Effect of capacity constraints on population and employment distribution

Project report delivered to the National Infrastructure Commission

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Contents

1. Overview

The report is intended to provide an overview of data and methods produced in accordance with the following deliverables under two phases of the project:

Phase 1:

- Developing a baseline projection for population and employment in UK cities and other places, based on ONS sub-national population projections.
- Sensitivity testing of ONS projections to consider outcomes under different assumptions about future growth patterns.

Phase 2:

- Developing alternative scenarios for population and employment growth in cities reflecting transport infrastructure constraints.
- Developing alternative scenarios for population and employment growth in cities reflecting housing constraints, and reflecting the combined effect of transport and housing constraints.

2. Rationale and background

Here a brief review is offered on three topics: evidence that transport capacity constraints impact on employment growth; evidence linking the supply of housing to employment growth; and utility (and caveats) around using projection-based approach for analysis. This section serves to provide the rationale for the study and the scenario analysis undertaken.

Transport and employment

Most of the literature is focused on the link between road congestion/capacity and employment growth. A number of studies for US metropolitan areas offer evidence that increased traffic congestion has a negative impact on employment growth. See for example Hymel (2008), who finds that employment growth returns from capacity expansion are substantial, Jin and Rafferty (2017) who conclude that increases in congestion negatively effects employment growth, Boarnet (1997) finds that congestion reduction aids economic growth, and Sweet (2013) finds that congestion slows job growth in metropolitan areas.

Evidence from the UK is more limited, but Noland and Lem (2002) review research into the demand inducing effects of new transportation capacity reported in both UK and US literature. They conclude that *“VMT* [vehicle miles of travel] *growth is likely to be larger with more highway capacity relative to less highway capacity”* (p.23), suggesting that higher capacity equates to more road transport uptake.

One reason for the focus on road transport in the literature may be that non-transport benefits of rail investments are not often successfully accounted for. Banister and Thurstain-Goodwin (2011) argue that the usual approach to assessing the impact of rail investment generally assume that the net (UK level) effect on the economy is zero. Rather it is the impact on the *location* of economic activity which is impacted, i.e. displacement through a lack of capacity and other effects are felt locally.

In a study undertaken for the GLA, Tongi (2015) finds that for larger areas within London (those with over 0.7 million people) which have high public transport accessibility, that accessibility is a strong determinant of employment density. In a theoretical study, Venables (2007, p.187) finds that increased employment (and by extension productivity) increases as transport capacity increases *"not only by drawing more people into the city as a whole, but also by enabling more of the city's initial inhabitants to work in the CBD."* The mode of transport in this study is not specified.

Taken in combination, these studies suggest that transport infrastructure capacity increases are often utilised, areas with good accessibility have higher employment densities and that capacity constraints inhibit employment growth.

Housing and employment

Evidence for a direct link between housing constraints and rate of employment growth is more limited in the literature. However, Glaeser *et al.* (2006, p.89) makes the salient point that "*firms in a region cannot expand employment without new homes to house new workers*." Saks (2008), in a US based study, argues that in times of overall increased labour demand, metropolitan areas with low elasticity (i.e. low supply) *vis-à-vis* those with high elasticity will see lower employment growth. Tongi (2015) makes the link between population growth and local job creation, arguing that every increase of 1,000 people will give rise to, on average, 230 jobs in the locality. What is not clear in the literature is the adaptations to behaviour which may arise from housing constraints. These might include people being more willing to accept higher housing density (e.g. sharing housing) or moving but increasing their commuting distances to retain employment in a city. These complex adaptations are not captured in this project.

Utility of using projections

The perils of interpreting projections as absolute truth is widely reported. This is because demographic behaviour is inherently uncertain and projections rely upon past information to inform predictions of future trends. Lutz and Goldstein (2004) provide a foreword to 11 papers published in the *International Statistical Review* which deal with uncertainty in population projection results and propose a number of ways to quantify this. Despite inherent uncertainties associated with projections, Wilson and Rees (2005) argue that they are essential for the planning and delivery of a wide range of services, which is why projections are so widely used across a multitude of disciplines. They are produced globally (e.g. see the World Population Prospects produced by the UN (2017)); nationally (e.g. see the National Population projections produced by ONS (2017)); and locally (e.g. by the GLA (2017) for London boroughs). Clearly there is a need to provide some evidence of future population size and structure, but interpretation needs to be sensible and users need to understand uncertainty is inherent.

The UKCES (2016) have, since 2002, published several editions of the *Working Futures* analysis, providing projections of the UK labour market at a macroeconomic level. The 2016 report highlights that the analysis is based on rigorous assumptions, but that figures *"should not be interpreted as a concrete snapshot of the future labour market… the projected values are broad indicators of scale, not precise estimates"* (p.5).

In a review of the accuracy of official UK population projections produced by ONS, Shaw (2007) finds that projections of working age population have been relatively accurate, while larger discrepancies between observed and projected population are evident for the very young and very old. It is in this context that Shaw (ibid, p. 127) highlights that it is *"important* *that users of population projections act with a knowledge of their likely limitations and that projection makers provide the information to enable them to do so."*

One way of assessing future possible outcomes is through scenario projection, whereby components in the model are changed and the results interpreted. This is an approach used by national statistical agencies around the world (e.g. Statistics Canada, 2017). In the 2016 based National Population Projections, the Office for National Statistics produce 18 variants, where the population of the UK in 2041 is projected to range from somewhere between 77 million under the 'high population' scenario (which assumes high fertility, high life expectancy and high migration) and 67.3 million under the 'zero net migration' scenario. In the work presented in this report there are 24 different scenarios which provide different outcomes using a range of demographic and transport capacity inputs. Users should pay attention to the variation in these results and compare the effect that different growth and capacity scenarios have for the cities of study.

Phase 1 – baseline and sensitivities

3. Defining city centre boundaries

The transport consultancy Steer Davies Gleave have produced a set of city centre 'cordons' for 54 cities of study within England. These cities have been defined using the Centre for Cities definition of primary urban areas[1]. These cordons are defined using the transport network of the city (e.g. roads encircling the city centre) but do not align completely with the Output Area geography used in our analysis. Output Area is the finest spatial resolution of geography at which demographic information is available from the 2011 Census, which provides the most comprehensive information about spatially disaggregated employment figures and commuter flows. We employ a best-fit methodology to define the spatial extent of the city centre using Output Areas. This involves:

- Defining a bounding box for each city centre based on the transport cordon
- Accepting an Output Area as part of the city centre if population-weighted centroid is within cordon; or if over 50% of the area is within the cordon
- Manually adding or removing Output Areas based on visual inspection of the results

4. Developing a baseline employment projection for Local Authority Districts (LADs)

Working population is defined as all persons aged 16-74 who are in employment. Persons aged under 16 or over 74 are excluded from our analysis to ensure consistency across all datasets used for the project. Investigation reveals that population outside of this age range has little impact on results. Workers aged 75 and over account for less than 0.4% of total commuters in the 2011 Census origin-destination tables and those aged under 16 are not eligible to work so are excluded from all data available.

[1] http://www.centreforcities.org/puas/

Initial employment rates are taken from the 2011 Census of population for each local authority in four age bands: 16-34; 35-49; 50-64; 65+. This captures the geographical variability in employment rate by LAD (not available in other datasets) and also by broad age group.

We then apply the employment rate for each local authority and age group to the 2014 based ONS sub-national population projection for that LAD to produce an initial working population for each area in each year up to 2039. Overall employment rates between 2011 (the census year) and 2018 (the latest data available) have risen for the 16-74 age group from 70.5% to 75.4% so to account for this, the working population is scaled up to ensure that the sum of all LADs matches the UK total in employment estimated using the overall employment rate. Using the average rates reported in ONS official labour market statistics[2] over the last three years, the rates used in each projection year are:

- Age 16 to 74: 74.4%
- Age 65 to 74: 37%

Three-year average rates are used because the 2018 rate of 75.4% is higher than in any previous years and may represent an anomaly. The result is a working population defined by their **place of residence** available for all years up to 2039, the year in which the ONS SNPP constraint ends.

For years 2040 to 2050 the growth is determined by linear extrapolation of the marginal growth rate for the LAD between 2038 and 2039 - in other words the growth rate in each LAD is constant over the period 2038-2050, drawn from the last year of the official projection. Finally the projection in every year is constrained to the 2016 based National Population Projection total, which includes updated assumptions about demographic rates (but excludes any sub-country breakdown).

5. Allocating Residential Populations to Workplaces

Once a baseline *residential* population projection for people aged 16 to 74 has been estimated, we then allocate these people to *workplaces*. Workplaces are defined as:

- 54 city centres (as defined in Section 2 using Output Areas)
- 54 LADs *excluding* the city centre it contains
- Other LADs which do not contain a city centre of interest

The data used in this redistribution is the 2011 Census origin-destination (OD) flow tables, which detail the number of people moving from place of residence to place of work on a regular basis. We include all commuters aged 16 to 74 in our analysis. The total flows are recalculated as distributions and these distributions are applied to our estimated working population by place of residence in each year of the projection to allocate them to a place of work. The result is an estimate of working population for each LAD in England and Wales and a total working population for Scotland and for Northern Ireland. The UK total is

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2 https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/bulletins/uklabourmarket/latest

constrained to an estimate of the UK working population which assumes that on aggregate 74.45% of 16 to 64 year olds and 37% of 65 to 74 year olds are in employment in each year.

Calculating Commuter flows for city centres

This process involves identifying flows in to and out of the city centre. Firstly we define the following regions:

- **C** the city centre (a set of contiguous Output Areas)
- **Lx** the locality excluding the city centre (output areas within the local authority/ies containing the city, excluding those used to define **C**)
- **R** elsewhere (the set of LADs excluding the one(s) containing the city centre)

We are concerned with the following commuter flows:

- Commutes from outside the city centre into the city centre: (**Lx**, **R**) -> **C**
- Commutes out of the city centre: **C** -> (**Lx**, **R**)
- Commutes (or non-moves) within the city **C** -> **C**

Only moves to the city from elsewhere (**Lx**, **R**) -> **C** are used to assess transport capacity constraints (discussed further in Section 6). Moves in the other direction, out of the city, and workers who stay within the city are used to provide an estimate of total working population in the city (the former are removed and the latter are retained).

The total city centre population is subtracted from the LAD in which it is located to provide an estimate of the rest of the LAD working population.

6. Validating the projection totals

While validation is difficult for a projection, there are two data sources available for comparison. The first is the ONS produced labour market statistics for 2018. The second is a projection of the UK labour market, published by the UK Commission for Employment and Skills (UKCES)[3] called *Working Futures*. The UKCES projections are produced for the period 2014 to 2024. See Table 1 for a comparison of estimates from the sources. The UKCES analysis includes caveats around the projected values, in that their results should be interpreted as broad indicators of scale, not precise estimates. Table 1 demonstrates that no estimates line up exactly, but that the principal constrained projection is close to the ONS estimate in 2018. Due to differences in methodology and assumptions, the principal projection is lower than the Working Futures estimate in 2024, but is largely consistent given the time horizon and uncertainty involved.

Table 1. A comparison of the principal constrained estimates with ONS and UKCES

Year	Principal constrained	ONS Estimate[4]	Working Futures Labour Force[5]
2018	33,441	32,262	-
2019	33,514	-	33,415
2024	33,834	-	34,237

[3] https://www.gov.uk/government/publications/uk-labour-market-projections-2014-to-2024

[4] ONS (2018) Table 1: Summary of labour market statistics for December 2017 to February 2018, seasonally adjusted

[5] UKCES (2016) Evidence Report 100, Working Futures 2014-2024, Table 2, page 22

7. Sensitivity testing of ONS projections under different outcomes

This section outlines the approaches used to provide alternative baseline working populations for redistribution. All sensitivities need to be applied at Local Authority scale to the *residential* working population. The method to distribute these populations to *workplaces* is that described above and is always consistent. Two approaches to sensitivity testing are used in this project:

- A macro level constraint, borrowed from the ONS National Population Projection, is used to test the sensitivity of the sub-national projection
- Individual city level scenarios are altered by borrowing a trajectory of growth from another city.

Macro level variants

At the macro level, we borrow the ONS National Population Projection variants to scale up and down our results. Caution is advised in interpretation of results under these sensitivity tests. It is likely that the growth will likely fall *somewhere* between the high and low bands.

We use the ONS NPP 2016 and constrain LAD projections to three scenarios which provide a plausible range of results:

- principal projection
- high growth scenario projection
- low growth scenario projection

We also run an urban growth scenario, where:

- the 54 LADs containing a city of study are grown in line with the high variant of the NPP
- all other (non-city) LADs are grown in line with the change reported in the principal projection
- the UK table is adjusted to agree with the principal projection of employed population
- a similar projection is run which substitutes the high NPP for the low NPP, producing a low urban growth scenario

City specific variants

Cities which are growing strongly now were in many cases in decline until relatively recently. These variants demonstrate the impact on cities where slow growth is projected in the ONS SNPP if we assume a higher rate of urban growth. In particular there are two large cities, Liverpool and Newcastle, which in the ONS SNPP are projected to grow much slower than other large cities. The method adopted here is to ‘borrow’ growth trajectories from cities which are growing faster in the ONS SNPP:

- Newcastle borrows the growth trajectory of Bristol.
- Liverpool borrows the growth trajectory of Manchester.

Both Manchester and Bristol demonstrate population growth in the SNPP so this sensitivity demonstrates what might happen to Liverpool and Newcastle if they experience similar growth. Only the rate of growth is borrowed, the starting population is retained in this scenario.

Phase 2

8. Developing alternative scenarios for transport constraints

The transport consultancy Steer Davies Gleave have provided capacity constraints for each of the 54 cities under study. These constraints are used to measure the difference between the number of inflowing commuters under the unconstrained scenario outlined above and the number of commuters who can access the city in a given period. If commuters from elsewhere in the LAD plus commuters from other LADs exceeds the capacity constraint of the city, we are left with a number of *excess commuters* who need to be redistributed to alternative employment locations. A **high capacity** and a **low capacity** constraint scenario is applied to each city.

Redistribution of excess commuters

Once the city reaches capacity, i.e. (**Lx**, **R**) -> **C** is constrained by a commuting scenario, there is an excess of commuters. These commuters are first reallocated back to their local authority of origin and then redistributed to another local authority employment location based on the distribution reported in the census origin-destination tables. The new location can be elsewhere in the LAD in which the city centre is located or another LAD. The only location not available for redistribution is the city centre where the excess occurred. For each of the LADs which contain a city of interest, the reallocated commuters are split between the city and the rest of the LAD, based on employment concentration reported in the 2011 Census.

9. Developing alternative scenarios for housing constraints

The reason for including a housing constrained scenario is to test if there are any cities where the availability of housing limits growth more than transport constraints. Any housing constraints applied to the model are used to constrain the *residential* population which is then distributed to employment areas as described above. We have developed an **urban constrained housing scenario** because constraints are applied to only the LADs which contain one of the 54 cities of interest. For non-urban (i.e. all other LADs) no housing constraint is applied.

To create a housing capacity constraint, we take the average rate of net dwelling stock additions for each local authority containing a city centre of interest, as reported in the Department for Communities and Local Government data[6]. These are then extrapolated forward through the projection to give a measure of how housing stock may increase going forward. Two crude assumptions are made in creating this constraint:

- That past stock change is a predictor of future stock change. Housing provision is a complex mechanism which requires long-term planning, however there is no readily accessible data on that pipeline of supply. Our assumption has the advantage of differentiating between local authorities. Those where housing demand is high (i.e. past additions are high) are assumed to remain attractive locations for building.
- That each new dwelling could house 2 working people. The average UK household size is 2.3 people (including children) and *"Two people households accounted for the*

[6] https://www.gov.uk/government/collections/net-supply-of-housing

largest number of households in the UK"[7]. While people are likely to adapt their behaviour based on dwelling stock availability (e.g. renting shared rooms) this is too complex to capture in this project.

If the dwelling stock does not keep up with the projection (with the assumption of two additional people per dwelling), the growth of working population in that LAD stops and the excess population who are not allocated to a dwelling are allocated to a 'surplus' pool. The total surplus is collected across all 54 local authorities containing a city of study. We then distribute this surplus pool of people to other local authorities proportionally, based on the size of the resident population. LADs with larger populations get a larger share of the excess population. The conditional rule to this allocation is that a housing capacity constrained area will not receive a share of the excess population. There will be a chance that the reallocation will push an area over its housing capacity, but this will be corrected in the following year by implementing the same method. This population is then distributed to the workplace location based on the method described above.

It is important to note that this model allocation is necessarily simple. The dynamics of reallocation to include destination choice cannot be tackled in this project because it would require a fully dynamic set of models which are outside of scope. Projecting housing scenarios is extremely difficult because the only information on allocated land or committed schemes is held by individual local authorities. Collecting this data across the UK is beyond the scope of this project.

Using this methodology, in most cases results for the housing constrained scenarios do not differ substantially from the ONS central projection (see Annex 1 for presentation of these results). We suggest that there is a need for further work to investigate the impact of housing constraints given that the assumptions used here are necessarily simplistic. It would be expected that a stricter assumption about supply would deliver employment growth results which are more constrained than those presented in our results. These assumptions however need to be based on good evidence about future land supply and building rates.

10. Outputs

Where no transport capacity constraints are applied to the 54 city centres we produce eight working population scenarios. See Annex 1 for results of the projected change between 2018 and 2050 for these scenarios:

(1) Central population scenario, no transport capacity constraint on growth.
(2) High urbanisation population scenario, no transport capacity constraint on growth.
(3) Housing constrained population scenario, no transport capacity constraint on growth.
(4) Central population with top-up for Liverpool and Newcastle, no transport capacity constraint on growth.
(5) High urbanisation with top-up for Liverpool and Newcastle, no transport capacity constraint on growth.
(6) Low urbanisation population scenario, no transport capacity constraint on growth.
(7) High ONS population scenario, no transport capacity constraint on growth.

[7] https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/bulletins/populationandhouseholdestimatesfortheunitedkingdom/2011-03-21

(8) Low ONS population scenario, no transport capacity constraint on growth.

The combination of population components and transport capacity components results in 16 scenarios:

(1) Central population scenario, high transport capacity.
(2) Central population scenario, low transport capacity.
(3) High urbanisation population scenario, high transport capacity.
(4) High urbanisation population scenario, low transport capacity.
(5) Housing constrained population scenario, high transport capacity.
(6) Housing constrained population scenario, low transport capacity.
(7) Central population with top-up for Liverpool and Newcastle, high transport capacity.
(8) Central population with top-up for Liverpool and Newcastle, low transport capacity.
(9) High urbanisation with top-up for Liverpool and Newcastle, high transport capacity.
(10) High urbanisation with top-up for Liverpool and Newcastle, low transport capacity.
(11) Low urbanisation population scenario, high transport capacity.
(12) Low urbanisation population scenario, low transport capacity.
(13) High ONS population scenario, high transport capacity.
(14) High ONS population scenario, low transport capacity.
(15) Low ONS population scenario, high transport capacity.
(16) Low ONS population scenario, low transport capacity.

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ANNEX 1: Results from transport unconstrained scenarios

Table A1 lays out the projected employment growth between 2018 and 2050 in each of the unconstrained transport scenarios.

Table A1. Employment growth between 2018 and 2050

National	ONS Central	High urban	Housing const.	Central plus top up Liverpool, Newcastle	High urban plus top up Liverpool, Newcastle	Low urban	High ONS	Low ONS
UK	4%	4%	4%	4%	4%	4%	11%	-5%
City centres (excluding London)	6%	10%	6%	7%	10%	1%	8%	-2%
Central London	17%	23%	17%	17%	23%	10%	25%	7%
Rest of Greater London	19%	26%	18%	19%	26%	11%	28%	9%
Rest of UK	1%	-1%	1%	1%	-1%	2%	8%	-8%
City centre								
Aldershot	2%	3%	2%	2%	3%	0%	9%	-6%
Barnsley	5%	12%	5%	5%	12%	-3%	12%	-3%
Basildon	11%	16%	11%	11%	16%	6%	19%	3%
Birkenhead	-3%	2%	-3%	-3%	2%	-9%	4%	-10%
Birmingham	9%	14%	9%	9%	14%	3%	1%	1%
Blackburn	-4%	-1%	-4%	-4%	-1%	-9%	2%	-12%
Blackpool	-4%	-1%	-4%	-4%	-1%	-8%	2%	-11%
Bournemouth	10%	16%	10%	10%	16%	3%	17%	1%
Bradford	4%	10%	4%	4%	10%	-2%	11%	-4%
Brighton and Hove	10%	15%	10%	10%	15%	4%	17%	2%
Bristol	13%	17%	13%	13%	17%	7%	1%	4%
Burnley	-4%	0%	-4%	-4%	0%	-9%	2%	-11%
Cambridge	9%	9%	9%	9%	9%	9%	17%	1%
Chatham	14%	19%	14%	14%	19%	8%	22%	5%
Coventry	17%	21%	17%	17%	21%	11%	24%	8%
Crawley	12%	15%	12%	12%	15%	8%	20%	3%
Derby	6%	10%	6%	6%	10%	1%	13%	-2%
Doncaster	-2%	4%	-2%	-2%	4%	-8%	5%	-9%
Exeter	7%	8%	7%	7%	8%	5%	14%	-1%
Gloucester	6%	7%	6%	6%	7%	5%	13%	-2%
Huddersfield	5%	11%	5%	5%	11%	-2%	12%	-3%
Hull	-1%	0%	-1%	-1%	0%	-4%	5%	-9%
Ipswich	1%	2%	1%	1%	2%	0%	8%	-6%
Leeds	6%	11%	6%	6%	11%	-1%	0%	-3%
Leicester	10%	13%	10%	10%	13%	5%	17%	1%
Liverpool	1%	5%	1%	6%	6%	-3%	8%	-6%
Luton	17%	20%	15%	17%	20%	12%	25%	8%
Manchester	8%	13%	7%	8%	13%	1%	1%	-1%
Mansfield	1%	5%	1%	1%	5%	-3%	8%	-6%
Middlesbrough	-1%	3%	-1%	-1%	3%	-7%	5%	-9%

Table A1 continued. Employment growth between 2018 and 2050

City centre	ONS Central	High urban	Housing const.	Central plus top up Liverpool, Newcastle	High urban plus top up Liverpool, Newcastle	Low urban	High ONS	Low ONS
Milton Keynes	13%	16%	13%	13%	16%	9%	21%	4%
Newcastle	1%	6%	1%	5%	6%	-4%	8%	-6%
Northampton	10%	13%	10%	10%	13%	6%	17%	1%
Norwich	7%	9%	7%	7%	9%	4%	1%	-1%
Nottingham	6%	10%	6%	6%	10%	1%	0%	-2%
Oxford	7%	8%	7%	7%	8%	5%	14%	-1%
Peterborough	10%	12%	10%	10%	12%	6%	17%	1%
Plymouth	2%	6%	2%	2%	6%	-2%	9%	-5%
Portsmouth	6%	11%	6%	6%	11%	-1%	13%	-2%
Preston	-2%	2%	-2%	-2%	2%	-7%	5%	-10%
Reading	5%	8%	5%	5%	8%	2%	12%	-3%
Sheffield	7%	12%	7%	7%	12%	0%	14%	-2%
Slough	11%	15%	11%	11%	15%	6%	19%	3%
Southampton	8%	12%	8%	8%	12%	3%	15%	-1%
Southend-on-Sea	9%	15%	9%	9%	15%	1%	16%	0%
Stoke-on-Trent	1%	4%	1%	1%	4%	-4%	7%	-7%
Sunderland	-2%	3%	-2%	-2%	3%	-8%	4%	-10%
Swindon	5%	9%	5%	5%	9%	0%	12%	-3%
Telford	0%	4%	0%	0%	4%	-4%	7%	-8%
Wakefield	2%	9%	2%	2%	9%	-5%	9%	-5%
Warrington	2%	5%	2%	2%	5%	-2%	9%	-6%
Wigan	0%	5%	0%	0%	5%	-6%	7%	-7%
Worthing	9%	13%	9%	9%	13%	3%	16%	0%
York	5%	10%	5%	5%	10%	0%	13%	-3%