chapter 3.

Stage 1: Establish unconstrained employment forecasts

Smith and Lomax (2018) employment projections

2.3 The starting point for the assessment was the 'unconstrained' employment forecasts for each city centre, provided by the NIC, and derived from Smith and Lomax (2018)[1]. These set out the forecast increase in employment within each city centre, from 2018 to 2055[2], for two scenarios, based on a forecast change in the size of the working-age population:

- '**ONS Central'**, which assumes growth in the working-age population in line with the principal ONS National Population Projection (NPP). Two versions of this were adopted for this project:
  - ONS Central 'M0', which is derived from a 2014-based sub-national population projection (pre-Brexit and other long-term downward influences on national growth);
  - ONS Central 'M1', which is a refresh of M0 undertaken by the NIC to update to a more recent, 2018-based projection (with a broadly lower level of national growth).
- '**ONS High Urban'**, which assumes that:
  - the 54 Local Authority Districts (LADs) containing a 'city of study' are grown in line with the 'high', 2014-based variant of the NPP;

[1] Smith and Lomax (2018) **Effect of capacity constraints on population and employment distribution**

[2] Note that the Smith and Lomax projections are from 2018 to 2050; they were extrapolated based on average growth within the last five years of the projection to 2055 by the NIC.

   - all other (non-city) LADs are grown in line with the change reported in the principal projection;
   - the UK total is adjusted to agree with the principal projection of employed population.

2.4 All these forecasts use 2018 as a base year, the date of the previous NIC **Urban Capacity study**[3], and do not explicitly capture the implications of the Covid-19 pandemic. 2018 was hence adopted as a pre-pandemic 'base year' for the basis of the capacity and demand assessment, since:

- there remains significant uncertainty and variability in 2021/22 data, with significant short-term effects from the pandemic still present and effecting cities in different ways;
- there are several compounding effects such as inflation and the cost-of-living crisis, and uncertainty about how long it will take for short term impacts to unwind, that make it challenging to adopt a robust post-pandemic base year for the analysis.

2.5 The use of this 2018 base year is hence considered to provide a better basis for applying the future scenarios, which are discussed in Chapter 3 and capture a range of long-term uncertainties arising from the pandemic.

2.6 These unconstrained forecasts provide an indication of both the scale of uplift in employment, and by extension commuting between 2018 and 2055, prior to considering any scenario effects (e.g. increased propensity of hybrid working). Within the baseline forecast, there is no assumed change in the scale of commuting 'per job' – an increase in employment from 2018 to 2055 will result in an equivalent percentage increase in commuting to 2055.

2.7 It was noted however, that the scale of employment growth within the Smith & Lomax forecasts for city centres was relatively conservative compared to long-term, pre-Covid trends, particularly for the largest cities. Figure 2.1 summarises the scale of employment growth within the two projections, for the twenty case study city centres.

2.8 For example, the 'central case' and 'high urban' scenarios forecast employment growth for the 37-year period from 2018 to 2055 of 14.7% and 16.3% for Birmingham, 8.2% and 15.4% for Manchester, and 1.5% and 13.4% for Leeds. As set out below, this is markedly lower than observed employment growth (since 2009) within the largest cities.

Recent observed employment growth

2.9 Birmingham and Leeds, for example, experienced growth of 23% and 41% over the 13-year period from 2009 to 2021 – notably greater than UK employment growth of 14% for the same period and the 37-year Smith and Lomax projections. This is illustrated in Figure 2.2, which presents the observed city centre employment growth from 2009 to 2018 (pre-pandemic) and 2021 (post-pandemic), based on Business Register and Employment Survey data.[4]

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[3] Steer Davies Gleave (2018) **Urban Transport Analysis: Capacity and Cost**

[4] Analysis undertaken from BRES data, using LSOA boundaries of city centres – note that these do not exactly match the transport cordons adopted for the rest of the study, but have been specified to be keep consistent boundaries 2009 – 2021

Figure 2.1: Smith and Lomax (2018) employment growth forecasts

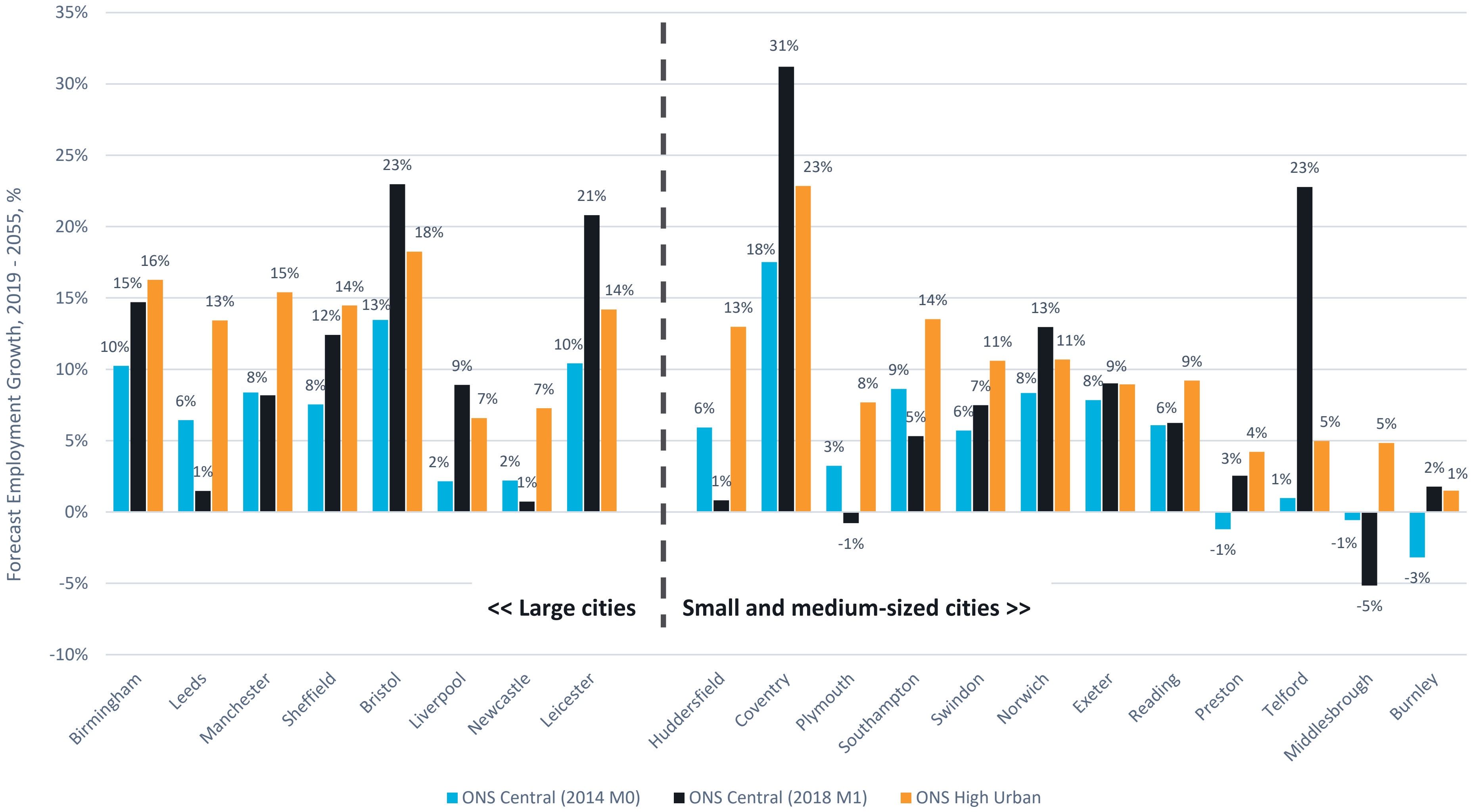
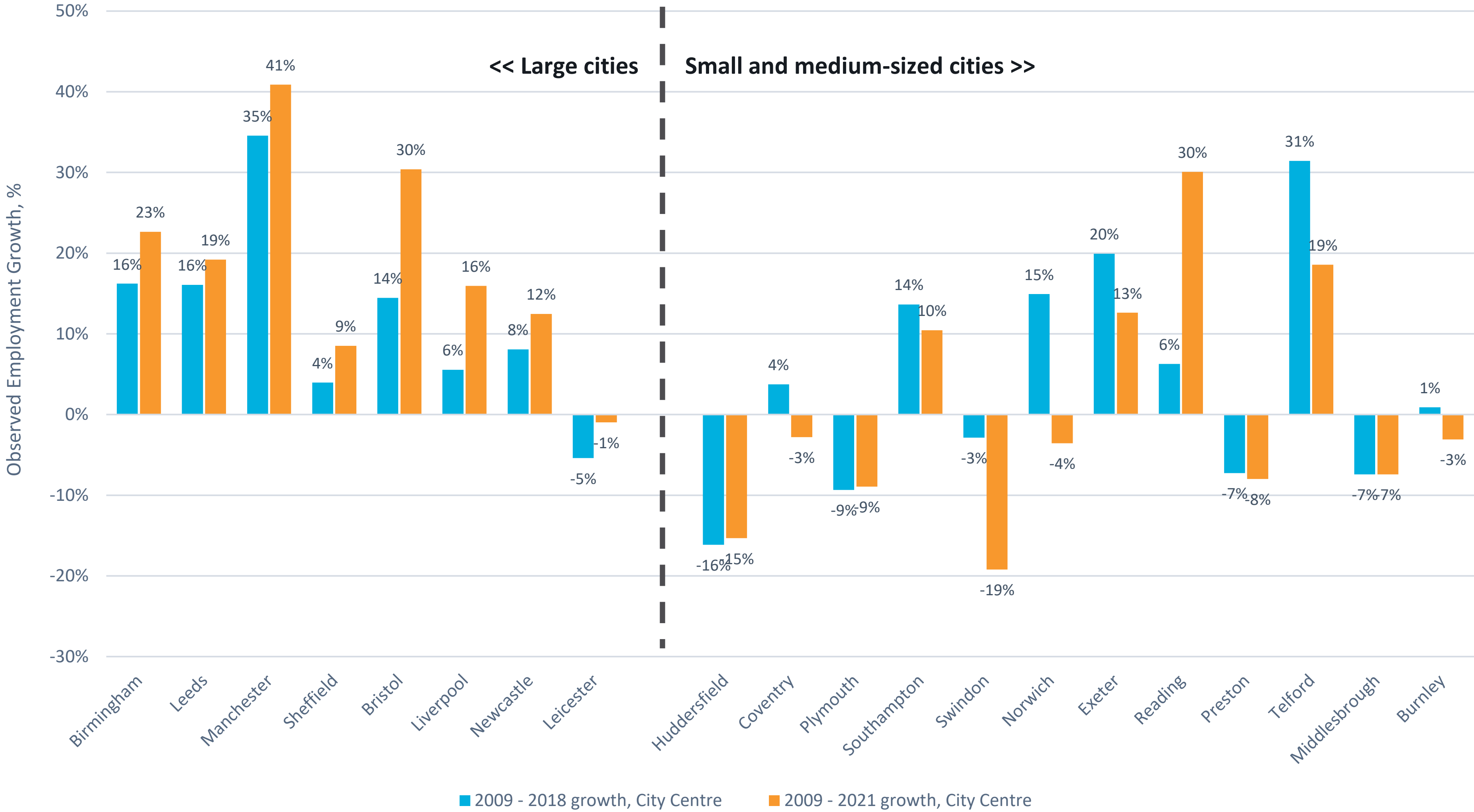


Figure 2.2: Observed City Centre Employment Growth (2009 – 2018/2021)



2.10 Indeed, for large cities, city centre growth appears to have accelerated post-pandemic, with all large city centres having a greater number of jobs in 2021 versus 2018[5]. Growth rates within medium and smaller cities are more varied, largely reflecting local economic circumstance.

2.11 One key factor that explains this is a clear '**centralisation'** effect for employment within the largest cities, where employment growth within the city centre is greater than both the rest of the local authority, metropolitan area and/or national average. Average 2009 to 2021 employment growth within the city centres of the 'large' cities is 22%, greater than both the rest of the local authority area for each (16% average), and the national average (14%).

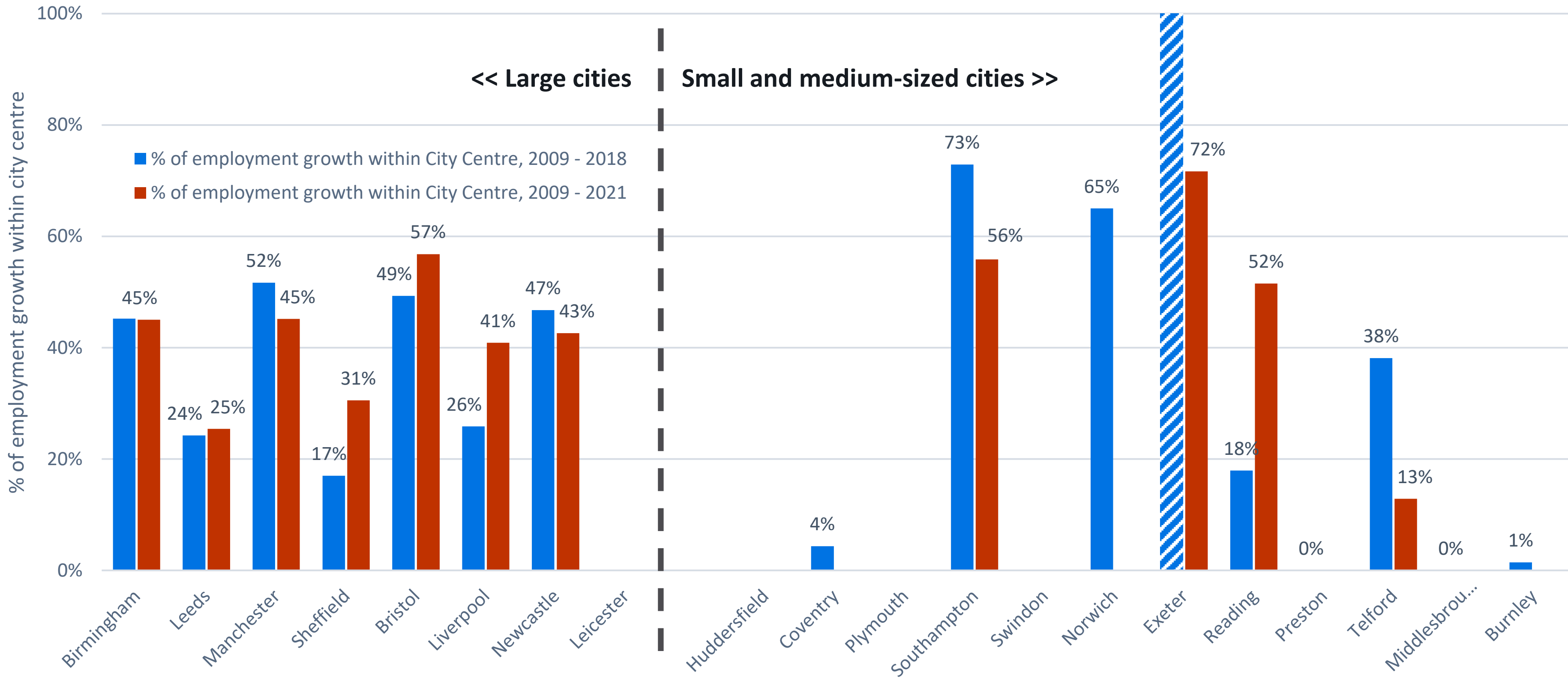
2.12 Figure 2.3 presents observed employment growth within each city-centre, relative to the rest of the local authority. It highlights how, within the larger cities, **city centre employment growth** has **outpaced** that within the rest of the local authority in question. However, within small and medium cities, there is no discernible pattern. Overall, the 2009 to 2021 period growth is similar within city centres (10%) to elsewhere in the local authority (11%), although reflecting local economic factors, there is significant variation within cities.

2.13 Consequently, within those cities experiencing significant growth, a high proportion of employment growth has occurred within city centres. Figure 2.4 presents the percentage of total local authority employment growth that has occurred within the city centre, for those cities that experience significant growth.

[5] This continued increase in city centre employment broadly exceeds national employment growth over this time (which from BRES, measuring 'total employees' grew from 30.1m to 30.4m from 2019 to 2021 for Great Britain; and from ONS total number of people in employment fell from 32.9m to 32.6m for Oct 2019 to Oct 2021 for the UK as a whole). Since the number of people in part-time employment fell Oct 2019 – Oct 2021, while those in full-time employment grew, this may reflect how city centres have a higher proportion of full-time workers than the rest of the UK.

Figure 2.3: Observed employment growth, 2009 – 2021, city centres versus rest of local authority

Figure 2.4: Estimated percentage of employment growth occurring within the city centre, by local authority[6]



[6] Note Exeter city centre employment grew 20% to 2018, but in the rest of the LA fell by 6%

2.14 It highlights how, within the larger cities, across the 2009 – 2021 period, **circa 30 – 50% of all local authority employment growth occurs within the city centre** – a materially higher proportion than envisaged in the current Smith and Lomax projections.

2.15 The scale of future city centre employment growth reflects the derivation of the Smith and Lomax projections, which allocate the baseline working-age population to workplaces (either the 54 city centres; the rest of the 54 LADs excluding the city centre it contains; and other LADs which do not contain a city centre of interest) based on 2011 Census origin-destination (OD) commuting flows. Total flows (in 2011) are recalculated as distributions and these distributions are applied to the residential working-age population to allocate the residential population to a place of work, and hence derive the employment forecast. In essence, this means that city centre employment grows in proportion to the total employment in the LAD that it sits. However, what has happened in the decade before the pandemic is that (in the main) city centre employment has grown at a faster rate than the rest of the LAD.

Implications for the urban capacity and demand analysis

2.16 The implication is that the Smith and Lomax projections do not assume or forecast any long-term shift in the location of employment, either within city centres versus the wider local authority area or region, or as a result of internal migration. They do not therefore capture the clear 'centralisation' trend in employment within city centres observed over the pre-pandemic decade, that partly explains why the recent observed city centre employment growth rate has been materially greater than the future growth rate of the Smith and Lomax projections.

2.17 Considering the small scale of employment within city centres outside London (1.4 million) versus the rest of the UK (33.4 million), even a small centralisation trend compounded over time could result in the rate of city-centre employment growth being materially greater than that for the UK as a whole.

2.18 We have therefore developed several alternatives to the Smith and Lomax projections, which capture how a continued 'centralisation' trend could result in materially higher city-centre employment growth. This trend is linked to the future role of city centre **agglomeration** – the scale of productivity benefits to firms that arise from locating in close proximity to one another – in shaping the extent to which firms choose to locate in town and city centres in future, and hence the scale of future city centre employment growth. These alternative projections allow this effect to be captured when considering future urban capacity and infrastructure requirements in the later stages of the study.

2.19 As discussed further in Chapter 3, this 'centralisation' trend is applied only for scenarios where agglomeration continues to play an important role in guiding future cities' growth.

Developing alternative employment projections for the urban capacity and demand analysis

2.20 These alternative employment projections are based upon two key principles:

- **National employment growth remains constrained** to the Smith and Lomax projection, and in turn the 2014 and 2018 ONS National Population Projections – the alternatives do not assume that national employment is greater, merely that a greater proportion of that growth occurs in city centres;
- **Growth is instead re-allocated** within individual local authorities and/or metropolitan areas – informed by historical trends - such that more employment growth accrues to city centres, and less to the rest of the local authority or metropolitan area region, based on a 'rules-based' approach.

2.21 Several alternative approaches were developed, tested and discussed with the NIC, leading to a mechanism to 're-allocate' employment to city centres. This was based on a series of assumptions, as set out in Table 2.1, and informed by BRES data analysis. Two versions of the mechanism were developed, for a 'high' intensity (used for the scenarios where the role agglomeration continues to be very important in guiding city growth) and a 'medium' intensity (where agglomeration remains important, but less than pre-pandemic, leading to a smaller scale of 'centralisation' effect).

Table 2.1: Approach to 're-allocation' of employment

		'High' re-allocation intensity	'Medium' re-allocation intensity
Metropolitan area *Tyne & Wear; West Yorkshire; South Yorkshire; Greater Manchester; Merseyside; West Midlands*	**LA with 'core' city-centre** *e.g. Leeds; Birmingham*	**40%** of growth is allocated to occur within the respective city centre (CC). Remaining 60% is allocated to the rest of the LA. Note does not apply for Liverpool and Newcastle, as more than **40%** of growth already forecast to occur in city centre within Smith and Lomax projection.	**30%** of growth is allocated to occur within the respective city centre (CC). Remaining 70% is allocated to the rest of the LA. Note does not apply for Liverpool and Newcastle, as more than 30% of growth already forecast to occur in city centre within Smith and Lomax projection.
	LA with 'local' city centre *e.g. Huddersfield CC in Kirklees LA; Coventry*	**20%** of employment growth is allocated to the 'core' city centre within the met area – e.g. 20% of Kirklees' growth goes to Leeds city centre (CC). **20%** is allocated to the 'local' city centre with the LA – e.g. to Huddersfield CC within Kirklees LA. Remaining **60%** is allocated to the rest of the LA.	**15%** of employment growth is allocated to the 'core' city centre within the met area – e.g. 15% of Kirklees' growth goes to Leeds city centre (CC). **15%** is allocated to the 'local' city centre with the LA – e.g. to Huddersfield CC within Kirklees LA. Remaining **70%** is allocated to the rest of the LA.
	LA without one of 54 defined city centres *e.g. Calderdale; Walsall*	**20%** of employment growth is allocated to the 'core' city centre within the met area – e.g. 20% of Calderdale's growth goes to Leeds CC. Remaining **80%** is allocated to the rest of the LA.	**15%** of employment growth is allocated to the 'core' city centre within the met area – e.g. 15% of Calderdale's growth goes to Leeds CC. Remaining **85%** is allocated to the rest of the LA.
Non-metropolitan areas	**LA with defined city-centre** *e.g. Bristol*	**40%** of growth is allocated to occur within the respective city centre. Remaining **60%** is allocated to the rest of the LA. Does not apply where more than 40% of growth already forecast to occur within city centre, or if forecast growth is negative.	**30%** of growth is allocated to occur within the respective city centre. Remaining 7**0%** is allocated to the rest of the LA. Does not apply where more than 30% of growth already forecast to occur within city centre, or if forecast growth is negative.
	LA without defined city-centre	Not considered in study	

2.22 Figure 2.5 presents, using this 're-allocation' mechanism, the three employment projections adopted for the study, noting that:

- the 'high' city centre employment projection uses the ONS High Urban employment forecast, with a 'high' re-allocation intensity to city centres;
- the 'medium' city centre employment projection uses the mean of the ONS High Urban and ONS Central M0 employment forecast, with a 'medium' re-allocation intensity to city centres;
- the 'low' city centre employment projection uses the ONS Central M1 employment forecast, with no re-allocation intensity to city centres[7].

2.23 Compared with Figure 2.1, which shows the three ONS forecasts without the 're-allocation' mechanism, highlights the sensitivity of the scale of the growth to these assumptions. For example, considering Manchester:

- Growth in the ONS Central M1 forecast to 2055 is just 8%, which increases to 15% in the High Urban – a significant increase, but still materially less than recent observed city-centre employment growth;
- Applying the 'high' intensity re-allocation mechanism to the High Urban employment forecast increases growth from 15% to 35% - this is adopted as the 'high' employment projection for this study, as it is considered a more realistic 'upper bound' for future growth within city centre considering recent precedent;
- Applying the 'medium' intensity re-allocation to the mean of the High Urban and ONS Central forecast results in growth of 19% - broadly between the lowest projection of 8% (ONS Central M0) and the highest of 35% (High Urban, with 'high' reallocation).[8] This is adopted as the 'medium' employment projection for the study;

2.24 Each of these employment projections is used within each of the different scenarios, dependent on the role of agglomeration (which dictates both employment growth in city regions, and the degree to which this growth is concentrated within city centres) envisaged. This is set out in further detail in Chapter 3.

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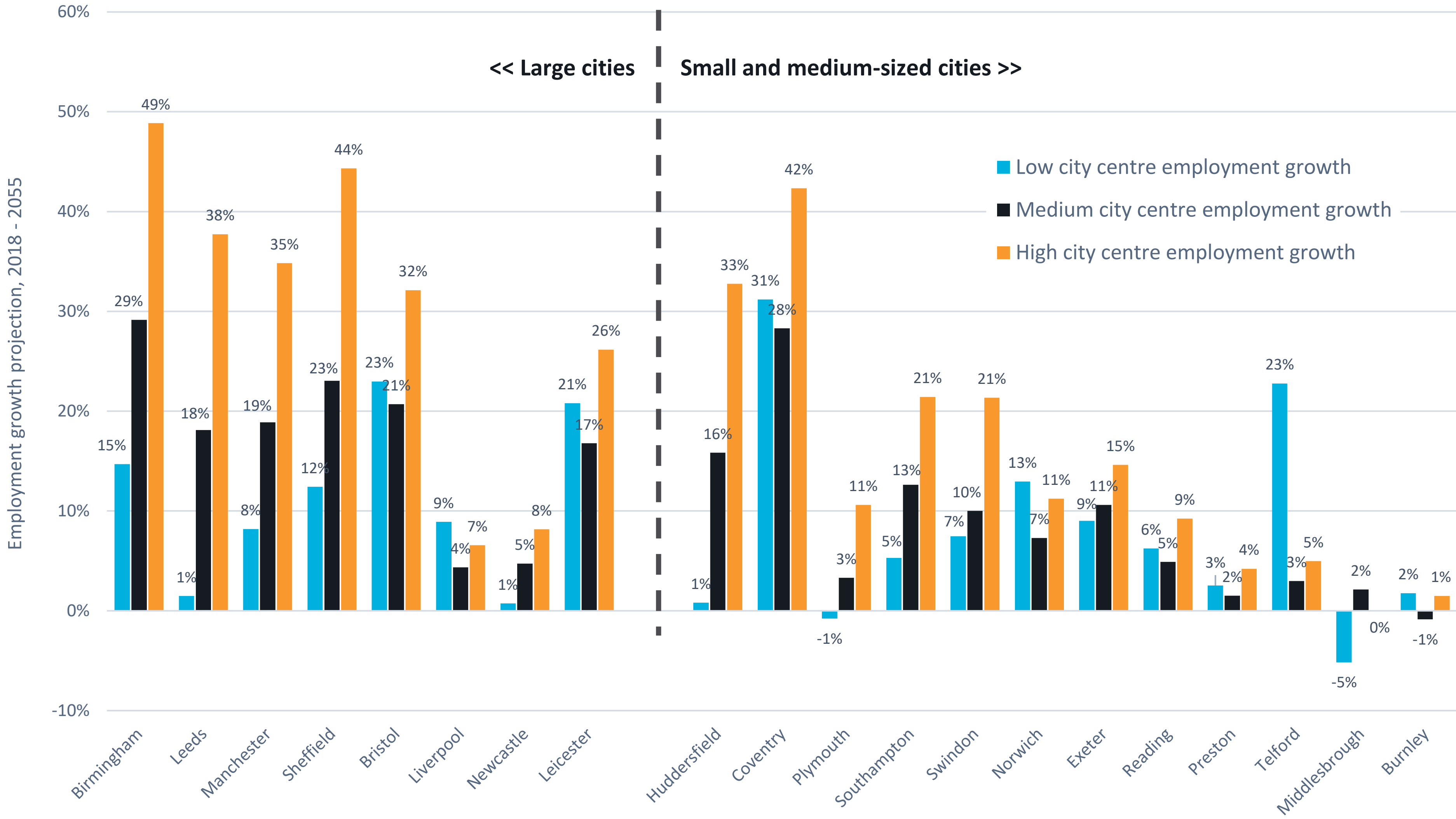
[7] Note that the projections consider growth across all urban areas and city centres nationally; differences between the projections at the level of specific cities mean that, for a small number of cities, the 'high' projection is lower than the 'medium' or 'low' (such as Liverpool and Telford). For example, the 'low' projection uses a 2018-based ONS projection for national employment growth, and the 'high' a 2014-based projection when **national** growth was envisaged to be greater, but this does not mean that growth is necessarily greater in the 'high' rather than the 'low' projection for **every** city.

[8] When taking the average of the ONS Central and High Urban forecasts for this purpose, the ONS Central M0 is used as it is 2014-based (rather than 2018-based for M1) which corresponds to the 2014-based High Urban. This also reflects how the ONS Central M1 has a lower level of national growth, reflecting Brexit and other macroeconomic factors.

Figure 2.5: Employment projections adopted within scenario analysis



Stage 2: Establish current and 'committed future' capacity

Revise 'bottom-up' 2018 Urban Transport Capacity Metric

2.25 The previous 2018 study developed an Urban Transport Capacity Metric (UTCM), which provided a measure of the theoretical transport capacity for the AM peak hour (08.00-09.00) crossing a tightly-defined city centre cordon. The rationalisation and limitations of this measure are discussed in Paragraphs 3.5 to 3.8 of the **2018 report**. It provides a consistent measure of urban capacity across all case study cities.

2.26 We undertook a review of the 2018 UTCM for each city, and the data that underpins it, to assess the extent to which the metric required updating to reflect current (and future committed) transport capacity across the case study cities. This was informed by data and information provided by DfT regarding local transport schemes committed, funded and/or delivered,[9] and our wider industry knowledge.

2.27 It should be highlighted that the current capacity provided by bus, rail and light rail networks is in many cases materially lower than that provided in 2018 pre-pandemic. This is a result of both lower demand and/or short-term staff shortages being reflected in a lower level of service (e.g. lower frequency on existing routes). We have made a simplifying assumption assume that if required this capacity can be restored to meet demand without incurring capital cost. The effects of the pandemic and the on-going cost-of-living crisis means that it is difficult to derive an effective and consistent measure of 'current', 2022 public transport capacity due the short-term variability in timetabled provision in different cities, and as previously set out this is partly a reason for using 2018 as the 'base year' for the analysis.

2.28 The focus of the review was therefore on understanding where – if at all – additional capacity has been delivered or was committed over and above that included in the 2018 metric. It highlighted that, broadly speaking, the level of current and 'committed' transport capacity is similar to that estimated in 2018.

2.29 Table 2.2 discusses the broad changes in capacity across the city-centre cordons, by mode, and how the capacity metric has been amended to reflect this.

Table 2.2: Approach to updating 2018 Urban Transport Capacity Metric, by mode

Mode	Background and Discussion	Implication for study
Rail	The 2018 rail capacity was estimated from 2017 timetable data and assumptions regarding train lengths to derive the capacity into each city. Between 2017/18 and the pandemic, some additional capacity (both through new services and longer trains) was delivered, together with further future 'committed'	As a simplifying assumption, we have assumed that the rail capacity of each city is unchanged since the previous study. The capacity provided today is broadly less than 2017/18, and our approach:

[9] Any project (outside London) that has had a material impact on transport capacity is likely to have been funded through a DfT funding source (such as the Local Growth Fund), so this approach captures the vast majority of committed and delivered transport schemes within English cities.

	increases within franchise specifications. However, a proportion of this additional timetabled capacity (particularly within North of England, following the May 2018 timetable) could not be operated reliably, with high levels of delay and cancellations, and was not 'delivered' in practice. Largely this reflected infrastructure constraints, for which enhancements were **not** committed or funded. It is not therefore appropriate to include this capacity within an updated metric. Post-pandemic, the scale of capacity provided by the rail network into large city centres has fallen – both as a result of declining post-Covid demand and short-term staff shortages, but also a realisation that in some locations the level of capacity provided and 'committed' prior to the pandemic was unachievable to operate reliably within the infrastructure available.[10]	• Assumes that capacity can return to 2018 levels without infrastructure enhancements; Recognises that it is not practical within the constraints of the project to determine exactly how much capacity could be provided over and above 2018 levels before reaching fixed infrastructure constraints. Note an exception is made for Merseyrail, which operates largely independently from the rest of the rail network, and for which a new fleet has been delivered and expected to be introduced into service imminently. This will increase capacity by an estimated 50% because of a more efficient seating layout and longer trains. This increase has been included in the revised capacity figure for Liverpool.
Bus	The 2018 bus capacity data was derived from bus frequency data of the number of services crossing the city-centre cordons, combined with assumptions regarding the capacity of each bus. Since 2018, and especially post-pandemic, the number of bus services entering city-centres has declined, largely due to a short-term decrease in demand post-pandemic. Several enhancements to bus services have been committed, funded and/or delivered since 2018, largely through the Transforming Cities Fund and/or City Region Sustainable Travel Settlements (CRSTS), including both new Bus Rapid Transit services (e.g. SPRINT in the West Midlands) and local priority	We have amended the bus capacity and demand based on refinements to the 2018 data and methodology,[11] but the baseline capacity continues to be estimated from 2018 data. This reflects: • Actual bus capacity has fallen post-pandemic – so 2018 represents a 'high point' for the capacity provided; • Committed schemes will result in a small increase in capacity – but this is difficult to robustly estimate, and

[10] An example of this is the new **December 2022 timetable for Manchester and the North of England**, which has been designed to reduce the number of trains and simplify services to improve reliability. This delivers a reduction in capacity compared to that pre-pandemic (and that proposed and 'committed' to be delivered under the 2016 **Northern** and **TPE** franchise agreements), and recognises how additional services cannot be operated without (uncommitted and unfunded) infrastructure investment in Central Manchester.

[11] This results in a significant change for Manchester, Birmingham, Coventry and Liverpool (higher utilisation), but more minor changes for other cities. This is a result of refinements to assumptions regarding converting 2011 Census journey-to-work demand by bus to AM peak hour bus demand, combined with revised assumptions for estimating bus capacity from real-time data.

	enhancements. These will increase bus capacity entering city centres; however the extent of this increase is difficult to determine in the absence of detailed service proposals. BRT schemes such as SPRINT typically involve new high-frequency services, but along only a small number of corridors, and are accompanied by amendments and withdrawals to other services along the same corridors; local priority measures may enhance capacity but at the expense of private car, and/or not impact on capacity but simply increase the attractiveness of bus versus other modes.	is small in comparison to other areas of uncertainty in the study. The approach to costing reflects that, particularly for those cities that have recent or committed investment in new BRT and bus priority infrastructure (e.g. through CRSTS), there is the ability to deliver additional services and capacity without infrastructure spending, and instead through simply increasing bus frequencies.
Highway	A review of schemes funded by DfT (through CRSTS, TCF, etc) showed that very few schemes (if any) schemes will deliver a material increase in capacity across city-centre cordons.[12] In practice, a reduction in highway capacity relative to 2018 is more likely as a result of delivered and committed investment in urban realm, active travel and bus priority schemes.	No change to highway capacity assumed relative to 2018. Increased capacity as a result of CAVs is tested through the application of the scenario effects, discussed in Chapter 3.
Metro and light rail	Of the 20 core cities under assessment, only Birmingham, Manchester and Newcastle have light rail networks. Of these, since 2018: • **Birmingham** has delivered the Edgbaston Extension. This does not provide additional capacity across the city-centre cordon. • **Manchester** has delivered the Trafford Park Line, but this not increase capacity into Manchester City Centre. No further extensions or upgrades are currently committed or funded. • The **Tyne-and-Wear Metro** has a funded fleet upgrade, which will increase capacity by circa 20%.	No change to the light rail capacity has been assumed within Birmingham or Manchester. A 20% increase to the capacity of the Tyne-and-Wear Metro has been assumed for Newcastle.
Active modes	The capacity of active modes is not ‘defined’ within the UTCM, and instead is assumed to match active travel demand – which can increase in line with the mode share in 2011.	

[12] Of the small number of highway schemes funded and delivered, there is a greater focus on providing new orbital capacity (e.g. East Leeds Orbital Route), maintenance schemes, and/or limited junction upgrades.

Normalisation to convert from 'theoretical' to 'realistic' capacity

2.30 The UTCM provides an estimate of the 'theoretical' transport capacity (for all journey purposes – not simply commuting) crossing each city-centre cordon. However, in practice not all this capacity is available for trips to and from each city centre, since:

- for **highway**, traffic congestion, other constraints elsewhere on the highway network (e.g. upstream or downstream of the cordon) and/or parking limitations, will limit the amount of theoretical capacity which can be utilised.
  – For example, cordon counts from Leeds (2018 utilisation of 85%) and Birmingham (utilisation of 83%) suggests that traffic flows in the AM peak have been broadly stable over many years, despite increased latent demand for travel from employment growth (and other trip purposes). This suggests that, for these cities, for highway only circa 80% of the 'theoretical' capacity can be taken up in practice;

- for **public transport**, several factors will mean that not all theoretical capacity is available for trips to and from city centres, since:
  – some capacity is 'wasted' as it is provided on corridors that do not require it, even where other corridors operate near capacity. Rail services, for example, are planned on the basis of entire routes, and capacity cannot always be matched to local demand. For example, rail capacity into Birmingham provided by CrossCountry services is planned not simply for the needs of Birmingham but for numerous towns and cities along the entire route;
  – some users become 'crowded off', and are no longer willing to travel, when approximately 80-90% of the seated capacity is taken up, even when there is significant standing space available;
  – high-frequency bus services will 'bunch together' as in practice services cannot be operated at close to even headways which reduces the efficiency of capacity utilisation – some vehicles will be entirely full, while others partly empty;
  – the public transport network will not be viewed as a viable choice for some commuting trips compared to car, either due to users' perception of the service (e.g. not willing to travel by bus) or a lack of connectivity compared to private car. This is particularly the case for smaller cities.

- For **active travel**, the previous 2018 study noted that levels of active travel are constrained not by network capacity itself but by (current) user preference, the distance of journeys being made not suitable for active travel, and/or the quality of infrastructure provision. We have hence assumed that active travel capacity matches current demand (as derived from the previous study), but is allowed to grow such that the mode share for active travel remains constant i.e. if total employment grows by 10%, and active travel accounts for 10% of commuting trips, then active travel capacity can grow by 10%, and only 90% of total employment growth is required to be supported by highway and PT capacity.[13]

Normalisation factors

2.31 Since the assessment of future urban capacity requirements needs to reflect the 'realistic' capacity of the network to support future employment growth, rather than the 'theoretical' capacity, we apply a series of factors to 'normalise' the capacity. These factors vary by mode and broad size of city, reflecting that city size affects the efficiency of the network (as discussed in the bullet points above), and broadly those living and working in larger cities are more willing to tolerate more crowded conditions.

2.32 Two sets of factors were derived – a 'high' set of factors, which results in urban transport networks having a greater ability to support growth – and a 'low' set of factors, which are more pessimistic regarding the ability of the network to accommodate growth, and assume that employment is constrained by transport capacity at lower levels of demand.

2.33 These are presented in Table 2.3. The utilisation and capacity requirement, for each city in each scenario, was calculated using both sets of factors, and ultimately the 'low' factors were adopted for the study. This reflects how using these factors produced more plausible results, and how using the 'low' factors also accounts for how, while cities may have excess capacity, not all of this may be suitable to support future employment growth – for example, the available capacity may be on a different corridor to the demand requirement, or (especially for smaller cities) the public transport network does not provide an adequate alternative to highway trips, and hence highway trips 'crowded off' the network cannot be expected merely to shift to public transport.

Table 2.3: Normalisation factors to convert 'theoretical' capacity to 'realistic' capacity

	'High' factors >>			'Low' factors >>			
City Size	Very Large	Large	Small and Medium	Very Large	Large	Small and Medium	Justification
Highway	0.8	0.7	0.6	0.7	0.6	0.5	Evidence, for large cities, suggests that further demand cannot be accommodated at >80% theoretical utilisation. For smaller cities, a lower figure is applied as Congestion is less 'common', and viewed as a greater deterrent to travel.

[13] In reality this is conservative, as recent decades have seen housing growth disproportionately focused in 'inner city' areas, a short distance from city centres, and significant increases in the mode share for walking and cycling for city centre employment.

National Rail	0.7	0.6	0.5	0.6	0.5	0.4	Some users will be 'crowded off' rail travel before the train reaches theoretical capacity. For smaller cities, rail capacity is harder to match to demand, since overall services will not be planned on the basis of peak-hour requirements at e.g. Burnley or Coventry, and services will not uniformly arrive.
Metro	0.7	0.6	N/A	0.6	0.5	N/A	Similar to rail - some users will be 'crowded off' rail travel before the tram reaches theoretical capacity.
Bus	0.7	0.7	0.7	0.6	0.6	0.6	Higher-frequency bus services will 'bunch together', meaning that it is not possible for every seat/standing space to be occupied on every service, since an even headway cannot be provided in practice. Compared to other transit modes, bus services are more scalable than rail and metro, and better able to be designed to match demand at their busiest point
Active travel	1.0	1.0	1.0	1.0	1.0	1.0	Active travel is not constrained by capacity, rather demand and quality of infrastructure, so no normalisation required.

Stage 3: Revise 2018 utilisation calculations

2.34 We then calculate revised 2018, pre-Covid transport utilisation estimates, of 2018 demand divided by 'realistic' transport capacity, for each city for each mode, and a total utilisation across all modes. These utilisation metrics are materially higher than the previous 2018 work as they will have been adjusted to account for both:

- the difference between 'theoretical' and 'actual' capacity, as discussed above;
- amendments to the capacity and demand for bus in each city, and rail and light rail capacity in Liverpool and Newcastle respectively;
- the inclusion of active travel within the utilisation calculation, which was not previously captured.

2.35 This utilisation metric forms the basis for assessing the 'capacity gap' – the scale of additional travel demand that can be accommodated prior to employment growth being constrained, as discussed in the following steps.

2.36 Table 2.4 provides an example of how Stages 2 and 3 are applied in practice for Bristol city centre, and how this differs from the previous 2018 study.

Table 2.4: Bristol capacity, demand and utilisation

Mode	2018 demand	Theoretical Capacity	Theoretical Utilisation	Revised 2018 demand	Revised theoretical capacity	Normalisation factor	Normalised Capacity	Normalised Utilisation
	Previous 2018 approach >> *As previously presented*			**Updated assumptions >>** *Normalisation factors to convert to realistic capacity; changes to estimated demand and future capacity*			**Figures used for capacity and demand assessment >>**	
Highway	14,000	21,000	68%	14,039	20,528	0.7	14,370	97.7%
National Rail	4,000	7,000	58%	4,048	7,030	0.6	4,218	96.0%
Metro / light rail	N/A	N/A	N/A	-	-	0.6	-	
Bus	10,000	16,000	61%	5,223	8,904	0.6	5,343	97.8%
Sub-total	**24,000**	**44,000**		**23,310**	**36,462**		**23,930**	**97.4%**
Active	14,200	14,200 *Assumed 'capped' at current demand in capacity assessment*	*Utilisation excluded walking and cycling*	14,914 *39.0% mode share of current demand*	N/A *Capacity of active modes not constrained*	1.0	15,310 *Can increase to keep mode share constant at 39.0%*	100%
Total	**38,000**	**58,000**	**64%**	**38,224**	**36,462 + active**		**39,241**	**98.4%**

Stage 4: Application of 'capacity cap'

2.37 Our approach then assumes that additional transport demand arising from an increase in city-centre employment and commuting can be accommodated up to 100% of the normalised utilisation figure, but no further. Above this, no further employment can be supported by the city's transport network. The justification for this is discussed below.

Commuting and employment can grow up to a city's 'realistic' transport capacity, but no further

2.38 Our overall approach assumes that this 'realistic capacity' acts as a total constraint on travel demand, commuting demand, and hence overall city centre employment. Once this capacity is reached, no further commuting demand or employment growth can be accommodated by the transport network. This represents a simplification, since:

- in practice, there is a more complex relationship between 'capacity' and 'employment'. Even at low levels of network crowding, some employment growth will begin to be constrained, and as crowding increases – more and more employment growth will be constrained and instead occur elsewhere. However, the 'London experience' of recent decades suggests that employment growth can occur even when the transport network is highly constrained, and many large regional cities (such as Leeds) have experienced city centre employment growth despite **highway** capacity being reached. This suggests that as well as there being a relationship between capacity and employment, the scale and nature of the employment in a city centre will influence commuters' tolerance of travelling in crowded conditions;

- our capacity metrics **only** account for demand within the high peak hour (08.00-09.00). As crowding increases, further commuting and employment growth can accommodate through '**peak spreading'**. Even if the network is heavily congested in the high peak hour, 'spare' capacity in the shoulder peaks can be used to facilitate further employment growth, and commuters instead continuing to work in a city-centre location but with less 'optimum' travel patterns.
  - Highway cordon counts from Leeds suggest that this has supported significant increases in travel demand: while traffic flows in the high peak hour have remained constant for many years, flows have increased in the shoulder peaks to cater for increased travel demand. Similar observations can be seen on the London Underground network, where passenger growth has been greatest in the shoulder peak periods.

2.39 The derivation of the normalisation factors in Table 2.3 reflect this – they have deliberately been set at a level above which employment will start to be constrained (e.g. from traffic congestion), but well below the level whereby no further employment growth can be accommodated, by the transport network, at all.

Multi-modal capacity is assumed to cap employment, not simply highway capacity

2.40 Further, it is assumed that the 'capacity cap' is applied to total 'realistic' capacity across all modes, rather than simply highway capacity, or a given level of highway congestion. This has been assumed for two primary reasons:

- **Recent experience of large cities outside London**: Recent experience of the link between traffic congestion, commuting and employment growth suggests that significant employment growth in city-centre, knowledge-intensive employment can occur well after all highway capacity has been utilised. Within Birmingham and Leeds over the past two decades, significant growth in employment has seemingly been facilitated despite limited or no growth in peak-hour inbound traffic demand, and high levels of traffic congestion, largely through the latent demand for commuting being accommodated through available capacity on the public transport network (particularly rail).

  - The implication of this is that, **as long as** the public transport network provides a viable mode for city-centre commuting trips,[14] employment growth is only constrained when demand approaches overall transport capacity (not just highway), and that the utilisation cap should reflect this.

- **Implications for investment approaches**: The application of the cap also has implications for how the investment approaches are developed in subsequent stages. If a 'capacity cap' is based on highway capacity, in effect this means that when a city's road network reaches a certain level of congestion, then no further employment growth can occur and there is a need for more investment in transport capacity. However, all the proposed investment approaches outlined in Chapter 4 are based around delivering further public transport capacity ('bus-based'; 'transit-based' and 'rail-based') and none involve new highway capacity (which is in practical terms is likely to be undeliverable). While additional public transport capacity will enable more people to access city centres, it is unlikely to materially reduce peak highway congestion.[15] With this approach, since highway utilisation has not been significantly reduced, city-entre employment remains constrained and 'capped' – even with the delivery of further investment to increase public transport capacity. This represents an inconsistency in the theory of change for how public transport investment can support increased employment within city centres.

Sensitivity to these assumptions

2.41 We recognise that these assumptions have a significant impact on the scale of the overall capacity requirement for each city, under both the 'baseline' and 'scenario' forecasts.

2.42 We have therefore tested two sets of normalisation factors (as shown in Table 2.3), together with the previous assumptions of constraining employment growth above a 49% and 68% level

[14] This is less likely to be the case in smaller cities, which is partly the justification for applying a greater reduction in the highway capacity for smaller cities when transport capacity is normalised (as shown in Table 2.3.

[15] Experience across a range of urban contexts suggests that increased public transport provision only has a very small effect on reducing traffic congestion through mode shift, and additionally enhanced PT provision typically requires a reallocation of road space, which can itself have a negative effect on congestion. Charging and demand management plays a far greater role as a policy tool in achieving reductions in congestion.

of highway utilisation,[16] while assessing the scale of the required scale of required capacity in each city. The decision to adopt the 'low' factors was informed by this analysis (as discussed in Paragraph 2.33) and the effects of the different approaches presented in the main report.

Stage 5: Estimate constrained employment and 'capacity gap' for each city

2.43 The last stage involves combining the unconstrained employment forecast and adjusted utilisation, and applying the 'capacity cap' of 100% of adjusted utilisation to understand:

- the scale of employment growth that cannot be accommodated by the city's transport network, and;
- the 'capacity gap' for each city – the scale of additional capacity required for the city to meet its unconstrained employment forecast.

2.44 Consider Bristol, with an 'normalised' transport capacity of 38,844. The 2018 AM high peak hour demand, across all modes and journey purposes, is 38,224 – giving a utilisation of 98.4%:

- Based on these figures, highway and public transport **demand can increase by only 620 trips** prior to the 'capacity cap' being reached. Since walking and cycling trips are also allowed to increase while keeping their mode share constant (high at 39% in the case of Bristol), **total demand can increase by 1,017 trips, or 2.7%,** prior to the 'capacity cap' being reached, at 100% utilisation;
- Assuming that any increase in commuting trips will be accompanied by an increase in other trip purposes (business; leisure; etc) in equivalent proportions,[17] then a 2.7% increase in commuting trips can be accommodated;
- In the 'baseline' scenario – with no change in the assumed frequency of commuting trips - this then equates to an increase in 2018 employment of 2.7%;

2.45 Now consider the total 2018 employment of 77,099. The 'High Urban' unconstrained city centre employment forecast, with 'high' re-allocation of growth to the city centre within the LA district – is 101,869 in 2055, an increase of 32.1%, and:

- Since only a 2.7% increase in 2018 employment can be accommodated by the transport network, only 8.3% of the additional employment projected for Bristol within the unconstrained forecast can be accommodated (0.027/0.321 = 0.083);
- This means that only 2,050 (8.3% of the original 24,770) new jobs can be accommodated, and hence the 'constrained' 2055 employment forecast is 79,149 – a 'loss' of 22,720 jobs;
- **Hence, the additional AM high peak capacity required to meet the 'unconstrained' demand forecast is 11,264 for the 'baseline' scenario.**[18]

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[16] These figures were based on the levels of congestion in Newcastle and Bristol respectively, and this approach previously used by the NIC with outputs from the previous study.

[17] i.e. the journey purpose split between trip purposes does not change between 2018 and 2055

[18] If the unconstrained increase in employment of 32.1% is applied to current demand, this would equate to an additional 12,281 trips. Only 8.3% (or 1,017) of these extra trips can be accommodated by

2.46 The advantage of this approach is that neither a specific journey purpose split, nor an assumed 'number of commuters per job' figure, are not required. Both of these would be difficult to robustly estimate at an individual city centre level, as they will vary significantly based upon not only levels of remote and hybrid working in 2018 (in turn linked to industry/occupation mix), but also factors such as annual leave, the amount of shift-working, and the structure of employees working weeks, and the available data does not provide assessments of these attributes. Instead, the approach is based on assessing different uplift factors from current commuting trips. This, in effect, assumes that:

- The number of commuters per job does not change between 2018 and 2055 (this is subject to the scenario testing from remote working assumptions discussed in Chapter 3);
- Every additional commuting trip is accompanied by a number of business, leisure, shopping and other trips, in equal proportion to that in 2018.

2.47 It is these proportions that are amended in the scenario tests – as discussed in the next Chapter.

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the transport network; 11,264 cannot be accommodated – this forms the additional peak capacity requirement.

3 Future Capacity and Demand Assessment

Introduction

3.1 This Chapter discusses how the 'baseline' capacity and demand assessment for each city is:

- updated to reflect a **range of uncertainties** in future demand to 2055, such as increased levels of hybrid and remote working;
- grouped into **eight distinct scenarios** that represent a different 'future' facing city centres; and
- used to **assess the potential scale of employment constraint and future transport requirements** for each city.

3.2 Two key 'drivers' were identified that will shape the future development of city-centres, and inform which of the uncertainties and employment projections are combined to form scenario. These are:

- **Trends in homeworking** – increased adoption of remote and hybrid working is one of the most disruptive impacts of the pandemic, with long-term consequences for both travel demand into cities, and the potential role of city-centres in future;
- **Role of agglomeration** – partly (but not entirely) a result of homeworking, a change in the importance of agglomeration (the productivity advantages to firms, and especially knowledge-intensive firms) of locating in close proximity to one another and their workers will shape the extent to which businesses choose to locate in city-centres in future.

Future uncertainties

3.3 The future uncertainties considered, which follow from the drivers of change, are:

i. **Future employment growth**, and the extent to which it is concentrated in:

   a. **city regions**, captured within the choice of the ONS Central or High Urban employment forecast;
   b. **city centres**, captured with the extent to which employment growth is 're-allocated' to occur within city centres, versus the rest of the local authorities and the wider metropolitan area;

ii. **future levels of hybrid and remote working**, including how levels of homeworking vary across the week (**temporal effects**);

iii. **business centralisation,** a measure of how or if businesses further concentrate within city centres if increased homeworking results in falling demand and rents for physical workspace;

iv. **household suburbanisation,** a measure of how individuals may choose to relocate further from city centres as a result of increased homeworking; and

v. **uptake of new transport technologies** such as connected and autonomous vehicles.

3.4 Each of these uncertainties (except iv.) is captured within the analysis through deriving and applying a series of factors within the approach previously described in Chapter 2 to adjust either:

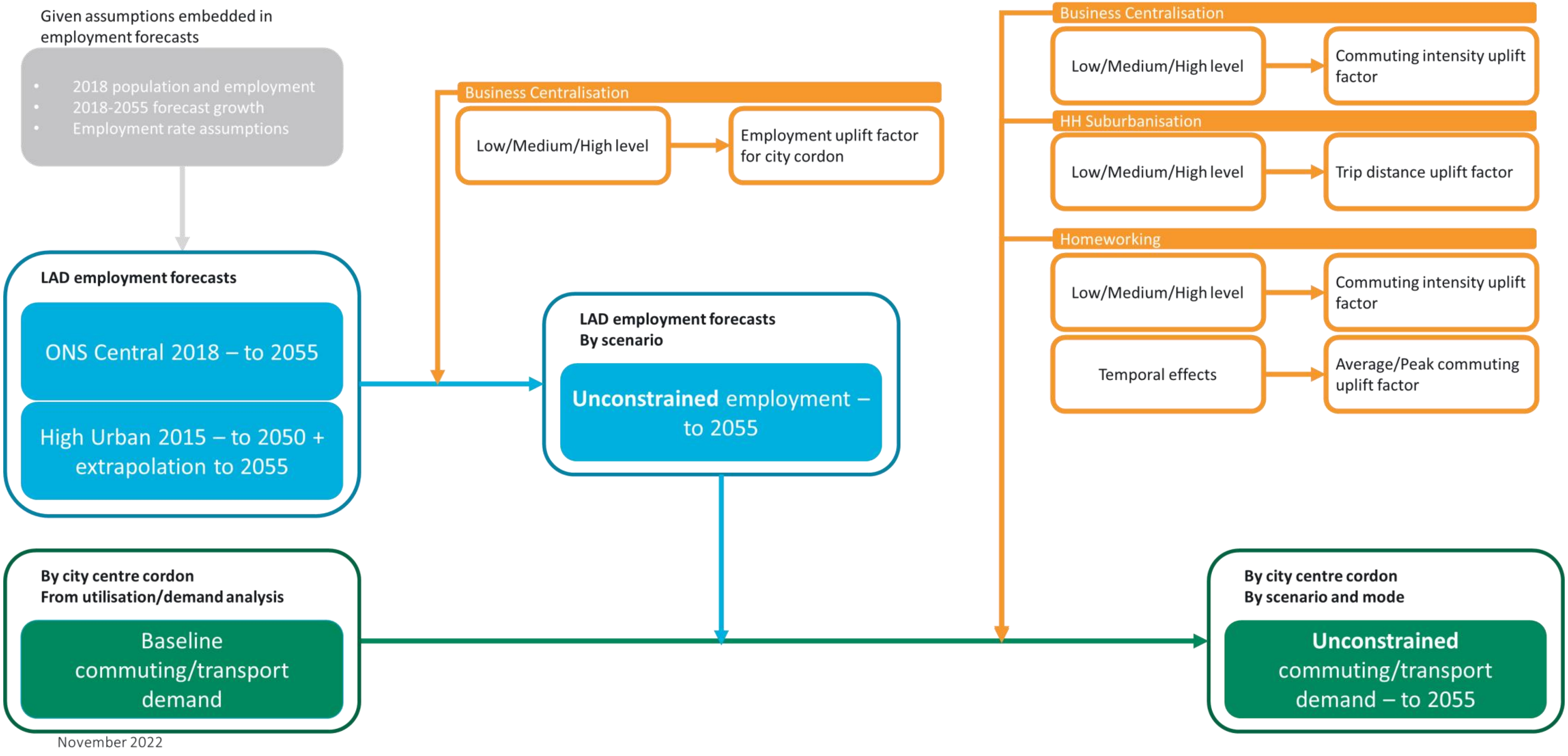
- the unconstrained employment forecast (i. above)
- the underlying transport capacity (v. above)
- baseline travel demand (ii – iii. above).

3.5 Suburbanisation effects (iv. above) are captured independently, since they are assumed to impact only on the distance individuals travel to city centres, rather than the total demand crossing the city centre cordons. The rationale this is discussed from Paragraph 3.46 onwards.

3.6 These factors are unique to each city, derived from local data and evidenced assumptions, to provide a more granular understanding of each effect. The overall approach is summarised overleaf.

3.7 The basis for the employment growth projections (i. above) was discussed in Chapter 1. The background and approach to capturing each of the four other uncertainties is discussed in in turn below.

Figure 3.1: Summary of approach to applying scenarios within capacity assessment



Future levels of hybrid and remote working

Introduction

3.8 These assumptions affect the rate at which workers attend their workplace each week. They are highly dependent on the ability of the workers to work effectively remotely and whether or not personal interaction is an essential part of business activities, and hence vary based on both occupation and the industry of employment. They consist of two effects:

- **Levels of hybrid and remote working**– changes in the underlying proportion of workers, within each occupational group, who undertake hybrid or remote working;
- **Temporal distribution** – for those who undertake homeworking, the extent to which periods of homeworking occur equally across the week, or are distributed on specific days – e.g. more people commute to a physical workplace on Tues/Weds/Thurs, and fewer Mon/Fri.

3.9 The direct impact of these assumptions is to change the frequency (and distribution across the week) with when workers attend the workplace. Increased levels of hybrid and remote working raises the possibility that a city centre could gain additional total employment, but without a commensurate increase in commuting demand.

3.10 The following six steps explain how this uncertainty is applied in practice to the demand analysis.

Step 1: Estimate current level of hybrid/remote working for each city

3.11 The 2018 city centre AM high peak travel demand, commuting demand, and its relationship to city centre employment, will be unique for each city. This will partly reflect variations in jobs (some cities will have greater numbers of commuters not travelling in the peak, working shifts, etc), and related to this, the baseline levels of homeworking in 2018.

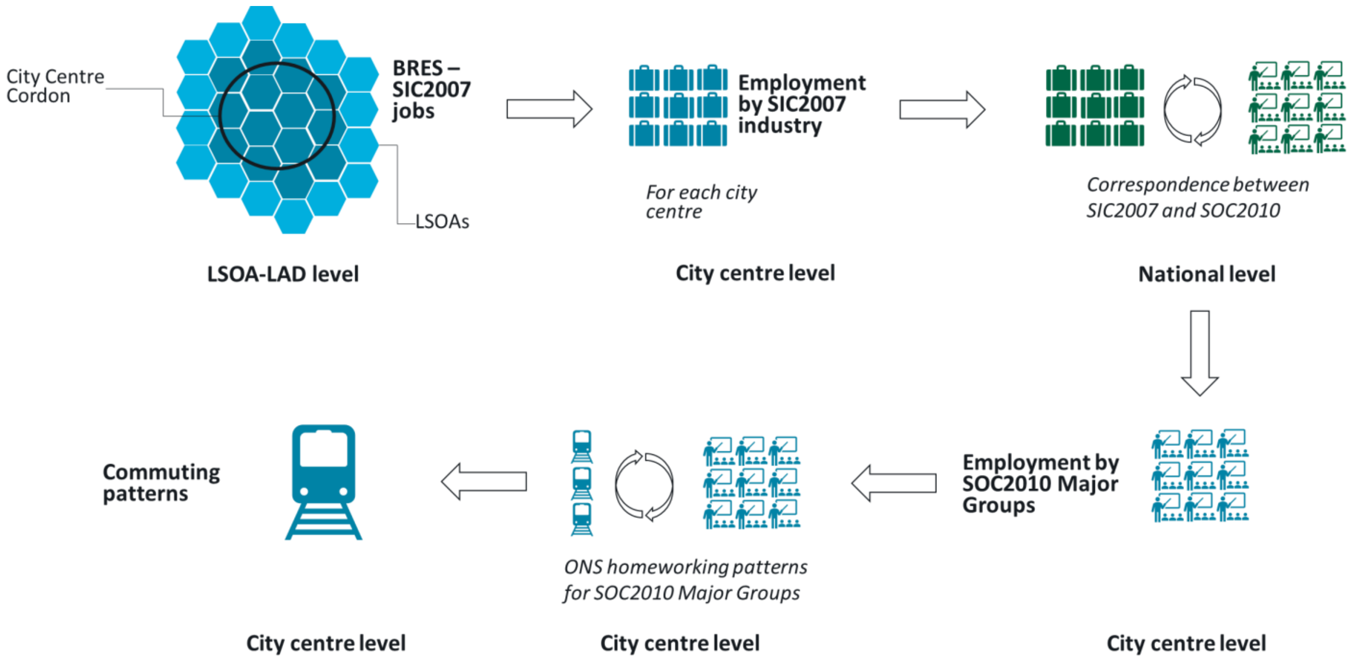
3.12 For each city, we will estimate the level of 2018 homeworking, based on combining data for the number of workers within each city centre by Standard Industrial Classification (SIC), for 2018, with a lookup from SIC to the Standard Occupational Classification (SOC), and the observed level of homeworking by each SOC group derived from the ONS Homeworking Survey. This provides a unique percentage of workers hybrid, and remote, working for each city centre within 2018, which reflects the unique breakdown of employment within each.

3.13 The approach reflects how employment by SOC is provided by the ONS at a local authority level, but not at a more granular level, and is therefore not specific to the jobs that are located within each city centre cordon. To address this, we have extracted the ONS Business Register and Employment Survey (BRES) to provide employment by SIC 2007 2-digit code level (e.g. '69: Legal and accounting activities), within the city centre cordons, which is available at LSOA level.

3.14 We then translate these job figures from the SIC 2007 codes into the nine SOC major groups using a SIC 2007 – SOC 2010 correspondence at a national level. We have explored the data and have concluded that this correspondence is consistent across different areas in the country, and similar to the national average. Once the distribution of jobs by SOC major group has been determined for each study area, we calculate the overall commuting volumes, using homeworking figures by SOC major groups, as published by ONS.

3.15 The ONS Homeworking Survey does not provide a specific 'percentage of time at the workplace' or equivalent metric to adopt for their data. We hence made assumptions to convert working status to an estimated '% of working time in workplace' metric as follows:

- Not hybrid or remote working – 5 days at workplace (100% typical week)
- Hybrid working status – 2 to 3 days at workplace (50% typical week)



3.16 Figure 3.2 summarises this initial step for developing the homeworking assumptions.

Figure 3.2: Summary of calculation of commuting patterns by study area

Step 2: Estimate future scenario level of hybrid / remote working for each city

We then undertake the same calculation using revised 'low', 'medium' and 'high' assumptions for the proportion of homeworking, for each SOC group. These are informed by observed levels of homeworking from ONS Annual Population Survey, both before and during the pandemic, shown in Table 3.1.

3.17 The 2019 data has been used as a baseline, for pre-pandemic levels of homeworking. Data during the pandemic (in 2021) provides a plausible 'upper bound' to the scale of homeworking across the different occupations – and in particular the percentage of workers who have 'Ever WfH'. The three right-hand columns summarise the change during the pandemic – it is greatest amongst SOC groups 1-4, but also group 7 – Sales and Customer Service Occupations.

Table 3.1: Observed levels of homeworking, 2019 (pre-pandemic) and 2021 (during pandemic), ONS Annual Population Survey

Occupation (SOC) Group	ONS data, 2019 pre-pandemic – used as baseline			ONS data, 2021 – during pandemic			Change during the pandemic (percentage point change)		
	Perm-anent WfH	Hybrid WfH	Ever WfH	Perm-anent WfH	Hybrid WfH	Ever WfH	Perm-anent WfH	Hybrid WfH	Ever WfH
1 Managers, Directors And Senior Officials	10%	14%	47%	22%	24%	58%	**+12**	**+21**	**+11**
2 Professional Occupations	6%	15%	45%	21%	28%	62%	**+15**	**+29**	**+17**
3 Associate Professional and Technical Occupations	8%	11%	37%	23%	26%	59%	**+15**	**+29**	**+23**
4 Administrative And Secretarial Occupations	7%	4%	20%	20%	24%	50%	**+13**	**+34**	**+30**
5 Skilled Trades Occupations	2%	3%	18%	4%	5%	19%	**+2**	**+3**	**+1**
6 Caring, Leisure And Other Service Occupations	5%	1%	14%	5%	3%	14%	**-**	**+3**	**-**
7 Sales And Customer Service Occupations	2%	2%	9%	10%	9%	22%	**+8**	**+16**	**+14**
8 Process, Plant And Machine Operatives	1%	1%	6%	2%	1%	7%	**+1**	**+1**	**+1**
9 Elementary Occupations	1%	0%	4%	1%	1%	4%	**-**	**+1**	**-**

3.18 Table 3.2 presents the ‘low’, ‘medium’ and ‘high’ assumptions for homeworking used within the study. This are materially higher than adopted for the previous April 2021 **Infrastructure Demand Quantitative Analysis for Scenarios of Behaviour Change** research undertaken by Steer for the NIC, and reflects new information and insight on potential long-term trends post-pandemic.

3.19 The ‘Low’ assumptions are based upon a small increase in levels of homeworking in SOC groups 1-4, but largely assume a return to pre-pandemic working behaviours. The ‘Medium’ assumptions are based upon an uplift in levels of homeworking relative to 2019, but a reduction compared to 2021. The ‘High’ assumptions assume that levels of homeworking, by 2055, broadly return to near that seen during 2021.

Table 3.2: Levels of hybrid and remote working assumed within assessment

Occupation (SOC) Group	**Pre-pandemic baseline (ONS 2019)**		Low 2055 scenario assumption		Medium 2055 scenario assumption		High 2055 scenario assumption	
			Permanent WfH	Hybrid WfH	Perm-anent WfH	Hybrid WfH	Perm-anent WfH	Hybrid WfH
1 Managers, Directors And Senior Officials	10%	14%	10%	15%	15%	20%	22%	25%
2 Professional Occupations	6%	15%	6%	15%	10%	20%	20%	28%
3 Associate Professional and Technical Occupations	8%	11%	9%	12%	10%	20%	20%	28%
4 Administrative And Secretarial Occupations	7%	4%	7%	4%	10%	20%	20%	22%
5 Skilled Trades Occupations	2%	3%	Same as 2019 pre-pandemic		Same as 2019 pre-pandemic		3%	5%
6 Caring, Leisure And Other Service Occupations	5%	1%					4%	3%
7 Sales And Customer Service Occupations	2%	2%			5%	5%	4%	8%
8 Process, Plant And Machine Operatives	1%	1%			Same as 2019 pre-pandemic		1%	2%
9 Elementary Occupations	1%	0%					1%	1%

3.20 From combining the total jobs by homeworking status (hybrid; remote; and not homeworking), derived from the occupational breakdown of city-centre employment and the factors in Table 3.2, and assumed '% of working time at workplace' metric, we can then calculate a unique metric for each city for the 'percentage of working time spent at the workplace'.

3.21 Figure 3.3 presents this for each city, based upon:

- ONS data regarding observed level of homeworking pre-pandemic (2018) and during the pandemic (2021) by SOC group;
- The high, medium and low homeworking assumptions, applied to the specific employment mix within each city; and
- The assumed 50% of working time spent at the workplace for hybrid working, and 100% for remote working.

3.22 For the baseline, broadly 90% of time is spent at the workplace, with only a small amount of variation by city. For the 'low' WfH scenario, there is only a small reduction to 2055, and across all cities, circa 90% of working time is spent 'not at home' – reflecting a return to broadly pre-pandemic trends.

3.23 For the 'medium' and 'high' homeworking assumptions, there is a significant reduction to 2055, with the 'high' assumptions approaching those seen during the pandemic. The reduction in each city is distinct, linked to the different occupational split of employment within each. Across all cities, 85% and 76% of time is spent 'not at home' for the 'medium' and 'high' scenarios respectively.

Variation in levels of homeworking between cities

3.24 The approach above seeks to assess the variation in potential levels of homeworking between cities, based on capturing the different occupational split of employment within each. Cities with a greater share of employment in the upper 4 SOC groups have higher projected levels of homeworking, which means that cities with a greater share of employment within these groups experience stronger homeworking effects to 2055.

3.25 Figure 3.3, particularly for the 'high' homeworking assumptions, does demonstrate this with higher levels of homeworking in larger cities that tend to have more knowledge-intensive economies, and a greater proportion of employment in the upper SOC groups. However, the scale of variation between cities is relatively small – under the 'high' assumptions, the percentage of time spent in the workplace in Bristol is 74% compared to 80% in Plymouth, the highest and lowest levels of homeworking respectively.

3.26 This reflects how our approach captures an 'occupation' effect (those in higher SOC groups are more likely to homework) but not an 'industry' effect (Managers and Directors, for example, in finance or healthcare are arguably less likely than those in technology to homework). We are not aware of reliable data regarding levels of homeworking by sector that isolates two effects, and so have not been able to capture this without our analysis. However, in practice – even if we could capture this – the implications of the results would be limited, since:

- The number of industries, and more so the total number of employees, with meaningful differences in levels of homeworking would be relatively small;
- Much of city centre employment is in the lower SOC groups, in sectors such as retail, where levels of homeworking are low and consistent across cities regardless.

Step 3: Calculate change in working time at physical workplace

3.27 Figure 3.4 presents the implications of applying these homeworking effects to commuting demand within each city, when applied to the 2018 baseline. Broadly, the reduction in travel demand relative to the baseline is circa 0.5% for the 'low' homeworking assumptions, 6% for 'medium' homeworking and 16% for 'high' homeworking.

3.28 Especially under the 'high' assumptions, this represents a material reduction in travel demand to 2055 relative to 2019. If this reduction is greater than forecast employment growth, a city will not have a capacity requirement by 2055 at all.

3.29 These figures are then used to reduce the scale of commuting journeys (from the baseline to the scenario) as a result of increased level of homeworking within the model, and are unique for each city.

Figure 3.3: Percentage of working time spent at the workplace, ONS observed data and Steer calculations

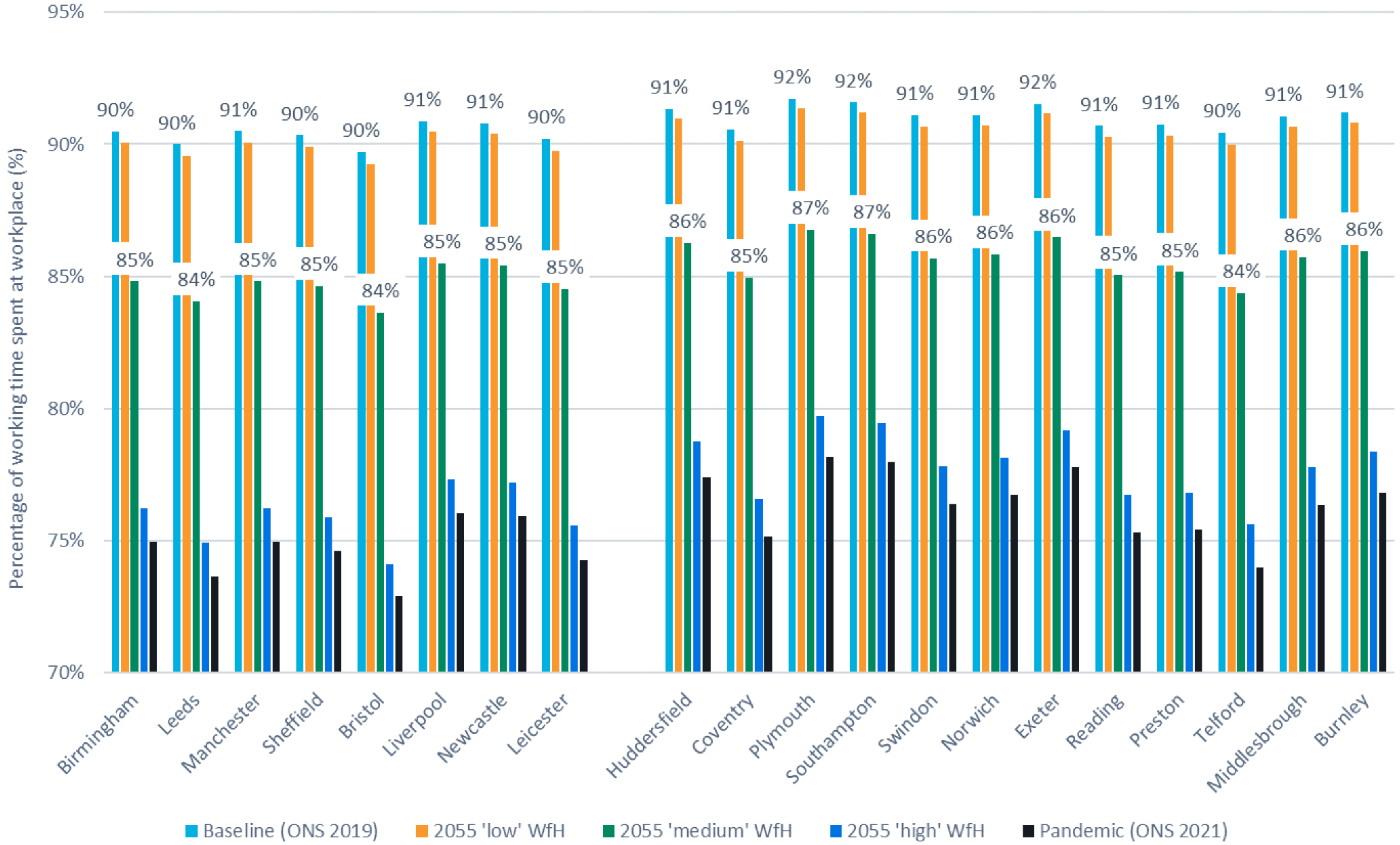
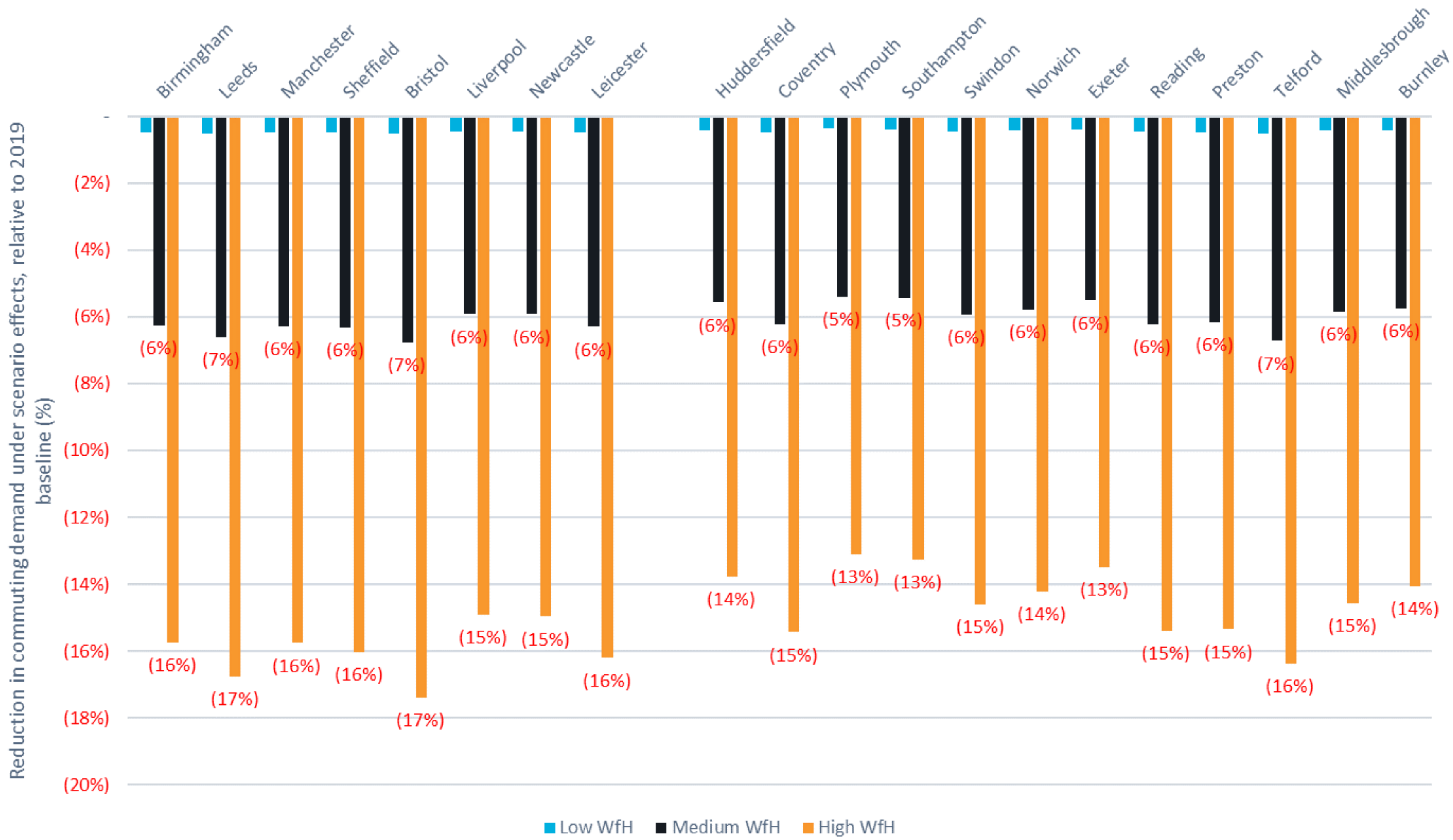


Figure 3.4: Projected reduction in commuting demand under homeworking effects, by city, relative to 2019 baseline (%)



Step 4: Adjust for temporal effects

3.30 Directly applying these changes directly to commuting demand implicitly assumes that an individual's tendency to homework is spread equally across the week, with the result that commuting demand is reduced equally across all days of the week. However, in practice this may not occur if businesses or workers have a tendency to attend a physical workplace on specific days. We describe these as 'temporal effects'.

3.31 Currently rail demand, for example, is understood to be around 20% greater on Thursdays compared to Mondays. Thursdays being busier than Mondays was a facet already identifiable pre-pandemic. Similarly, Transport for London is reporting that currently there are 13% fewer passengers on Tube and London Overground services on Mondays than Tuesday to Thursday, and Friday mornings have 28% less demand than mid-week.[19]

3.32 Temporal effects are captured in the analysis by calculating changes in commuting demand for both an 'average day' and 'peak day'. Step 3 estimates the reduction in working time spent at the workplace, but consider if:

- There is no temporal effect, and the reduction in time spent at the workplace is spread equally across the working week, there will be no difference between a 'peak day' and an 'average day';
- If, illustratively, all workers across all businesses attend a physical workplace on Wednesday, demand will be far busier on a 'peak day' than an 'average day'.

3.33 Where temporal effects apply, we repeat the Step 3 process but assume that all workers with a 'hybrid working' status (assumed to be attend workplace 50% of the time) all travel, at least once, on the same day. This is more 'pessimistic' from a transport planning perspective, with implications for both:

- **Workplace usage** – firm workspace will be used less efficiently, as it is 100% occupied on the busiest days, but less so on others;
- **Transport planning** – greater fluctuations in demand day-to-day result in an increased capacity requirement on the busiest days (at greater capital/operating cost) but with more 'wasted' capacity on quieter days

3.34 This assumption is used to calculate the change in commuting demand on both an 'average day' and a 'peak day'. The remainder of the method as discussed in Steps 5 and 6 is then applied for both days.

Figure 3.5 present the change in commuting demand, relative to the baseline, when applying temporal effects to the 'medium' and 'high' homeworking effects. For an 'average' day – the solid bars – the reduction in commuting demand is the same as Figure 3.4. The dashed bars instead represent the change when temporal effects are applied.

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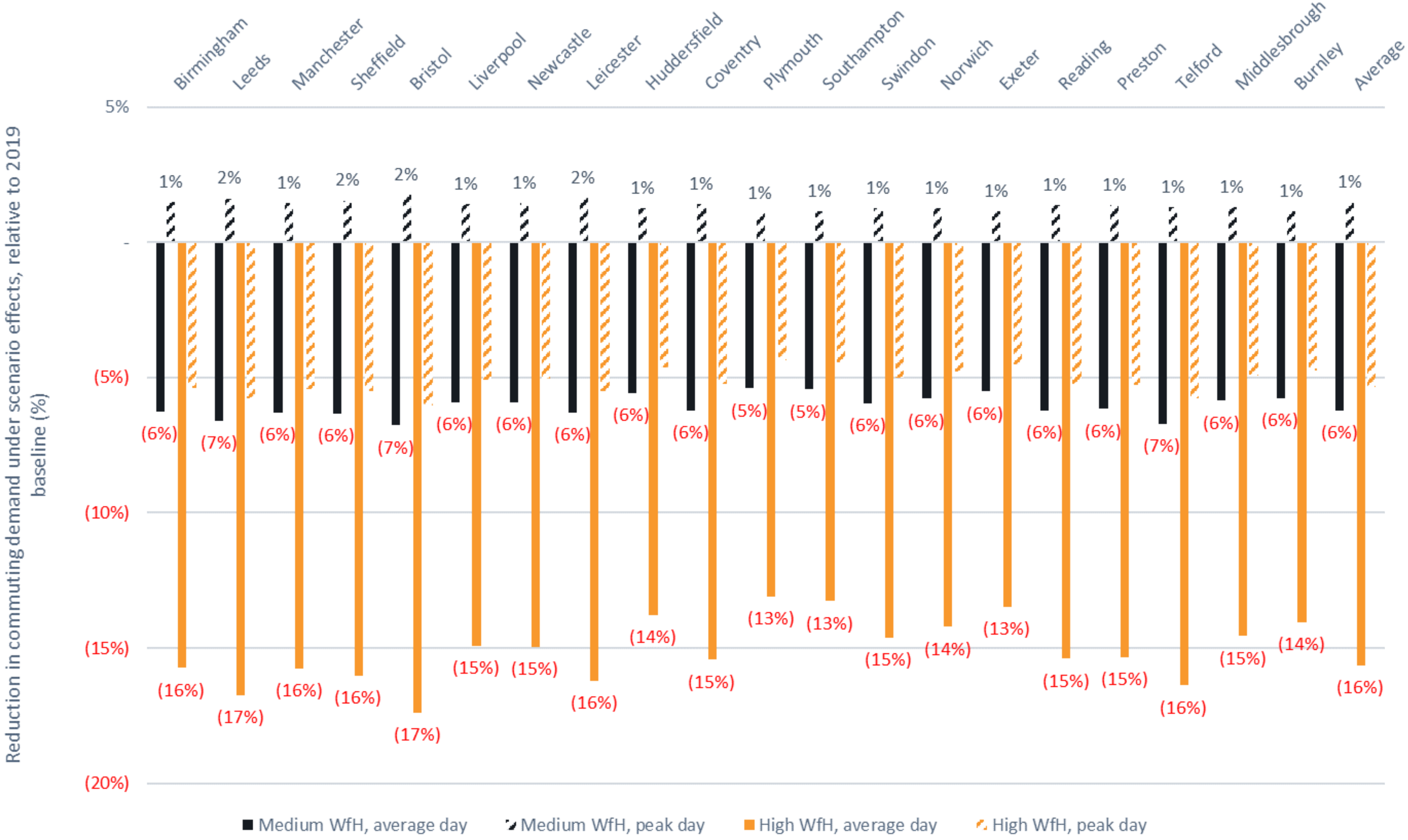
[19] Evening Standard, 24 Jan 2023, "*TfL aims to alter habits of the Tuesday – Thursday commuters*". Note total Friday demand is only 6% less than midweek, due to higher Friday evening (likely leisure-related) demand.

Figure 3.5: Projected reduction in commuting demand under homeworking effects, by city, relative to 2019 baseline, including temporal effects



3.35 Clearly, with these assumptions and compared with the baseline, the reduction in commuting demand on the 'peak' day is lower than on an 'average' day. Indeed, for the 'medium' scenario, this assumption actually increases travel demand relative to the baseline.

Step 5: Adjustment for all trip purposes

3.36 The change in commuting demand from Step 4 is then adjusted to reflect how not all journeys to city centres are commuting journeys, and hence applying this change to all demand would, in effect, assume that other trip purposes experience the same reduction as a result of home-working. This was partly tested within Steer's previous **Infrastructure Demand Quantitative Analysis for Scenarios of Behaviour Change** study[20] (for the NIC) through changes to trip rates under the 'Use of Virtual Tools' meta-trend, which explored how trip-rates could reduce as a result of a significant uptake in online and virtual activities in social, leisure, learning and consuming (including public services).

3.37 However, for this study, we have assumed that trip rates for other journey purposes will remain unchanged. This is part a simplification, but also a recognition that post-2021, leisure travel demand has largely recovered, whereas peak city centre commuting remains lower than pre-pandemic levels.

3.38 The exact trip purpose split, for AM high peak commuting, will be different for each city but limited data is readily available to inform what these splits should be. Informed by National Travel Survey data, we have assumed that 80% of trips to city centres in the AM high peak hour (the focus of our study) are for commuting purposes, and hence the factor is reduced by 20% so that trip-rates for other purposes are assumed to remain unchanged.

Step 6: Apply reduction to forecast change in commuting demand from 2018

3.39 This percentage reduction in travel demand is then applied to the calculations set out in Chapter 2 to calculate a revised unconstrained growth forecast and 'capacity gap'.

3.40 For Birmingham, as shown in Figure 3.5, the reduction in commuting demand assuming 'high' homeworking is 16% on an 'average day' and 5% on a 'peak day'. Since we assume that 80% of trips in the AM peak are commuting trips, and the frequency of other trips (education; business; leisure; etc) remains the same, then the reduction in overall travel demand will be lower – at circa 13% and 4% respectively.

This reduction is then applied to the 2018 transport demand, and the normalised capacity, to calculate a revised utilisation figure in line with the approach in Chapter 1. Since this will reduce the utilisation, the city will now have scope to increase employment by more than under the 'baseline' – so the constrained employment forecast and the overall capacity requirement will fall.

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[20] Steer (2021) **Infrastructure Demand Quantitative Analysis for Scenarios of Behaviour Change**.

Business centralisation effects

Background and discussion

3.41 Business centralisation refers to the change in firm density in the city centre. Density could increase if existing firms rationalise their floor space (e.g. office space or workspace generally) due to higher homeworking (e.g. less floor space is needed if workers only attend some of the time).

3.42 Such an effect would reduce a firm's rental costs as less space is occupied and also provide opportunities for more firms to locate centrally, increasing business density. On the other hand, density could decrease if firms disperse to take advantage of out of city centre locations (e.g. due to cheaper rent), in circumstances where proximity to other firms is less important. Another way that density could decrease is through firms repurposing offices to add collaboration spaces, staff cafes, social areas and the like, all with goal of increasing the attractiveness of employees attending the physical workplace.

3.43 The **key driver** of post-Covid centralisation effects is **trends in city centre office markets post-pandemic, conditional on increased levels of home-working.** If (and only if) increased homeworking results in a reduced demand for city-centre workspace, could this result in reduced demand and rents for such space. The implication of this are:

- If city centres are still viewed as attractive locations for firms to locate (as a result of strong, sustained agglomeration effects), despite increased homeworking, a reduction in rents will encourage the displacement of firms from less 'optimal' locations to city centres, taking advantage of greater availability and reduced rents. This will counteract any reduction in commuting demand caused by increased homeworking;
- However, if homeworking achieves very high levels, and/or if it results in the diminishing of agglomeration effects, or if in a post-Covid world workspace in more peripheral locations is viewed as more desirable, then while rents may fall firms will not relocate to take advantage of increased city centre workspace. The implication is either greater levels of vacant workspace, and/or greater conversion to other uses where there is a market to do so.

3.44 Arguably, the former is most likely in those cities within the strongest city centre office markets, demonstrated through high rents – which are typically the largest cities such as Manchester, Leeds and Birmingham, but these cities are also those that have a greater propensity for home-working (by virtue of the having higher concentration of knowledge-intensive jobs). Smaller cities with weaker city-centre office markets, such as Burnley or Preston with a high proportion of poorer-quality office space[21] will be those that do not experience strong centralisation effects, and could even experience business decentralisation as firms requiring physical workspace relocate to what they see as more attractive locations, either in other cities and/or better quality provision in out-of-town locations.

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[21] See 'Office Quality varies across city centres', page 18 and 19: **The performance of city centres | Centre for Cities**

3.45 A key point to consider is that centralisation effects can only occur with greater levels of home-working – as it is this increased homeworking that 'frees up' space for firms to locate there in the first place. It therefore follows that the extent of business centralisation should directly follow from the assumed uptake in hybrid and remote working.

We therefore have adopted an approach whereby the reduction in travel demand generated by increased homeworking is 'undone' as a result of business and employee density increasing. The scale of centralisation will therefore be materially greater for those cities that experience the greatest update of homeworking, linked to their industrial and occupational breakdown. The way we capture the centralisation uncertainty is set out in Table 3.3.

Table 3.3: Proposed assumptions to capture business centralisation effects

Level of business centralisation	Reduction in commuting journeys from increased homeworking 'undone'	Discussion
None	**0%**	No centralisation. Combined with a small update of homeworking, result in larger workspace per person and less 'efficient' use of floorspace. With larger update of homeworking, significant reduction in demand and rents for city centre floorspace. Likely increase in vacancy rates, and/or conversion to other uses.
Medium	**40%**	Some business centralisation. Some movement of businesses towards more optimal locations, but small compared to homeworking effects.
High	**80%**	High levels of centralisation. Redundant workspace is taken up by firms moving from more 'peripheral' locations, which significantly counteracts increased levels of homeworking. Significant reduction in demand for workspace in less central locations.

Household suburbanisation effects

Background and discussion

3.46 Household suburbanisation refers to the extent to which households change location and move further away from the city centre, as result of higher hybrid and remote working post-pandemic. Increased homeworking means some workers may be willing to trade a longer commute to a workplace for much less frequent commuting.

3.47 In other words, because they can commute less frequently people choose to place less of an emphasis on workplace accessibility in their residential selection. It follows that this effect is greatest (and most likely) where levels of homeworking increase the most relative to pre-pandemic trends.

3.48 Our approach draws from that defined for the 'Dispersal from Cities' scenario developed for by Steer for the 2021 NIC **Infrastructure Demand Quantitative Analysis for Scenarios of Behaviour Change** study. It is based upon assumed changes in the population distribution of Output Area Classification (OAC) super groups, as defined for the 2011 Census. Each Output Area (OA) in the country is assigned a OAC super group, and therefore everyone resident in that OA classified to the same super group.

Previous approach (2021)

3.49 The previous study sought to capture potential differences in the ongoing churn in population due solely to the pandemic and changing attitudes to homeworking. Any changes in the nature of employment were not captured, i.e. 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. This means it in inherently assumed that the nature of employment is not changed by suburbanisation, rather only where people live.

3.50 Since this suburbanisation effect only occurs as a result of changes in attitudes to homeworking, it was assumed that it applies only to those in SOC Groups 1 to 4, and only to who can readily work from home. Suburbanisation was represented in the study by movement of individuals between OAC groups as follows:

- 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.

3.51 The approach was based upon an acceleration of pre-pandemic trends that occur across one’s lifecycle – for example, the tendency amongst young people to move from ‘inner city’ to ‘suburban’ areas as they age and have a family. Three scenarios – high, medium and low – were adopted, which assume an acceleration of the pre-Covid trend for a five-year period:

- **High** rate of change – a doubling of the existing trend, that is an additional 1% of the in-scope population ‘suburbanising’, i.e. 5% of the in-scope population in total;
- **Medium** rate of change – an additional 0.67% of the in-scope population ‘suburbanising’, 3.4% of the in-scope population in total; and
- **Low** rate of change – an additional 0.33% of the in-scope population ‘suburbanising’, 1.7% of the in-scope population in total.

3.52 These effects were assumed to be time-bound since there is limited supply of housing, and increased demand would be expected to lead to a price response that in turn affects demand. Any change to anticipated supply was deemed out of scope of the scenarios.

3.53 From the earlier work, it is noted that “*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 (‘suburbanisation’) 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*”

3.54 The previous study estimated the implications of this ‘suburbanisation’ effect by assuming that those who move OAC group take up the trip-making behaviour (as derived from the National Travel Survey) of the group they move to. This was used as the basis for estimating changes in total trips and distance by purpose by mode, with implications for national travel demand.

Transport implications

3.55 It should be highlighted that, in itself, an increase in household suburbanisation will not in itself result in a change in overall peak trips across the city centre cordons. However, what will occur is individuals commuting from further afield – with the implication that a city centres transport network will need to accommodate more longer-distance commuters, who are more likely to travel by car or rail than bus or active modes.

3.56 This will result in a greater focus on providing longer-distance capacity and connectivity via these modes (or a combination of modes), as opposed to local bus services and active travel.

Also, it is reasonable to assume that people who make a longer commute have a greater propensity to work from home, but this is captured by the hybrid and remote working effect: there is a correlation between the two effects.

Study approach

3.57 Key to our approach is the notion that employment locations remain constant, but it is the location of residential that changes (becoming further away from city centres). The effects of employment relocating away from city centres is tested through the different employment growth assumptions (discussed in Chapter 1) and the business centralisation effects. The commuting behaviour of each group is based **solely** on those commuting to city centres, rather than those commuting to all destinations for which behaviours are markedly different.

3.58 It is recognised that the scope of greater suburbanisation effects is unclear, and is strongly linked to changes in housing and land-use policy (e.g. enabling greater housing development in rural and suburban areas, and likely on greenfield sites) rather than simply changes in individuals locational preferences. Hence, we have focused on understanding both:

- The implications on average commuting distance and likely mode if there is a population movement from the OAC *Cosmopolitans* and *Ethnicity Central* groups (typically living in central, inner-city locations) to *Urbanites* and *Suburbanites* (living further away from city centres);
- Assuming the same population movements as the 2021 study, the aggregate effects on investment requirements for city centres (and in particular mode).

Step 1: Understand the travel behaviour of each OAC super group

3.59 We have used 2011 Census travel-to-work data to understand the distribution of commuting distances of those working within the city centre cordons of the 20 case study cities. This is based upon:

- Identifying the circa 500,000 OA<>OA pairs which capture at least 95% of demand to each of the 'workplace OAs' within the city centre cordons, and extracting the number of journey-to-work movements on each pair and the OAC super group of the 'residence OA';
- Using GIS to calculate the distance of each of these pairs,[22]

3.60 For each city and for each OAC super group, we have then calculated the weighted average commuting distance, using the number of workers of each Residence OA – Workplace OA pair as the weights.

3.61 Census 2011 data also allows for the analysis of commuting mode share of city centre workers. While this is only provided by the ONS at MSOA<>MSOA level (mode share of commuting trips for all 'Residence MSOA' to 'Workplace MSOA' combinations), each OA<>OA pair can be

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[22] This has been calculated as the straight-line distances between the centroids of each OA pair. An uplift factor of 1.1 (10% increase) has been subsequently added to allow for actual commuting distances being longer than straight line distances.

wholly attributed to an MSOA<>MSOA pair. We assume that each OA<>OA commuting pair will have the mode share of its parent MSOA<>MSOA pair.

3.62 This approach is then used to derive the average commuting distance for each OAC group by city, and the corresponding mode share, **solely** for commuting trips to city centres.

Step 2: Assumed changes in population distribution within each group

3.63 We have modelled the suburbanisation effect on the same assumptions as the 2021 study, with an assumed population movement from the 'Cosmopolitans' and 'Ethnicity Central' super groups to the 'Urbanites' super group, and from the 'Urbanites' group to the 'Suburbanites' group. Only these four out of the total eight OAC super groups are affected by the suburbanisation effect.

3.64 The magnitude of the effect has been defined as 5% of the total population of each of the super groups, with an adjustment factor to account for the assumption that only workers in the Standard Occupational Groups (SOC) 1 to 4 would be subject to the effect.

3.65 The proportion of SOC 1-4 varies depending on the city in question, but is typically 60-70% of all workers. This means that the maximum population movement of each super group involved in the suburbanisation effect is around 3% of the total group population in each city.

3.66 This is used to calculate the estimated change in commuting distance, and commuting demand by mode, for each city centre when suburbanisation effects are applied.

3.67 It should be noted that this effect does not directly influence the capacity requirement or assessment for each city. Instead, it is used to highlight the implications for which investment strategies ('bus-based'; 'transit-based'; rail-based') are likely to be most appropriate if suburbanisation effects occur in practice.

Effect of new transport technologies on urban capacity

Background and discussion

3.68 This effect is intended to capture the potential increase in highway capacity delivered through the update of transformative and untested new transport technologies. This includes both connected and autonomous vehicles (CAVs), the subject of extensive research, together with other more transformative modes such as air cars/taxis.

3.69 However, the impact of CAVs and other new technologies on network capacity remains highly uncertain. For example, the extent to which they increase effective capacity will ultimately depend on many factors, including how CAVs are programmed to 'behave'. A study for DfT[23] considered a range of CAV market penetrations and cautious/assertive vehicle behaviour to understand the impact of CAVs on strategic and urban road networks

3.70 Within the DfT study a range of tests, using simple models for various junction and link types, showed capacity increases at junctions could range from 2.2% to 11.6% for vehicle behaviour

[23] DfT (2016) Research on the Impacts of Connected and Autonomous Vehicles (CAVs) on Traffic Flow

similar to current driver behaviour and 25% to 50% market penetration, as summarised in Table 3.4.

Table 3.4: Estimated impact of a 25%-50% CAV market penetration for various road types and links

Test/Model	Capacity Change (similar driver behaviour)
Single-lane link	+1.1% to +1.9%
Multi-lane link	+1.0% to +2.2%
Signalisation junction	+2.2% to +4.1%
Roundabout	+3.6% to +6.0%
Multi-lane with link with merge	+5.2% to +11.6%

Source: DfT (2016) Impacts of Connected and Autonomous Vehicles

3.71 Similarly, a literature review conducted by the NIC identified comparable figures for a similar level of market penetration, but highlighted how the uplift in capacity could be materially greater with an 100% uptake of CAVs. This is summarised in Table 3.5.

Table 3.5: Potential CAV capacity uplift across three European cities

City	Assumed CAV market penetration >>			Source
	20%	50%	100%	
Bilbao	6.9%	14.7%	15.5%	Tympakianaki et al (2022), Autonomous Vehicles in Urban Networks: A Simulation-Based Assessment
Budapest	2.6%	6.9%	16.0%	Lu et al (2019), The impact of autonomous vehicles on urban traffic network capacity: an experimental analysis by microscopic traffic simulation (tandfonline.com)
Barcelona	4.4%	11.9%	22.2%	Tympakianaki et al (2022), Autonomous Vehicles in Urban Networks: A Simulation-Based Assessment

3.72 Conversely, it should be recognised that while an increase in capacity from new technology may be theoretically possible, the concept of increasing vehicle movements within the UK's largest cities runs counter to current transport policy, which is typically focused on reducing traffic and reallocating road space, towards both public transport, walking and cycling provision, and wider urban realm improvement.

3.73 It is therefore entirely possible that the capacity uplifts described above do not occur in practice, and indeed a continuation of current trends would see city-centre and radial highway capacity decrease, at least in our 'large' case study cities. This is partly tested through the analysis of the potential effects of demand management, described in Chapter 4.

Approach

3.74 Reflecting the inherent uncertainty in the potential effects of new transport technologies on urban highway capacity, this effect is tested by applying a factor to represent the potential increase in capacity they could deliver. No change to public transport capacity is assumed.

3.75 This highway capacity uplift is assumed to be 10%, informed by the evidence above. Unlike the homeworking and business centralisation effects, this capacity uplift is applied before at the first stage of the modelling, and results in an amended 'baseline' network utilisation figure.

3.76 We do not assume that any of this capacity is 'taken up' through induced demand from CAVs, as this would be difficult to estimate, particularly the extent to which demand was wholly induced or merely shifts from other modes. Since the capacity and demand analysis is 'mode-agnostic', were mode shift to occur to highway as a result of CAVs, this would release capacity on the public transport which could be used for other users, this will be captured in the modelling as the total demand on the overall transport network remains unchanged, but capacity (as a result of the uplift in highway capacity) has increased.

Future Demand and Capacity Scenarios

Developing the scenarios

3.77 Each of the eight scenarios is based upon applying a combination of the five uncertainties described above. Each scenario is intended to represent an alternative perspective of how city-centres could develop and grow in future.

3.78 The two 'key drivers' were identified that will shape the future development of city centres – **trends in homeworking** and the **role of agglomeration** – inform which of the scenario effects and employment projections are paired together to form each scenario. This reflects how not every scenario effect is likely to occur alongside every other, for example since:

- Business centralization would only occur if both a) increased homeworking releases city centre workspace and b) agglomeration economies mean firms continue to prefer to locate in city centres versus more peripheral locations
- Temporal effects are most likely where demand and rents for physical workspace fall significantly – otherwise firms will be financially incentivized to make up maximum use of their space
- The 'high' Steer employment forecasts assume a continued concentration of employment in city centres in line with historic trends – this would only occur if agglomeration remains important in guiding urban growth.

Final scenarios

3.79 Each of the demand scenarios is described in Table 3.6 overleaf. They broadly fall into four groups:

- **Two scenarios** which drive high levels of urban transport demand, resulting in a significant, long-term growth requirement for city centres, and reflect a 'optimistic' view of city-centre growth. These are:
  - **1 Return to Office** – a return to pre-pandemic trends, where low levels of homeworking drive commuting demand;
  - **2 City Centre Renaissance** – increased levels of homeworking reduce travel demand, but this is counteracted by more firms centralising in city centres, which counteracts a reduction in commuting trips 'per job'
- **Three scenarios** which test the implications of 'recovery' in city centres, but a declining role of agglomeration, which reduces the scale of future city-centre growth:
  - **3A City Centre Recovery** – lower city-centre growth and reduced centralisation effects;
  - **3B City Centre Recovery, with temporal effects** – as 3A, plus 'temporal' effects which reduce the efficiency of the transport network;
  - **3C City Centre Recovery, with suburbanization** – as 3A, but where greater levels of homeworking reduce travel demand and result in suburbanisation effects

- **One scenario** – **4 Urban Dispersal** – which tests a 'pessimistic' outcome for city-centres whereby high levels of homeworking and significant decline in the role of agglomeration result in materially lower city-centre growth and with no 'centralisation' of employment;
- **Two scenarios** which test the role of new connected and autonomous vehicle technology in increasing urban highway capacity:
  - **5A Return to Office, with tech** – testing technology assumption with 'Return to Office' scenario;
  - **5B City Centre Recovery, with suburbanisation and technology** – testing technology assumption with 'City Centre Recovery, with suburbanisation' scenario.

3.80 The capacity and demand assessment, using the approach set out in Chapter 2 but with amendments to the projected employment, future demand and highway capacity as described above, is undertaken for each scenario, providing a revised unconstrained growth forecast and 'capacity gap' figure for each city. The results of this assessment are presented in the Main Report.

Table 3.6: Summary of proposed 'potential futures' under consideration

Scenario	Description	Levels of hybrid and remote working	Role of agglom-eration	Employment forecast	Temporal effects	Business central-isation	Household suburban-isation	Technology uptake
1 Return to office	Gradual return to pre-Covid trends, with a low uptake of homeworking in the long-term. Employment growth continued to be focused in city centres due to the productivity benefits of increased agglomeration.	✓ (✓) (✓)	✓ ✓ ✓	**High** **High Urban, with** with **high** re-allocation to city centres	**No**	**No effect**	**No effect**	**No effect**
2 City Centre Renaissance	Despite a significant increase in levels of homeworking, due to the continued role of agglomeration, city centres remain the optimal location for many businesses. Businesses previously located in more peripheral locations hence centralise, taking up vacated city centre space due to increased homeworking.	✓ ✓ (✓)	✓ ✓ ✓	**High** **High Urban, with** with **high** re-allocation to city centres	**No**	**High**	**No effect**	**No effect**
3A City Centre Recovery	City-centres remain important business locations, but their competitive advantage is reduced as the role of agglomeration effects decline, in part from a significant increase in levels of homeworking. Compared to #2, this results in: • Lower city centre growth – ONS Central, rather than High Growth; • Medium, rather than High, centralisation effects	✓ ✓ (✓)	✓ ✓ (✓)	**Medium** **Mean of ONS Central and High Urban** with **medium** re-allocation to city centres	**No**	**Medium**	**No effect**	**No effect**
3B City Centre Recovery, with temporal effects	As 3A, but additionally: • Reduced city centre growth reduces office rents, which encourages more 'inefficient' use of space, with more people at a physical place of work Tues/Wed/Thur than Mon/Fri; and • The transport network must cater for high demand on the busiest days, driving investment requirements, but with more 'wasted capacity' on the quieter days	✓ ✓ (✓)	✓ ✓ (✓)	**Medium** **Mean of ONS Central and High Urban** with **medium** re-allocation to city centres	**Yes**	**Medium**	**No effect**	**No effect**

Scenario	Description	Levels of hybrid and remote working	Role of agglom-eration	Employment forecast	Temporal effects	Business central-isation	Household suburban-isation	Technology uptake
3C City Centre Recovery, with suburban-isation	As 3A, except: • There is a greater uptake of homeworking, especially remote working, to broadly the level during the pandemic itself; • This drives suburbanisation effects, as faced with a less frequent commute, individuals can now live further from their place of work	✓✓✓	✓✓(✓)	**Medium** **Mean of ONS Central and High Urban** with **medium** re-allocation to city centres	**No**	**Medium**	**Yes**	**No effect**
4 Urban Dispersal	There is a large-scale uptake of homeworking, driving increased suburbanisation, and large decline in the role of agglomeration in guiding cities' growth. City centre employment growth is lower, and employment does not 'centralise' in city centres. Cheaper workspace results in 'temporal' effects, as there is less incentive for firms to use their space most efficiently.	✓✓✓	✓(✓)(✓)	**Low** **ONS Central,** with **no** re-allocation to city centres	**Yes**	**No effect**	**Yes**	**No effect**
5A Return to Office, with tech	A gradual return to pre-Covid trends, with a low uptake of homeworking in the long-term, and continued city-centre employment growth, but with new technology increasing the capacity of the highway network. As #1, but with technology effects.	✓(✓)(✓)	✓✓✓	**High** **High Urban, with** with **high** re-allocation to city centres	**No**	**No effect**	**No effect**	**Yes**
5B City Centre Recovery, with suburban-isation and technology	City-centres remain important business locations, but reduced role of agglomeration reduces city-centre growth and centralisation effects. There is a high uptake of homeworking and associated suburbanisation effects, and new technology increasing the capacity of the highway network. As #3C, but with technology effects.	✓✓✓	✓✓(✓)	**Medium** **Mean of ONS Central and High Urban** with **medium** re-allocation to city centres	**No**	**Medium**	**Yes**	**Yes**

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4 Assessment of Demand Management

Introduction

4.1 This Chapter sets out our approach and key assumptions to assessing the potential role of demand management within England's largest cities outside London. By reducing the demand for highway trips, and 'freeing up' or reallocating space for more 'efficient' modes (in terms of physical roadspace) such as public transport and cycling, demand management can act as a potential policy tool to better manage urban transport capacity and demand.

4.2 Our assessment of demand management within this study is focused on:

- exploring the range of high-level demand management options available to increase and/or better manage transport capacity to support growth;
- better understanding the role of demand management in encouraging mode shift to more 'space-efficient' forms of transport, and hence increasing the overall capacity of the transport network;
- a high-level assessment of the potential capital costs, and ongoing revenue impacts, of different types of demand management in each of the case study cities.

4.3 Demand management can also have wider societal benefits (and impacts) in terms of reducing transport externalities, but these are not considered in detail as part of this research.

Assessment scope

4.4 There are many types and variants of demand management. However, in an urban context these essentially fall into four broad categories. These are:

- **Urban Congestion Charging**: This involves vehicles having to pay a charge either to enter a specified area (cordon charge) or to travel within a specified area (area-based or zonal charge). The London Congestion Zone, introduced in 2003, is only large-scale UK example.
- **Workplace Parking Levy**: A Workplace Parking Levy (WPL) imposes an annual charge on businesses based on the number of eligible workplace parking spaces at their premises. The only UK example is the Nottingham WPL scheme, which started in 2008, although several other proposals are at mature stages of development by local authorities.
- **Emissions-based charging/Clean Air Zones:** These impose a differential charge on vehicles, depending on their emissions, to enter or travel within a specified zone. The London Ultra Low Emissions Zone (ULEZ) and Birmingham Clean Air Zone (CAZ) are among a number of UK examples.
- **Physical Demand Management**: These involve the physical restriction of certain vehicles from crossing specified entry points. Examples include city centre 'bus gates', adopted in a number of UK cities. Oxford has recently approved trial 'traffic filters' which would restrict car users (without a permit) from passing through filters which is aimed at reducing traffic levels across much of the central and inner areas of the city.

4.5 We have not, as part of this study, considered non-urban pricing or demand management interventions (tolling, fuel duty levy, other network-wide time/distance/congestion-based charge regimes). We also have excluded consideration of emissions-based charging/Clean Air Zones options for the purposes of this study on the basis that:

1. These schemes have a singular objective around reducing harmful pollutants below legal exceedance thresholds. The associated charging regime is therefore focused on vehicle types (charging higher polluting vehicles more), rather than capacity or congestion outcomes per se. They are not devised with demand and capacity management as a primary objective.
2. They are relatively shorter-term in nature, aimed at addressing the harmful effects of current pollution. As the vehicle fleet decarbonises over time associated 'tailpipe' pollution will reduce and the underlying rationale for CAZ will abate.

4.6 The infrastructure implemented for CAZ schemes (ANPR, back-office systems) and location of infrastructure (generally larger central areas) have the potential to be used to support a migration from 'emissions-based' scheme towards a congestion-based charging schemes in the future.

Assessment approach

4.7 Broadly, our approach consists of three stages, each informed by the previous stage:

- an **evidence review** of eleven case study schemes, and their costs, impacts and outcomes;
- a **qualitative assessment**, for each of the three types of demand management of:
  - the **implications for mode shift and demand suppression** – considering the evidence, what are the likely effects on overall transport patterns and the wider economy?
  - the **potential role of demand management within the different cities** – in which contexts is each approach likely to be more or less suitable?
  - the **implications for capacity requirements, investment approaches and capital costs** – how could the introduction of each type of demand management influence the overall scale of transport investment required in cities, and how this investment might be provided?
- a **quantitative assessment** of revenues, operating and capital costs for congestion (cordon) charging and workplace parking levies in the 20 case study cities.

Specification of Demand Management Options

4.8 Within our assessment, we adopt a consistent 'working definition' of what each demand management intervention would look like different cities. This definition captures:

- The **geographical area** covered by the intervention. From a practical perspective to ensure consistency across area, the spatial options come down to assessment either at the 'city centre cordon' level (consistent with that used to measure demand and capacity) or at the district level within which the intervention would be implemented.
- For options involving a charge or levy, an **assumed charge level.**

These assumptions, and their rationale, is set out in Table 4.1.

Table 4.1: Specification of Demand Management approaches

Intervention	Area of intervention and rationale	Assumed charge and rationale
Congestion charge	• Assumed cordon-based charge would apply to city-centre cordon area only. • Rationale for area – Consistent with city centre areas defined for NIC study – A 'district-based' geography would be reasonable for districts that are broadly contiguous with the built-up area and a logical boundary (e.g. ring road), but this does not apply across the 20 districts under consideration. • Rationale for cordon: – Cordon rather than area-based as consistent with NIC transport data – For small cordon area, trips wholly within the area would be relatively low as a proportion of this crossing the cordon. And, for many schemes trips within 'area-based' schemes are heavily discounted (resident discounts etc.)	• Proposed charge of £5 per car per day Rationale based on benchmarks: • Cambridge proposals for £5 per day charge. • Milan charge currently Eu 5. • Stockholm charge variable by time of day, but up to c. £5 to £7 per day travelling in morning and evening peaks. • The current London Congestion Charge of £15 is an outlier compared to benchmarks above, and reflects above benchmarks.
Workplace Parking Levy	• Assumed that WPL would apply at the district level. • Rationale: – Consistent with Nottingham and other authorities considering (or that have considered) WPL, including Oxford and Leicester. – A 'city centre' cordon area would be limited in terms of its effectiveness (through trips and non-commuting unaffected) and its revenue generating potential (central areas have less private workplace parking, and higher non-car mode shares)	• £500 per annum in current 2022 prices. Assumed constant in real terms (i.e. would increase with inflation) • Informed by current Nottingham Levy (£458 current, RPI based update pending) and proposed charges for other planned schemes (Oxford proposed £600 charge in assumed opening year of 2024 or 2025. Charge lower expressed in 2022 prices)
Physical demand management	Would apply to city centre cordon area. • Rationale: – Focused on city centre demand and capacity. – Consistent with most UK examples. – Consistent with NIC transport analysis. – District-level too wide an area to consider physical demand management	Not applicable (there are fines for non-compliance – i.e. driving through 'gates' of 'filters', but revenue raising is not an objective of the scheme and revenues from fines would be modest compared to WPL and RUC).

4.9 Additionally, there are a range of wider considerations that both inform how any demand management approach could be implemented in a specific city, and the wider suitability of demand management within that context. These are highly city and context-specific, and hence we have not considered them in detail, but include (and are not limited to):

- **The extent and nature of the problem that demand management is intended to solve**. For example, if congestion is less prevalent and capacity less constrained, the rationale for demand management will be lower. An understanding of this will be provided by the current NIC study. Examples are likely to include Burnley and Middlesborough.

- **Potential displacement effects**, whereby economic activity (businesses, workers, retail) is displaced from one location to another, as a result of the 'costs' (monetary and / or travel time) imposed by demand management. The potential for displacement is greater for smaller centres, and particularly those where there are 'competing' city centres (or large-scale out of town commercial and retail) nearby. Examples could include Coventry and Huddersfield;
- **Economic profile of areas**. In general businesses choose to locate in city centres because the benefits of doing so (access to labour, proximity to clients and markets, spillover effects) outweigh the higher costs (commercial rents, congestion). The characteristics tend to apply to higher-value 'knowledge economy' firms and sectors. The acceptability of demand management is likely to be greater where the proportion of such jobs and works is higher – both due to the 'drivers' of business location and as the costs of any demand management would be proportionately lower for higher-value / turnover businesses and higher income workers;
- **Geographical factors and transport network factors**. These are unique in each area, but fundamentally would affect the form of any demand management intervention in terms of its detailed specification.

Evidence Review

4.10 There are many variants within the above categories, and each implemented or planned scheme (UK and international examples) reflects the specific aims and geography of each location. However, there is also a sufficient body of evidence, based on the impacts from implemented and proposed schemes, that can be used to make an informed high-level assessment of demand management measures for this study.

4.11 We have undertaken a detailed case study review to inform our conclusions. The case studies explored are summarised in Table 4.2.

Table 4.2: Urban Demand Management case studies

Charging / Demand Management Regime	Status
Road User Charging – Area / Cordon based	
London Congestion Charge – Area Based	Implemented 2003
Singapore Electronic Road Pricing – Variable Pricing	Implemented 1998
Cambridge – proposed £5 area charge	Proposed. Consultation late 2022
Stockholm – Cordon charge	2006 Trial / 2007 Implementation
Milan 'Ecopass' Congestion charge	Implemented 2008
Workplace Parking Levy	
Nottingham	Implemented 2008
Physical Restrictions	
Gent / Ghent	Implemented 2015
Groningen	Implemented 1977
Rome	Implemented 2001
Oxford	Proposed. Experimental Traffic Filters approved November 2022. Planned implementation early

	2024.
Manchester	Bus gates implemented 2022

4.12 For each case study have reviewed the evidence and summarised the impacts of each scheme, based on available information, across four key areas:

- **Scheme definition and costs** – the demand management proposal and any associated improvements (e.g. directly funded by revenues);
- **Transport outcomes** – the transport effects following the intervention e.g. change in demand by mode, mode share, transport revenues;
- **Economic outcomes** – impacts on the wider economy, within the charge or demand management area and the wider city; and
- **Acceptability** – commentary on the acceptability of proposals.

Assessment of demand management revenues and cost

Workplace Parking Levy assessment

4.13 The approach to assessing the revenues, operating and capital costs of WLP is comprised of four stages:

- **Stage 1 – Defining the 'In-Scope' Market**– i.e., number of eligible parking spaces
- **Stage 2 – Developing a WPL Scheme Definition** and applying this to assess the degree to which WPL 'captures' or applied to the in-scope market.
- **Stage 3 – Assessment of Demand, Revenues, Costs** i.e., the 'first order' effects of the WPL scheme

Stage 1 – Defining the 'In-Scope' Market

4.14 The 'in-scope' market is defined by the total number of workspace parking spaces within each LAD. Since this information is not readily available (it would require a detailed parking survey of all businesses), we have estimated (and proxied) it using two alternative approaches:

- A 'demand-led' approach, based on the estimated number of car commuters into an LAD;
- A 'supply-led' approach, based on the assumed relationship between the number of jobs and associated workplace parking spaces.

4.15 These are summarised in Table 4.3 and Table 4.4.

Table 4.3: WPL In-Scope Market – Demand-Led

Evidence / data/ assumption	Provides…	Data issues / limitations
Census TTW – total	Benchmark against BRES • 2011 (Census year) and 2021 (latest BRES) total employees	
TTW mode share 2011	Mode shares: • Current PT/active shares a reasonable proxy for *relative* attractiveness of these modes. • Car mode share (as driver) – provides one estimate of 'in-scope' demand for WPL	2011 only (2021 census unsuitable due to pandemic trends)
WPL parking as %	Ratio of liable WPL spaces per total	Likely to differ by area; lower percentage where:

Evidence / data/ assumption	Provides...	Data issues / limitations
all commuter parking	number of car commuters. Using evidence from Nottingham and Leicester (WPL business case)	• Larger supply of cheaper non-workplace private parking (use of undeveloped plots) • More 'unrestricted' residential parking closer to city centre • Cheap 'all day' rates for public parking

Table 4.4: WPL In-Scope Market – Supply-Led

Evidence / data/ assumption	Provides...	Data issues / limitations
BRES jobs data	Total employees in LAD	
WPL parking as a ratio to employees	Ratio of liable WPL spaces per job Using evidence from Nottingham and Leicester (WPL business case)	If spaces (i.e., parking supply) is the starting point, then secondary assumptions required on: • % Occupancy (businesses would only license up to level of current occupancy)

4.16 Evidence from the Nottingham WPL example and from the business case developed for the Leicester WPL proposals has been used for both the demand-led and supply-led approaches summarised above for the definition of the 'in-scope' market. Both cases used the assumption that only utilised staff parking spaces provided by employers would be licensed, and of those only those belonging to employers with 11 or more spaces would be liable for the charge (i.e., employers with 10 or fewer staff parking spaces would be exempt).

4.17 Nottingham and Leicester have then been used as benchmarks to develop the demand-led and supply-led ratios, as defined above, using Census and BRES employee data from 2011 and 2021, at the Local Authority District level.

Stage 2 – Developing a WPL Scheme Definition

4.18 The WPL scheme for the 20 case study cities has been defined in terms of area of charge, level of charge, exemptions, and liable employers, as summarised in Table 4.5.

Table 4.5: WPL Scheme Definition & Assumptions

Evidence / data/ assumption	Provides...	Data issues / limitations
Area of charge • **LAD**		None
WPL charge = • **£500 per annum charge**	Basis for forecast revenue and demand response	None
'Core exemption' – • **Blue badge/ disabled spaces 2% spaces**	Reduction of in-scope spaces, based on 'core' exemption as per Nottingham and other WLP promoting authorities.	
Employers with <11 spaces	Reduction of in-scope spaces, based on 'core' exemption as per Nottingham and other WLP Promoting authorities (including GLA Mayoral	Will vary by location. The <11 spaces means that c. 90% of individual businesses are exempt, but that 90% spaces are eligible (medium / large employers

	Guidance on WPL).	account for 90% stock)
Non-core exemptions • **None**		Nottingham has a 100% discount for "front-line NHS" staff. Other options are to exempt NHS premises. Schools – similar rationale could extend to teaching staff.
WPL Funded Improvements – e.g. PT / active travel *Implicit assumption that WPL revenues would be used to fund wider improvements*	n/a.	The assumption is internally consistent with the assumed WPL behavioural response, which is benchmarked against schemes where WPL provides 'push' factors (from car) and associated complementary measures 'pull' (to PT / active)

Stage 3 – Assessment of WPL Demand, Revenues, Costs

4.19 Table 4.6 summarises the assumptions made for the quantification of WPL demand, the response to the implementation of the charge and the expected level of revenue and costs.

Table 4.6: WPL Assessment of Demand, Revenues, Costs

Evidence / data/ assumption	Data issues / limitations
Demand response – reduced commuter trips • 25% reduction in car commuter trips	Based on evidence from Nottingham. This reduction reflects: • Response of employees, where the charge is 'passed on'. Road users may choose to change mode or to not travel at all. • Response of businesses – who choose not to license spaces and to reduce their liability. • PT improvements that accompany/ funded by WPL.
Scenario impacts • Allowance for changes in commuting intensity as a result of homeworking and business centralisation patterns, as defined by the scenarios	
Revenues • Calculated based on above	
Capital costs • Informed by Nottingham and the (proposed) Leicester scheme	Implementation Costs Nottingham (£, 2008 prices) Scheme Development - £1,085k Scheme Implementation – £1,315K Total capital c. £2.5m (2008)
Ongoing costs • 5% annual revenues	Based on Nottingham

4.20 For the estimation of demand, revenue, and costs of a potential WPL scheme for the 20 case study cities, the **demand-led approach** for estimating the in-scope market has been used, chosen over the supply-led approach. The supply-led approach is directly based on the number of jobs in the district, while the demand-led approach is based on the number of workers commuting by car. The latter is expected to be a more accurate proxy for the in-scope market (liable parking spaces), as it accounts for differences in commuting mode share between cities, which the supply-led approach does not.

4.21 The ratio of WPL-liable spaces to car commuters has been calculated for Nottingham and Leicester for 2011 and 2021, respectively, to keep consistency with the time when the initial estimate of spaces liable for the charge was initially calculated for these cities. These ratios are close to 30% and therefore this figure has been used for the high-level assessment of WPL for this study.

4.22 It is recognised that using a blanket approach, with the same ratio for all cities, presents some limitations, as in reality this ratio is likely to differ by city as a result of factors such as distributions of workplaces by size (i.e. predominance of smaller or larger employers) and the availability of unrestricted and/or cheaper public or private parking close to workplaces. However, given the high-level nature of this assessment and the lack of detailed data to support these city-specific considerations, using a common ratio for all cities has been deemed reasonable and proportionate, provided this is caveated accordingly.

4.23 After the estimation of the number of liable spaces for each city (assuming that the minimum threshold of 11 spaces per employer would also apply), an allowance for initial demand reduction has been factored into. This has been set at 25%, informed by data from Nottingham and forecasts from the Leicester business case, and would cover the employer-led reduction of available parking to reduce total charge costs, but also demand response from commuters when the charge is passed on to employees. While the majority of employees would still be expected to commute and park, paying the charge, a proportion would choose to use a different mode, to car-share, or even not to travel at all.

4.24 An annual charge of £500 (2022 prices) per liable parking space has been used for the assessment, assumed to remain constant in real prices. The operating costs of the WPL scheme have been defined as 5% of gross revenues, based on evidence from Nottingham. Capital costs, covering development and implementation, have been derived for each city using Nottingham data (around £2.5m in 2008) and pro-rated proportionally to the estimated number of liable spaces in each city.

4.25 Finally, the homeworking and business centralisation effects defined in earlier chapters have been taken into account to reflect the impact of lower levels of commuting demand under each scenario, which are assumed to translate directly into a lower demand for workplace parking and therefore a subsequent reduction in licensed liable spaces. These reduction factors vary by scenario and city but range between 82% and 100% of baseline commuting demand.

Urban congestion (cordon) charging assessment

4.26 The key stages of the assessment are the same as for WPL. However, the nature of the scheme makes the forecasting of impacts (as a high-level) more straightforward for the cordon charge. Our approach is summarised in Table 4.7.

Table 4.7: Cordon Charge Assessment of Demand and Revenues

Stage	Approach
Stage 1 – Defining the 'In-Scope' Market	The in-scope market is defined by the transport trips, by mode, crossing each city centre cordon.
Stage 2 – Scheme Definition	Assumed £5 daily charge for cars, minicabs, LGVs and lorries. Bus, taxi and two-wheeled vehicles are exempt.

Stage 3 – Assessment of Demand, Revenues, Costs	80% of users continue to drive and pay the charge in the peak, 70% in the off-peak. A higher demand response is expected at off-peak times, as trip purposes are typically more discretionary (e.g. shopping)

4.28 The first stage for the assessment of urban congestion charging is the definition of the in-scope market, which in this case would include all road vehicles crossing the city centre cordons of our 20 case study cities in the inbound direction. Following the example of London, it is assumed that vehicles would be liable for the charge once per day, regardless of the number of crossings, and that the charge would apply only during a defined time period. The 07:00 – 18:00 charging period on weekdays currently operating in London has been used as the basis for the assessment.

4.29 To understand the number of vehicles that would be liable for the charge in each city, the highway peak hour (8-9 AM) cordon demand calculated for the 2018 study for the NIC has been used as a starting point. To expand these peak hour inbound flows to the full 07:00 – 18:00 charging period, traffic count data published by the DfT[24] has been used. For each city, hourly inbound traffic flow data from sites close to the city centre cordons, and located on roads crossing the cordons, has been analysed, and expansion factors (08:00 – 09:00 to 07:00 – 18:00) have been derived for each city.

4.30 To finalise the definition of the in-scope market, three adjustments needed to be made to the total inbound traffic flow figure calculated as per the above, to convert it to demand actually liable for the congestion charge payment. These are:

- **Adjustment for exempt vehicles**: taxis, buses and 2-wheelers were assumed to be exempt and account for 25% of all inbound road cordon traffic, based on pre-charge evidence from London.
- **Conversion from traffic flow (cordon inbound trips) to individual daily charges paid**: this accounts for the fact that some vehicles would cross the cordon more than once per day but would only be charged once. An adjustment factor of 58% has been calculated using London data, as the ratio of the annual average daily number of charges paid to the number of inbound cordon trips on a weekday in Spring/Autumn. This would account for lower number of charges paid on weekends, bank holidays and holiday periods.
- **Adjustment for a resident exception or discount**: in the London example, residents account for around 20% of the charges and have the right to a 90% discount. For simplicity it has been assumed that residents would be fully exempt of congestion charges in our analysis.

4.31 After defining the initial in-scope demand for the congestion charge in the case study cities, following the steps summarised above, an allowance for a demand response as a result of the implementation of the charges has been made. For the peak hour, a 25% demand reduction has been assumed, with some users opting for re-routing (when they were previously crossing

[24] https://roadtraffic.dft.gov.uk/downloads

the cordon as part of a through route), mode change to exempt modes (e.g., public transport) or not travelling into the cordon at all.

4.32 Based on evidence from other cities, the demand response is expected to be higher in off-peak periods, as the different nature of the trips (lower proportion of commuting) makes the demand less rigid and more susceptible to changes to avoid the charge. For this reason, a 35% demand reduction has been assumed outside the peak hour (8-9 AM).

4.33 A daily charge of £5 (2022 prices) per liable vehicle has been used for the assessment, assumed to remain constant in real prices. The operating costs of the congestion charge scheme have been defined as 28% of gross revenues, based on evidence from London. Capital costs, covering development and implementation, have been derived for each city using London data (around £160m in 2003 prices) and pro-rated proportionally to the estimated number of daily charges for each city.

4.34 Finally, as explained for the WPL analysis, the homeworking and business centralisation effects defined in have been taken into account to reflect the impact of lower levels of commuting demand under each scenario.

4.35 The above summarises the assessment undertaken for the congestion charge schemes, which is based in high-level assumptions, common to all cities. In reality, however, the feasibility and impacts of a cordon congestion charge could differ greatly between the case cities. As opposed to WPL, which assumes a LAD-level area of implementation, congestion charges would be applied only to the city centre cordon.

5 Assessment of Capital and Operating Costs

Introduction

5.1 This Chapter sets out the key assumptions that underpins the assessment of capital and operating costs. The overall approach is described in the Main Report, and is comprised of the following stages:

- determining the scale of capacity requirement across the 20 study cities – a 'low', 'medium' and 'high' requirement for each;
- developing three 'investment approaches' which dictate how this capacity is provided – 'bus-based'; 'transit-based'; 'rail-based';
- combining these into nine 'capacity uplift scenarios', which express the scale of additional capacity required on each mode, which forms the basis of the cost assessment;
- assessing what scale of infrastructure is required to deliver a given uplift in capacity for each mode;
- costing this infrastructure on the basis of established unit rates, evidenced assumptions and professional judgement.

This process is summarised in Figure 5.1 below.

Figure 5.1: Summary of cost estimation process

Capacity uplift scenarios

5.2 The basis for the capital and operating cost assessment are nine 'capacity uplift scenarios' that describe both the scale of capacity uplift, and the balance of modes through which it is provided, for each city. These are summarised in the matrix below:

Rail-based; low capacity requirement	**Rail-based; medium capacity requirement**	**Rail-based; high capacity requirement**
Transit-based; low capacity requirement	**Transit-based; medium capacity requirement**	**Transit-based; high capacity requirement**
Bus-based; low capacity requirement	**Bus-based; low capacity requirement**	**Bus-based; low capacity requirement**

5.3 The mode shares assumed for each of these approaches is summarised in the tables overleaf.

Table 5.1: Assumed mode uplift in capacity is delivered through, small cities

Mode	Bus-based approach>>			Transit-based approach>>			Rail-based approach>>		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
Active modes	15%	15%	15%	N/A	N/A	15%	15%	15%	15%
Road	0%	0%	0%	N/A	N/A	0%	0%	0%	0%
National Rail	5%	5%	5%	N/A	N/A	10%	50%	50%	50%
Metro / tram	0%	0%	0%	N/A	N/A	75%	0%	0%	0%
Bus	80%	80%	80%	N/A	N/A	0%	35%	35%	35%

Table 5.2: Assumed mode uplift in capacity is delivered through, medium cities and large cities without an existing tram / metro network

Mode	Bus-based approach>>			Transit-based approach>>			Rail-based approach>>		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
Active modes	15%	15%	15%	N/A	15%	15%	15%	15%	15%
Road	0%	0%	0%	N/A	0%	0%	0%	0%	0%
National Rail	10%	10%	10%	N/A	10%	10%	60%	60%	60%
Metro / tram	0%	0%	0%	N/A	75%	75%	0%	0%	0%
Bus	75%	75%	75%	N/A	0%	0%	25%	25%	25%

Table 5.3: Assumed mode uplift in capacity is delivered through, large cities with an existing tram / metro network

Mode	Bus-based approach>>			Transit-based approach>>			Rail-based approach>>		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
Active modes	15%	15%	15%	15%	15%	15%	15%	15%	15%
Road	0%	0%	0%	0%	0%	0%	0%	0%	0%
National Rail	5%	10%	15%	15%	15%	15%	60%	60%	60%
Metro / tram	10%	15%	20%	60%	60%	60%	15%	15%	15%
Bus	70%	60%	50%	10%	10%	10%	10%	10%	10%

Determining potential Infrastructure requirements

5.4 The output from the nine capacity uplift scenarios is then a specific increase for capacity, on each mode, across a wide range of cities. This section summarises, for a given scale of capacity increase, the process for determining how much additional infrastructure is required, which forms the basis for the costing exercise.

Expressing capacity requirement in terms of a number of vehicles

5.5 The starting point is converting the capacity requirement on each mode (measured in terms of a number of people per hour per direction) to a 'number of vehicles' metric for each mode. This better conceptualises the scale of the capacity increase, and forms a more realistic basis for the assessment of infrastructure requirements.

5.6 Table 5.4 summarises the capacity assumed for a vehicle on each mode.

Table 5.4: Vehicle capacities

Mode	Capacity (per vehicle)	Description / justification
Bus	87	Capacity of an Alexander Dennis Enviro 400v double-decker bus.
Light rail	206	Capacity of a single Bombardier M500 tram, as used on the Manchester Metrolink
Rail	140	Approximate capacity of a 20m rail carriage with a 'high-density' layout, informed by an 8-car Thameslink Class 700

Assessing scale of infrastructure requirements for a given increase in capacity

5.7 Once the capacity requirements were expressed in terms of numbers of vehicles / rolling stock, a series of rules were developed which dictate:

- How much additional capacity can be provided at 'minimal cost', without fixed infrastructure;
- The thresholds above which infrastructure investment is required, and the scale and nature of that investment;
- The point at which surface capacity becomes constrained, and very high-cost interventions are required to deliver further increases in capacity.

5.8 These were informed by professional experience and a range of benchmarks and comparisons, and are summarised for each mode in Table 5.5Table 5.7. Three sets of rules were derived:

- A 'core' assumption used to derive the central cost estimate – this is the most realistic view of the point at which infrastructure investment is required;
- A 'low infra' assumption, which assumes that **less** infrastructure is required to meet a given capacity requirement (and hence lower capital costs);
- A 'high infra' assumption, which assumes that **more** infrastructure is required to meet a given capacity requirement (and hence higher capital costs).

5.9 The 'core' assumption is used to derive the central capital cost estimate for each capacity uplift scenario. The 'low infra' and 'high infra' assumptions are used to derive the range presented on the cost estimate in Chapter 7 of the Main Report. The difference between the 'core' assumption and the two sensitivities is summarised in **red**.

Table 5.5: Infrastructure requirements for light rail

Nature of investment	Infrastructure assumed for costing exercise >>		
	Core	**Low infra**	**High infra**
New rolling stock	One new tram car required for every 206 people.		
New tram infrastructure	For up to **11 new tram cars** (or 2,500 people), no new infrastructure is required. Services can be lengthened or frequencies increased without a need for new lines. This is equivalent to: • Lengthening 24 inbound tram services per hour from single- to double-car • 6 additional double tram services per hour across the city centre cordon Above **12 new tram-cars**, the network must be expanded. Every subsequent 24 tram cars (or 4,900 people) requires a new tram line or expansion of the network – so: • Above 12 tram-cars -> 1 new line • Above 36 tram-cars -> 2 new lines • Above 60 tram-cars -> 3 new lines • Etc The length assumed varies by city size – each new line is assumed to be 8km in a small city, 10km in a medium city and 12km in a large city	For up **to 23 new tram cars** (or 4,900 people), no new infrastructure is required **(50% higher threshold than core assumption)** Above **24 new tram cars**, the network must be expanded. Every subsequent 24 tram cars (or 4,900 people) requires a new tram line or expansion of the network – so: • Above 24 tram-cars -> 1 new line • Above 48 tram-cars -> 2 new lines • Above 72 tram-cars -> 3 new lines • Etc The length assumed varies by city size – each new line is assumed to be 8km in a small city, 10km in a medium city and 12km in a large city **(unchanged)**	For up to **11 new tram cars** (or 2,500 people), no new infrastructure is required. Above **12 new tram cars,** the network must be expanded. Every subsequent 18 tram cars (or 3,700 people) requires a new tram line or expansion of the network (**more lines required for given capacity requirement**) – so: • Above 12 tram-cars -> 1 new line • Above 30 tram-cars -> 2 new lines • Above 48 tram-cars -> 3 new lines • Etc The length assumed varies by city size – each new line is assumed to be 10km in a small city, 13km in a medium city and 16km in a large city (**lines assumed to be 30% longer**)
Underground or 'high-cost' infrastructure	Above a requirement for **96 additional tram-cars**, an assumed 'high-cost' intervention is required – in most cases a new, city-centre tram tunnel to overcome surface constraints	Above a requirement for **144 additional tram-cars**, an assumed 'high-cost' intervention is required **(50% higher threshold than core assumption)**	Above a requirement for **72 additional tram-cars**, an assumed 'high-cost' intervention is required **(25% lower threshold than core assumption)**

Table 5.6: Infrastructure requirements for bus (and BRT)

Type of investment	Infrastructure assumed for costing exercise >>		
	Core	Low infra	High infra
New buses	One new double-decker bus required for every additional 87 people	One new double-decker bus required for every 129 people (equivalent to 'high-capacity' double-decker) **(assume larger vehicles compared to core assumption)**	One new double-decker bus required for every additional 87 people **(unchanged)**
New bus priority infrastructure	For up to 20 extra bus services (**1,700 people**), no new priority infrastructure required. Above 20 additional buses per hour, new bus priority infrastructure is required. Every subsequent 20 bph requires new priority infrastructure (or 'BRT lines'): • Above 20 buses or 1,700 people -> 1 'new line' • Above 40 buses or 3,500 people -> 2 'new lines' • Above 60 buses or 5,200 people -> 3 'new lines' • Etc The length assumed varies by city size – each new line is assumed to be 6km in a small city, 8km in a medium city and 10km in a large city.	For up to 20 extra bus services (**2,600 people**), no new priority infrastructure required (**unchanged)** Above 20 additional buses per hour, new bus priority infrastructure is required. Every subsequent 20 bph requires new priority infrastructure (or 'BRT lines'): • Above 20 buses or 2,600 people -> 1 'new line' • Above 40 buses or 5,200 people -> 2 'new lines' • Above 60 buses or 7,700 people -> 3 'new lines' • Etc **(larger vehicles results in less need and provision of BRT infrastructure)** The length assumed varies by city size – each new line is assumed to be 6km in a small city, 8km in a medium city and 10km in a large city **(unchanged)**	For up to 12 extra bus services (**1,000 people**), no new priority infrastructure required **(lower threshold than core assumption)** Above 12 additional buses per hour, new bus priority infrastructure is required. Every subsequent 12 bph requires new priority infrastructure (or 'BRT lines'): (**more infrastructure required for given capacity requirement**) • Above 12 buses or 1,000 people -> 1 'new line' • Above 24 buses or 2,100 people -> 2 'new lines' • Above 36 buses or 3,100 people -> 3 'new lines' • Etc The length assumed varies by city size – each new line is assumed to be 6km in a small city, 8km in a medium city and 10km in a large city **(unchanged)**

Table 5.7: Infrastructure requirements for heavy rail

Nature of investment	Infrastructure assumed for costing exercise >>		
	Core	**Low infra**	**High infra**
New rolling stock	One new rail coach required for every 140 people.		
Depot costs	New depot space for every additional coach (140 people)		
Platform lengthening	Platform lengthening or signalling enhancements to increase capacity. Infrastructure required Increases linearly by total number of additional coaches	Platform lengthening or signalling enhancements required to increase capacity, **only once requirement greater than 8 coaches (1,100 people).** Scaled by total number of additional coaches	Platform lengthening or signalling enhancements required to increase capacity. **Twice the scale of infrastructure / cost required compared to core.** Scaled by total number of additional coaches
Station upgrades	Upgrades to city centre rail stations to provide additional track and/or passenger capacity: • 'Small' enhancement required for an increase of 8 – 24 coaches per hour (circa 1-3 extra 8-coach trains per hour) • 'Medium' enhancement required for an increase of 25 – 40 coaches per hour (circa 3-5 extra 8-coach trains per hour) • 'Large' enhancement required for an increase of 41+ coaches an hour (circa 6+ 8-coach trains an hour)	Upgrades to city centre rail stations to provide additional track and/or passenger capacity: • 'Small' enhancement required for an increase of 16 – 37 coaches per hour (circa 2-5 extra 8-coach trains per hour) • 'Medium' enhancement required for an increase of 38 – 61 coaches per hour (circa 5-8 extra 8-coach trains per hour) • 'Large' enhancement required for an increase of 62+ coaches an hour (circa 8+ 8-coach trains an hour **Station upgrades required at a higher capacity requirement**	Upgrades to city centre rail stations to provide additional track and/or passenger capacity: • 'Small' enhancement required for an increase of 5 – 16 coaches per hour (circa 1 extra 8-coach trains per hour) • 'Medium' enhancement required for an increase of 17 – 24 coaches per hour (circa 2 extra 8-coach trains per hour) • 'Large' enhancement required for an increase of 25+ coaches an hour (circa 3+ 8-coach trains an hour) **Station upgrades required at a lower capacity requirement**
Underground and very 'high cost' infrastructure	Above a requirement for 96 additional coaches (circa 12 8-car trains an hour), a £4bn cost allowance for new tunnelled, city centre underground heavy rail infrastructure (similar to Crossrail). Increases to £8bn above a	Above a requirement for 192 additional coaches (circa 24 8-car trains an hour), a £4bn cost allowance for new tunnelled, city centre underground heavy rail infrastructure (similar to Crossrail). **Less underground, 'Crossrail-**	Above a requirement for 64 additional coaches (circa 8 8-car trains an hour), a £4bn cost allowance for new tunnelled, city centre underground heavy rail infrastructure (similar to Crossrail). Increases to £8bn above a

	requirement for 144 coaches (circa 18 trains per hour)	**type' infrastructure required**	requirement for 96 coaches (circa 12 trains per hour), and £16bn above 224 coaches (28 trains per hour) **Less underground, 'Crossrail-type' infrastructure required**

5.17 The output from this stage, and the assumptions set out in the tables above, is an assessment of the scale of additional infrastructure required, for each city, under each capacity uplift scenario. This infrastructure is what forms the basis for the capital cost estimate.

Assessment of scale of capital costs

Capital costing for 20 case study cities

5.18 Following this, the estimated capital costs of each capacity uplift scenario were derived from:

- Costing each element of infrastructure required on the basis of established unit rates, evidenced assumptions and professional judgement;
- Summing these costs for each of the nine capacity uplift scenarios, for the 20 case study cities;
- Aggregating and applying these costs to the wider group of 50 cities, to inform national urban transport investment requirements.

5.19 Table 5.8 summarises the assumptions and unit rates that underpin the capital cost estimate. Unit cost and allowances are presented in 2022 prices, consistent with the total costs presented in the Main Report.

Table 5.8: Capital cost assumptions

Infrastructure	Unit cost / allowance 2022 prices	Description / justification
Tram / light rail costs >>		
Additional trams	£3m per tram	Informed by recent Bombardier M5000 costs for the expanded Manchester Metrolink fleet
Additional tram line	£50m per km	Informed by recent extensions to the West Midlands Metro and Edinburgh Trams
New underground cross-city tram line	£2bn (one-off per city)	Assumed cost allowance for an underground tram / metro line across a city centre, including stations and portals, to provide additional capacity across a wider tram / metro network. Note no recent, comparable UK projects
Bus / bus rapid transit costs >>		
Bus cost	£0.45m per bus	Informed by recent costs for new, double-decker electric vehicles subject to DfT ZEBRA (Zero Emission Bus Regional Area) funding

Bus priority cost	£2.5m per km for priority infrastructure Further £2.5m per km for 'one-off' major structures / junctions	Informed by West Midlands SPRINT costs, which are relatively conservative in terms of extent of junction upgrades Assumption informed by typical costs for major junction enhancements
Heavy rail costs >>		
Additional rail coaches / trains	£2m per 20m coach (circa £16m for an 8-coach train)	Informed by rail experience and recent procurement for new, electric multiple-unit rolling stock
Depot space	£0.3m per 20m coach	Informed by recent costs for new rail depots in Wigan (completed 2020) and Blackburn (completed 2017)
Platform lengthening and/or signalling enhancements	£4.4m cost allowance to increase capacity (per 20m coach)	Informed by Network Rail costs for platform lengthening and/or signalling upgrades to increase capacity on commuter rail lines – broad cost envelope of £20-50m to either lengthen four services from 4- to 6-car **or** run an additional train per hour. Note this figure will **vary significantly** based on local context – it is intended as an average to be used across cities, and should not be viewed as the cost of this infrastructure in any specific location.
Station upgrades	£60m for a 'minor' station upgrade £90m for a 'medium' station upgrade £1bn for a 'major' station upgrade (or allowance across different stations)	Informed by a range of recent station upgrade costs, including: • Typical cost of 'new' two-platform station, footbridge and car park £20m • Manchester Victoria – £44m, completed 2015 • Coventry new station building - £82m, completed 2021 • Darlington station upgrade, including new platforms and station entrance – £100m, under construction • Cardiff station upgrade - £113m, proposed • Leeds station upgrade, including a new platform, lengthening of existing platforms and a new concourse – £161m, completed 2022 • Reading station upgrade, complete station rebuild and new track layout - £850m, completed 2014/15 • Birmingham New Street redevelopment – new city centre station - £750m, completed 2015
New underground cross-city tram line	£4, £8bn or £16bn cost allowance (one-off per city)	Assumed cost allowance for an underground heavy line across a city centre, including stations and portals, to provide a large-scale increase in rail capacity over and above that provided by enhancing existing terminal stations. Comparable projects include: • London's £18bn Crossrail (Elizabeth Line) scheme (completed 2022), the majority of the cost of which was 21km (13 miles) of twin-bore tunnels, two underground grade-separated junctions and 10 underground stations

		• Stuttgart 21, which includes a new underground 8-platform station alongside circa 57km of new lines and 30km of tunnelling in Germany, currently under construction with an estimated cost of circa €9.2bn

5.20 These cost unit rates and allowances, combined with the infrastructure requirements for each city, are then used to develop a cost estimate, for each city, for each of the nine capacity uplift scenarios. These are then summed to provide the total investment cost, across the 20 case study cities, for each of the nine scenarios.

Aggregation to 54 study cities

5.21 Costs were then aggregated to the wider group of 54 study cities, based on treating the 20 case study cities as a sample and extrapolating to the wider group based on their broad population group. Of the 20 case study cities, 8 are classed as large, 6 medium and 6 small, increasing to 11 large, 14 medium and 29 small across the wider 54.

5.22 Our approach is based on the notion that:

i. Only a subset of cities are expected to have a requirement for additional transport capacity and hence capital investment, as highlighted in the capacity and demand analysis;
ii. This percentage varies across the 'low', 'medium' and 'high' capacity requirements, and between the different sizes of city;
iii. For the subset of cities that require additional capacity, the broad scale and cost of the required infrastructure 'per city' can be calculated;
iv. Combining the percentage from ii. and the capital cost 'per city requiring investment' from iii. can be used to derive the total estimated cost across the wider group of 54 cities.

5.23 Table 5.9 summarises, for each of the 'low', 'medium' and 'high' capacity requirements, the number and proportion of cities in each size band that our analysis indicate require investment, for both the sample of 20 cities and the wider 54 under assessment.

Table 5.9: Number and proportion of cities expected to require capital investment

	20 case study cities >>			All 50 case study cities >>		
	Low capacity requirement	Medium capacity requirement	High capacity requirement	Low capacity requirement	Medium capacity requirement	High capacity requirement
Small	**1 (of 6 total)** 17% need capital investment	**1 (of 6 total)** 17% need capital investment	**1 (of 6 total)** 17% need capital investment	**17% of 29** 4.8 cities need capital investment	**17% of 29** 4.8 cities need capital investment	**17% of 29** 4.8 cities need capital investment
Medium	**1 (of 6 total)** 17% need capital investment	**1 (of 6 total)** 17% need capital investment	**1 (of 6 total)** 17% need capital investment	**17% of 14** 2.3 cities need capital investment	**17% of 14** 2.3 cities need capital investment	**17% of 14** 2.3 cities need capital investment
Large	**2 (of 8 total)** 25% need capital investment	**4 (of 8 total)** 50% need capital investment	**6 (of 8 total)** 75% need capital investment	**25% of 11** 2.8 cities need capital investment	**50% of 11** 5.5 cities need capital investment	**75% of 11** 8.3 cities need capital investment
Total	**4 (of 20)** need investment	**6 (of 20)** need investment	**8 (of 20)** need investment	**9.9 (of 54)** need investment	**12.7 (of 54)** need investment	**15.4 (of 54)** need investment

5.38 Using these percentages, we then:

- Derive the average capital cost of infrastructure enhancement for a city requiring additional capacity in each size band, under each of the nine capacity uplift scenarios. For example, the total capital cost (under the central cost assumptions) across the six ‘large’ cities under the high-capacity requirement, rail-based investment approach is £30.8bn – or £5.1bn per city;
- Since there are eight large cities (within the 20 studied in detail), but only six require investment, this equates to 75%.
- Applying this 75% across the 11 large cities (within the 54), we calculate that a notional ‘8.3 cities’ require investment;
- Multiplying the £5.3bn by the 8.3 provides the total capital cost across all the 8 large cities of circa £42bn;
- Applying the same approach to the small and medium cities, and summing the total, provides the total cost estimate across all 54 cities for the high-capacity requirement, rail-based scenario – equating to a total cost of £47bn (as shown in Figure 7.8 in the Main Report).

5.39 This approach is intended to allow for the more detailed assessment of individual cities to be scaled to the wider 54, and provide a broad ‘order of magnitude’ estimate of potential investment requirements. It should not be used to interpret the specific investment requirements in any city, or be used to determine an ‘average spend’ in each.

Assessment of potential scale of revenue, operating costs and subsidy requirements

5.40 The previous sections explain the process followed to define the capacity requirement, for each mode, across the 20 case study cities and for determining, for a given scale of capacity increase, the broad capital costs associated with delivering the expanded infrastructure.

5.41 This section summarises the method used for deriving the broad scale of additional operating cost, revenue and Government subsidy arising from this additional infrastructure. This analysis has been undertaken by mode (bus, rail and metro/tram), using a combination of publicly available official statistics and informed assumptions, which are summarised here.

Development of annualisation factors

5.42 The capacity requirement on each mode is measured in terms of number of people per hour per direction, for the AM peak hour (08:00 – 09:00). As the outputs of the analysis – operating cost, revenue and subsidy – are provided in annual figures, an expansion factor was needed to convert the AM peak hour demand, by mode, to an all-day figure, with a subsequent annualisation factor to convert it to an annual figure.

5.43 For bus, the expansion factor was derived as a combination of an AM peak hour to AM peak period (07:00 – 10:00) factor, an AM peak period to all-day factor, and a factor of 2 to account for the two directions of demand crossing the city centre cordons during the day. This was determined based on historic weekday bus passenger count data from Leeds, benchmarked against DfT traffic count data from roads crossing city centre cordons. The combined expansion and annualisation factor used to convert AM peak hour to annual figures is 6,500.

5.44 The factors derived for bus were also used for metro/tram, given the absence of specific data for this mode and the assumption that the peak hour-to-day pattern of tram/metro system demand across city centre cordons is broadly similar to that of bus.

5.45 For rail, a combination of DfT[25] and ORR[26] official statistics was used to derive the expansion and annualisation factors, using demand figures for National Rail stations located in city centres, following the same process of expansion first (AM peak hour to all-day) and then annualisation (all-day to annual). The 'peakier' profile of rail demand into city centres, compared to other modes of transport, is reflected in a lower annualisation factor of 3,000.

Calculation of revenue and operating cost 'per passenger'

5.46 Following the calculation of annualisation factors, the revenue and operating cost for each city under each scenario and capacity requirement were calculated. For this, the approach used

[25] Table RAI0202: City centre arrivals and departures by rail on a typical autumn weekday (**https://www.gov.uk/government/statistical-data-sets/rai02-capacity-and-overcrowding**)

[26] Table 1410: Passenger entries and exits and interchanges by station (**https://dataportal.orr.gov.uk/statistics/usage/estimates-of-station-usage**)

consisted in deriving a unitary value of revenue and operating cost per passenger journey, for each mode, and then multiplying these unitary values by the annualised demand figures to obtain annual totals for each city.

5.47 For bus, the average fare revenue and operating cost per passenger journey were derived from official DfT statistics[27] for 'English metropolitan areas'[28]. These are £0.95 and £1.53, respectively, in 2022 prices. The subsidy is the difference between these two figures.

5.48 For metro/tram, official DfT statistics[29] were also used to calculate the revenue per passenger journey, using data from West Midlands Metro, Sheffield Supertram and Tyne and Wear Metro[30].The average revenue per passenger journey was calculated as £1.56, in 2022 prices. Given the absence of reliable operating cost data for metro/tram services, it was assumed for the purposes of this analysis that the operating costs per passenger journey would be the same value as the revenue, therefore assuming a break-even operating financial position, which we understand to be the case on most UK light rail networks pre-pandemic.

5.49 For rail, ORR data[31] on franchised operator finances was used to derive a unitary figure of revenue per passenger journey. As opposed to bus and metro/tram, rail revenue and operating cost figures are more difficult to associate with individual cities, given the (in most cases) absence of city-specific operators, and the more regional and inter-city nature of this mode.

5.50 To address this, a rail-specific approach was developed, excluding both operators not present in the 20 case study cities and those with mostly catering for long-distance travel (different revenue and operating cost patterns to commuter/urban rail operations). This was done as a two-step process, with the first step involving the calculation of the revenue per passenger-km and the second step calculating the revenue per journey, using an assumed average journey length. Following this approach, and assuming an average journey length of 18 km for rail trips (based on Merseyrail data), the rail revenue per passenger journey equated to £3.22, in 2022 prices.

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[27] Table BUS04: Operating revenue per passenger journey; Table BUS05: Net government support per passenger journey (**https://www.gov.uk/government/statistical-data-sets/bus-statistics-data-tables#costs-fares-and-revenue-bus04**)

[28] These refer to the metropolitan areas of Tyne & Wear, Merseyside, Greater Manchester, West Midlands, South Yorkshire and West Yorkshire.

[29] Table LRT0301: Passenger revenue on light rail and trams and undergrounds by system; Table LRT0101: Passenger journeys on light rail and trams and undergrounds by system. (**https://www.gov.uk/government/statistical-data-sets/light-rail-and-tram-statistics-lrt**)

[30] Manchester Metrolink was excluded from this calculation, as revenue per passenger on the Metrolink is significantly greater than the other systems, in part because uniquely fare revenue is used to help fund the capital costs of constructing the network.

[31] Table 7226: Franchised passenger train operator finances (**https://dataportal.orr.gov.uk/statistics/finance/rail-industry-finance/**)

5.51 The operating costs for rail were calculating as the sum of the revenue per passenger journey, as described above, and the total operator subsidy (including network grants), as published by the ORR[32], using the same assumptions on operators and average journey length as for the revenue calculation. This produced a figure of an average operating cost per passenger journey of £4.95, in 2022 prices.

5.52 The overall fare revenue and operating costs were then calculated for each of the 20 case study cities, based on the multiplying the 'per passenger' operating cost and revenue figures by the annualisation factors, and the total scale of each city's 'capacity gap'. Government subsidy requirements are assumed to be the different between the total fare revenue versus operating costs.

Aggregation to 54 study cities

5.53 Following the same approach used for the capital costs, estimates of operating costs and revenue were aggregated to the wider group of 54 study cities, based on treating the core 20 cities as a sample and extrapolating to the wider group based on their size band.

[32] Table 7273: Government subsidy by franchised passenger operator (**https://dataportal.orr.gov.uk/statistics/finance/rail-industry-finance/**)

Control Information

Prepared by	**Prepared for**
Steer 14-21 Rushworth Street London SE1 0RB +44 20 7910 5000 www.steergroup.com	National Infrastructure Commission 4th Floor, Finlaison House 15-17 Furnival Street London EC4A 1AB
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