

ANALYSING BUS STOP SPACING IN ENGLISH CITIES: IS CURRENT PRACTICE FIT FOR PURPOSE?

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1 SUMMARY

The correct spacing of stops along any public transport route is a balance: between making it easy for passengers to access the network (which points to close spacing), and allowing the vehicles to make efficient progress and offer fast journey times (which points to wider spacing). A similar balance applies to the spacing across an area, involving trade-offs in network design.

A long-standing recommended maximum walking distance of 400m to a bus stop has influenced practice and guidance in the industry for many years, although recent research suggests that many people walk further. More detailed guidance points out that to achieve the 400m walk distance in a real-world street network, urban bus stops should actually be spaced around 300m apart, subject to factors such as topography, local age demographics, housing density and service frequency.

The extent to which this advice is followed, or is reflected in existing spacing, in the UK has not been widely researched. But this is a vital step in understanding the accessibility of local bus networks.

In this paper, we set out the background, the principles of stop spacing, and a summary of the existing guidance. We then set out a method to investigate bus stop spacing on existing routes in English cities and towns, using National Public Transport Access Nodes (NAPTAN) data and the National Public Transport Data Repository (NPTDR). Using this method, we examine four case study locations: Leeds, Manchester, Nottingham and Reading. The results illustrate how far the guidance is reflected in reality, and we examine possible factors underlying the differences shown in our case studies. Finally, we consider what this means for public transport accessibility and explore implications for transport policy.

2 INTRODUCTION

2.1 Background

Local bus and light rail networks are key to mobility; in light of the climate emergency and growing awareness of social inequalities, they are becoming increasingly important. As transport planners endeavour to shift the public's reliance on private cars onto more sustainable modes, we must consider how to improve public transport's accessibility, attractiveness and efficiency.

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(which points to wider spacing). A similar balance applies to the spacing across an area, involving trade-offs in network design.

This is a pertinent issue; at least three UK cities have recently looked at reducing the number of bus stops (in effect, increasing the spacing) to improve in-vehicle journey times, reliability and viability of bus services.

- A 2017-18 trial by the West Midlands Combined Authority (WMCA) in southern Birmingham closed 59 stops, after which 32 remained closed permanently (Forster, 2017; LTT, 2017a, 2017b, 2018a; Clark, 2017; Forster, 2018).
- In 2018-20 Edinburgh City Council considered, but did not proceed with, rationalisation on a trial route that would have closed 26 stops (City of Edinburgh Council, 2018a, 2018b, 2020a, 2020b; LTT 2018b, 2020a, 2020b).
- In 2018, the Belfast Rapid Transit System (“Glider”) came into operation. According to the Department for Infrastructure; “in order to provide more reliable journey times, Glider halts are around 400 metres apart. Where there are key locations of high demand, halts are closer together. This means that the number of bus stops on the BRT routes was reduced by about a third.” (Department for Infrastructure, accessed May 2023)

A previous paper (Wakenshaw and Bunn, 2015; Bunn and Wakenshaw, 2018) suggested that there was little available evidence behind the walking catchments recommended in the (then) guidance and that the role of walking distance in public transport’s convenience required further study. As an interim measure, they examined National Travel Survey data to understand how far people actually do (rather than ‘would’) walk to bus stops and railway stations. Outside London, the observed walking distances were greater than the typical planning values (Table 1). But the authors concluded that there was “no simple answer” to what a reasonable planning value should be.

Table 1: Actual walk distances to bus stops and stations – Wakenshaw and Bunn analysis

Situation	Actual distances walked (NTS data) (m)		
	Median	Mean	85 th %ile
Walk to a bus stop – not London	480	580	810
Walk to a bus stop – London	400	490	810
Walk to a railway station – not London	810	1010	1610
Walk to a railway station – London	640	740	1290

Source: Wakenshaw and Bunn, 2018. NTS = National Travel Survey. For technical reasons, very short walk distances are under-counted in NTS (White et al, 2018)

These observed figures, of course, reflect the services actually provided, not necessarily what is desirable or attractive (Hunter, 2018; White et al, 2018). They also reflect current bus users, not people who are put off from using buses by the distance, such as some people with disabilities (Rayner 2018; Beecham 2018).

This background raises some key questions:

- What does current guidance say?
- How far apart are bus stops in practice? Is this in line with the guidance? If not, why?
- Are both the guidance and the practice appropriate for today's needs?

2.2 Aims

In this paper, we start to tackle these critical questions. We summarise the existing guidance, present a method for assessing bus stop spacing, and use it in four case study cities and towns to investigate how current practice compares to the guidance. We hope the paper will spark discussion and further work.

The paper focuses on:

- Bus stops, rather than rail or intermediate modes – although we refer to these other modes where relevant.
- The guidance in England.
- Urban areas where the demand is, in effect, spatially continuous – rather than rural areas where stop spacing is more likely to reflect individual demand generators.
- Bus stops with predominantly walking catchments – rather than special cases such as park-and-ride.

Our data analysis has so far focused on a sample of English cities and towns, but the underlying questions and methods are applicable to any urban area in the UK or beyond.

We are focusing on stop *spacing*. The guidance and practice on *siting* (i.e., precise locations), and other issues such as the 'splitting' of stops or the use of express services that omit some stops, are outside the scope of this paper. In reality, of course, all these factors exist together and will influence each other in particular locations.

The remainder of the paper:

- Sets out the basic principles of bus stop spacing (Section 3).
- Summarises the existing guidance (Section 4).
- Sets out a method for assessing actual stop spacing, and applies it to some case study cities and towns (Sections 5 and 6).
- Offers conclusions, and identifies next steps and questions for practitioners and researchers (Section 7).

3 BASIC PRINCIPLES OF STOP SPACING

3.1 Along a route

In principle, stop spacing along a route is a balance between:

- Having stops near the locations that people are travelling to or from – for the service to be useful and attractive.

- Not stopping too often – as this will slow the service down and make it less attractive. Each stop costs time: a trip that lets one person on at one stop, then another at the next, takes longer than a trip that stops only once to board both passengers together.

What should that balance be? Mathematical models could be used to find the optimum solution in each location. There is some technical, and much academic, literature on this (e.g., Lesley, 1976; Tirachini, 2014; Chen et al, 2016; Taplin and Sun, 2019; Hansson et al, 2021). But in practice, we need a guideline to follow.

A way to strike a balance and set a guideline is to understand what maximum walk distance to/from the stop is acceptable or preferable; this, in turn, will set the stop spacing. This comes through in the guidance, which is expressed sometimes as a walk distance, sometimes as a stop spacing, and sometimes as both.

Complications then arise:

- The walk distance creates a catchment area circle around the stop. Inevitably there will be overlaps or gaps (Figure 1). A closer spacing means fewer gaps but more overlaps, and vice versa. The stop spacing will therefore be a compromise.
- In reality there is no ‘how far will people walk?’ cliff-edge at a particular radius from a stop. Instead, there is a distance-decay function (Figure 2). For any individual, a shorter walk is more attractive than a longer (but potentially still acceptable) one. This decay function differs between individuals and between groups: for example, elderly people compared to the population as a whole.
- The acceptable distance (or rather, the decay function) may vary with the public transport service level, quality or speed. This is seen in the guidance that assumes or recommends longer acceptable walk distances to railway stations than to bus stops (e.g., IHT, 1997; CIHT, 2015), but also for different levels of bus service (e.g., Pharaoh, 2018).
- A simple walk radius or circular distance-decay function would not reflect the street pattern. For example, a home 400m from the stop as the crow flies might be 500m, or more, away by street, particularly in more spacious or less-connective street layouts (Figure 3).
- Similarly, gradients may affect the acceptable walk distance. An uphill walk is less easy and less attractive than the same distance on the level.

Hence a simple “walk distance” metric may be too simplistic. The guidance documents described in section 4 each cover these factors to a greater or lesser extent.

Figure 1: The basic relationship between catchment walk distances and stop spacing

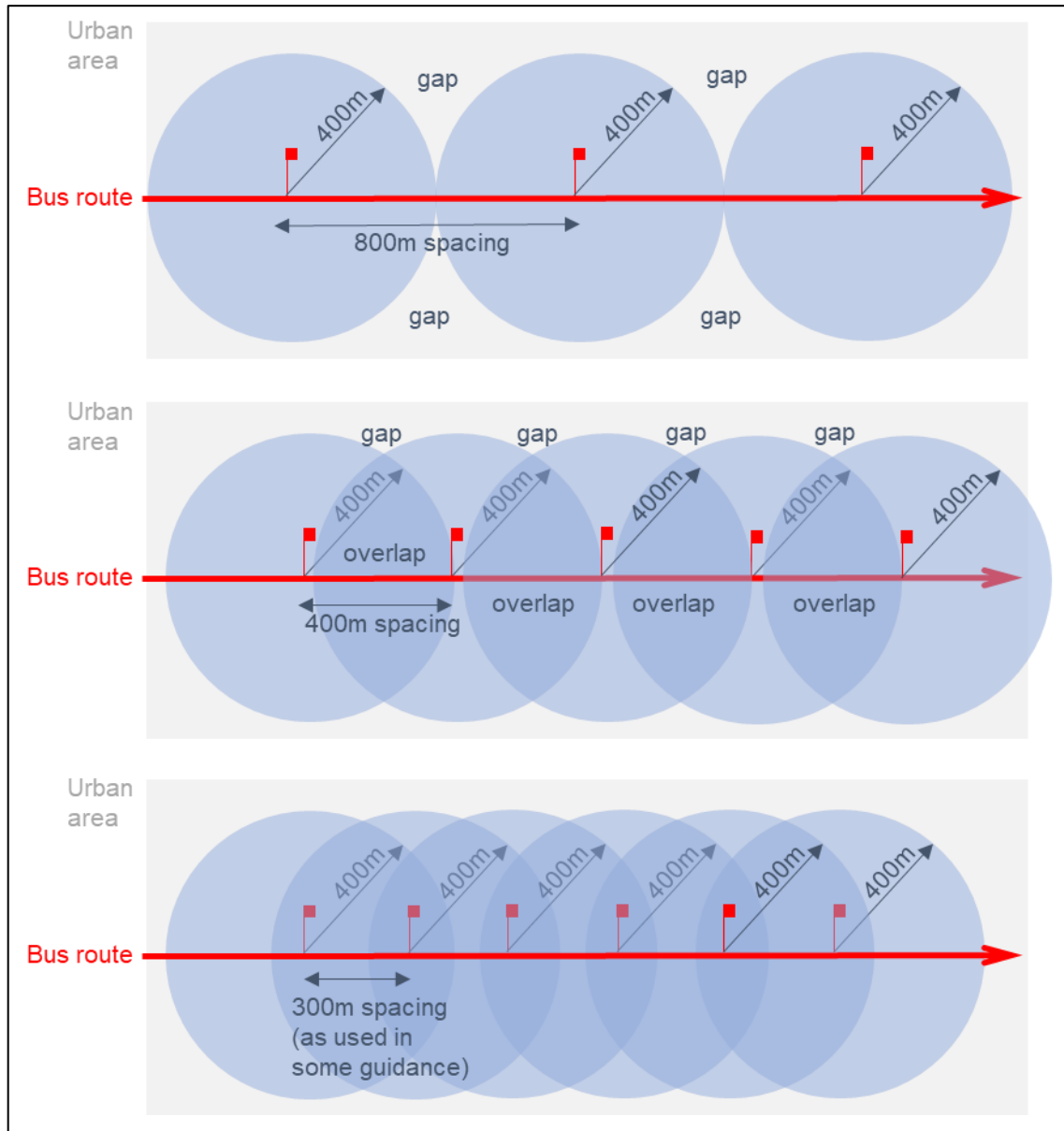


Figure 2: Catchment areas are in reality a decay-function, not a cliff-edge

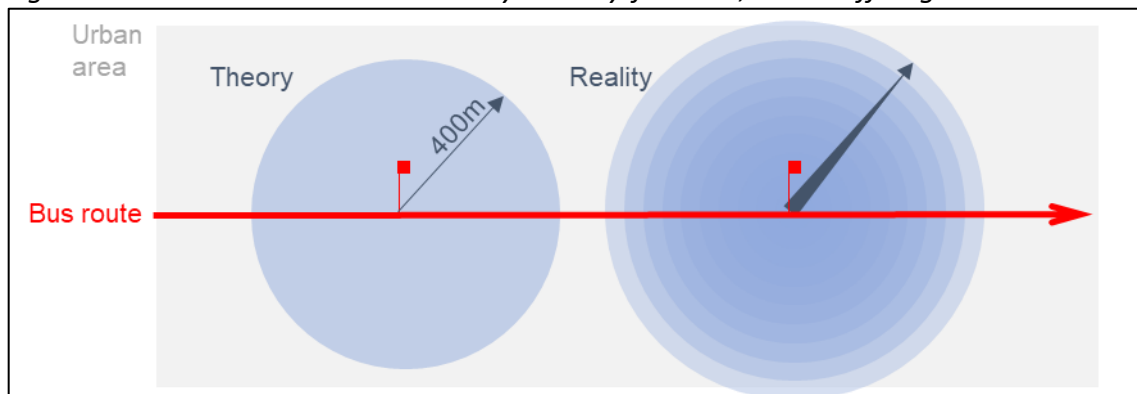
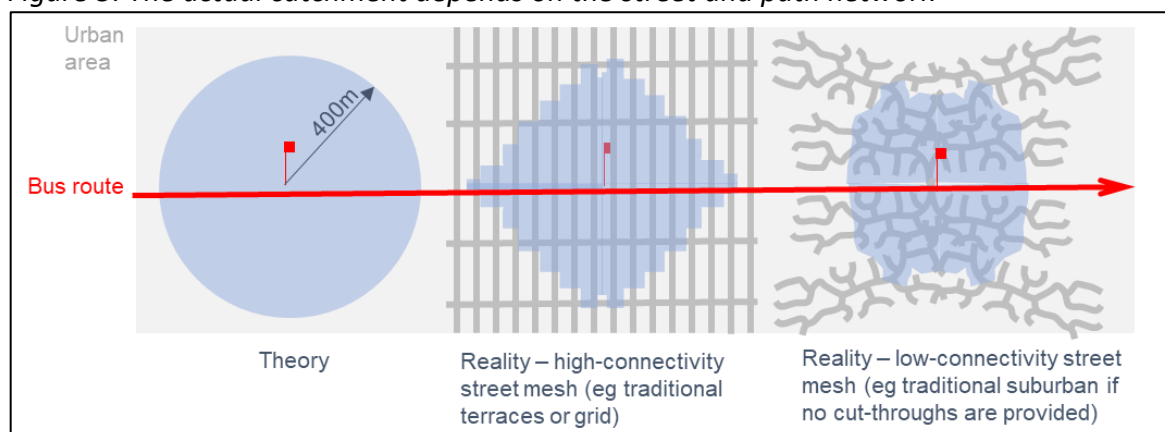


Figure 3: The actual catchment depends on the street and path network



3.2 Within an area

The same principles can be expanded to consider stop spacing within an area – which involves the spacing between routes as well as along a single route. However, several network planning factors come into play, which are mostly outside the scope of this paper.

We would highlight one of those factors: current bus planning philosophy often favours running a smaller number of more widely-spaced, more frequent routes, rather than a denser mesh of lower-frequency routes. In part this is a recognition that for passengers as a whole, waiting time at a stop has a greater disutility than walk time or in-vehicle time, meaning that a longer walk is preferable to a longer wait. This of course is not true for every individual, hence the existence of lower-frequency ‘local’ infill routes, particularly serving clusters of elderly people, and this is reflected in some of the guidance on acceptable walking distances.

4 THE GUIDANCE ON STOP SPACING

4.1 The guidance documents

Most of the available guidance on public transport stop spacing is about bus stops. There is less about other modes such as light rail, although textbooks talk about typical spacings for different modes (e.g., White (2016) p89; Vuchic (2007) p76,311).

Table 2 summarises the main English guidance on bus stop spacing, chronologically from a significant 1973 circular. This is not an exhaustive literature review but refers to the main guidance used in practice. The authors would welcome further contributions to this list, including local guidance.

Table 2: Summary of guidance on bus stop spacing

Document	Relevant key points: walking distances	Relevant key points: stop spacing
<p>DoE Circular 82/73: Bus Operation in Residential and Industrial Areas (DoE, 1973) [quoted in Lesley, 1976 and Wakenshaw and Bunn, 2015]</p>	<ul style="list-style-type: none"> Walking distances along estate footpath systems to bus stops should not be more than 400m from the furthest houses and workplaces they serve. [para 4.3] 	<ul style="list-style-type: none"> On average, bus stops will be spaced 2-3 per km. [para 4.4]
<p>Transport in the Urban Environment (The Institution of Highways & Transportation, 1997)</p>	<ul style="list-style-type: none"> In new residential developments, no dwelling should be more than about 400m from a bus stop [29.6, p397. In context of development site layout. Chapter on non-residential developments has no equivalent guidance]. The walk-in catchment for a fixed-track system is limited to a radius of about 1km from each track or station [34.3, p451. In context of feeder services – no further guidance on stop spacing for these systems]. 	<ul style="list-style-type: none"> Typical bus stop frequency 2-3 stops per km. [24.11, p339. Implies 333-500m spacing; in context, presumably intended to cover rural areas, although it seems to match the 1973 DoE guidance]. In densely populated areas, town centres and residential developments, bus stops should preferably be no more than 300m apart. [24.11, p339. I.e. urban areas.]
<p>Guidelines for Planning for Public Transport in Developments (The Institution of Highways & Transportation, 1999)</p>	<ul style="list-style-type: none"> Max walking distance to bus stop should not exceed 400m, preferably no more than 300m. [p11] Quotes Centro standard of 400m maximum for 0700-1900, reduced where there are severe gradients or many elderly people. For 1900-0700 the max can be 700m. [p73] Also quotes the DoE 1973 400m recommendation. [p73] City centre max walking distance to bus stop 200m. [p73] These should be treated as guidance – direct, frequent, easily-understandable services are more important than slavish adherence to the criteria or reducing walking distances by a few metres. [p11, 73] Max walking distance to rail station 800m. [p73] 	<ul style="list-style-type: none"> Nil directly but would flow from the walking distance guideline.
<p>Quality Bus Infrastructure: A Manual and Guide (The TAS Partnership, 2000)</p>	<ul style="list-style-type: none"> Nil directly. 	<ul style="list-style-type: none"> Generally bus stops should be located 400m apart, but consider a closer spacing in town centres and residential areas [section 4.2.2, p18]

Document	Relevant key points: walking distances	Relevant key points: stop spacing
TfQL Masterplanning Checklist for Sustainable Transport in New Developments (Taylor and Sloman, 2008)	<ul style="list-style-type: none"> • 800m maximum distances from residences to the main public transport hub. This defines a ten-minute walk ‘ped-shed’ [p39]. Refers to some US and Australian material supporting this. [p34] • 400m maximum for local links such as buses. [p39] 	<ul style="list-style-type: none"> • 300-400m (about a 5-minute walk time) is often taken as a practical standard for urban bus stop spacing. [p37]
TfL Guidelines for Planning Bus Services (Transport for London, 2012)	<ul style="list-style-type: none"> • In residential areas, the bus network should be within about 5 mins walk of homes, if practicable. This is about 400m at average walking speed. [para 35] • The 400m guideline will be used alongside other indicators of accessibility to the network – demographic (eg low car ownership) or physical (eg steep hills or severance). [para 36] • In town centres, passengers should be taken close to the places they want to reach - shopping centres, rail stations, etc. But avoid complicated or indirect bus routeings. [para 37] 	<ul style="list-style-type: none"> • Nil directly but would flow from the walking distance guideline.
CIHT Planning for Walking (Mitchell and Bendixson, 2015)	<ul style="list-style-type: none"> • For bus stops in residential areas, 400m traditionally seen as a cut-off point. In town centres, 200m. People will walk up to 800m to get to a railway station, reflecting the greater perceived quality or importance of rail services [section 6, p9] 	<ul style="list-style-type: none"> • Nil directly but would flow from the walking distance guideline.
TfL Accessible Bus Stop Design Guidance (Transport for London, 2017)	<ul style="list-style-type: none"> • Nil. 	<ul style="list-style-type: none"> • Consider the street’s place and movement functions, and passenger demand for the stop. Consider mobility-impaired users. Refers to the Bus Network Planning Guidance. [p16]
Bus Services and New Residential Developments (Stagecoach UK Bus, 2017)	<ul style="list-style-type: none"> • Accepts 400m as the maximum convenient walking distance to urban stops, per IHT 2000 advice. [this might mean the 1999 guidelines] • This can flex to allow efficient bus routing – rather than having an inefficient or contrived layout to achieve this standard. • Recommends that affordable housing and higher-density development are all within the 400m and preferably closer. [p17] 	<ul style="list-style-type: none"> • Bus stops in developments should normally be 280-320m apart “to maximise the number of dwellings within easy walking distance of stops, while avoiding stops being so close together that buses cannot make efficient progress”. [p19]

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<p>CIHT's Buses in Urban Developments (Pharoah, 2018)</p> <p>[This is part of CIHT's Streets and Transport in the Urban Environment series, which is seen as a successor to Transport in the Urban Environment as listed above. It is focused on new urban developments.]</p>	<ul style="list-style-type: none"> • Quotes the Stagecoach guidance (above) on flexing walk distance to achieve efficient routing. [p14] • Refers to a 400m maximum walking distance as "custom and practice" and as recommended in 1973 guidance, but identifies some factors that should challenge this. [see main text of this paper] [p18] • Hence suggests the following, but should have regard to the location's characteristics, not applied slavishly. Emphasises that this is actual walking distance, not notional circles. [p18, Table 4] <table border="1" data-bbox="523 779 962 1115"> <thead> <tr> <th>Situation</th> <th>Max walk distance (m)</th> </tr> </thead> <tbody> <tr> <td>Core bus corridors with 2+ high-frequency services</td> <td>500</td> </tr> <tr> <td>Single high-frequency routes (every 12 mins or better)</td> <td>400</td> </tr> <tr> <td>Less frequent routes</td> <td>300</td> </tr> <tr> <td>Town/city centres</td> <td>250</td> </tr> </tbody> </table>	Situation	Max walk distance (m)	Core bus corridors with 2+ high-frequency services	500	Single high-frequency routes (every 12 mins or better)	400	Less frequent routes	300	Town/city centres	250	<ul style="list-style-type: none"> • The spacing of parallel or adjacent bus routes will relate to the size of catchment areas around stops. Thus, if a 300m catchment is used, adjacent routes should be no more than 600m apart. New development should be configured to enable this. [p13] • Bus stop spacing generally 200-400m. Wider spacing is appropriate for BRT, express and principal corridor services. [p14] <table border="1" data-bbox="999 685 1401 1541"> <thead> <tr> <th>More frequent stops are appropriate for:</th> <th>Less frequent stops are appropriate for:</th> </tr> </thead> <tbody> <tr> <td data-bbox="999 819 1225 1507"> <ul style="list-style-type: none"> • Hilly routes. • Short routes (eg in small towns). • Less frequent services. • Local routes focused on particular destinations (eg schools, hospitals). • Routes serving areas with a high proportion of elderly people. • Areas with high-density housing (to distribute demand). </td> <td data-bbox="1225 819 1401 1507"> <ul style="list-style-type: none"> • Fast/express bus routes. • Long routes (including inter-urban). • Frequent services. • Direct 'core' services (mostly on radial roads). • Routes serving areas with a younger age profile. • Medium/low-density areas. <p>[Table 3]</p> </td> </tr> </tbody> </table> <ul style="list-style-type: none"> • Quotes the Stagecoach 280-320m spacing recommendation. [see above] [p14] • Quotes a TfL recommendation of 200-400m spacing but may need to be closer in town centres and residential areas to meet passenger needs. [p14] 		More frequent stops are appropriate for:	Less frequent stops are appropriate for:	<ul style="list-style-type: none"> • Hilly routes. • Short routes (eg in small towns). • Less frequent services. • Local routes focused on particular destinations (eg schools, hospitals). • Routes serving areas with a high proportion of elderly people. • Areas with high-density housing (to distribute demand). 	<ul style="list-style-type: none"> • Fast/express bus routes. • Long routes (including inter-urban). • Frequent services. • Direct 'core' services (mostly on radial roads). • Routes serving areas with a younger age profile. • Medium/low-density areas. <p>[Table 3]</p>
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Inclusive Mobility - 2022 edition (Department for Transport, 2022a)	<ul style="list-style-type: none"> • In residential areas, bus stops should be within 400m of all homes. • Stop spacing should take account of gradients on walking route. Suggests reducing the max by 10m for every 1m rise or fall. <i>[section 9.1. Section 9 covers bus, LRT and tram stops but the guidance on spacing is explicitly for bus stops; there is no guidance on LRT and tram stop spacing.]</i> 	<ul style="list-style-type: none"> • See column on left, re stop spacing. <p><i>[The now-withdrawn 2005 edition (Department for Transport, 2022) included the following additional guidance, not present in the 2022 edition:]</i> Regular bus services designed particularly with elderly and disabled people in mind, have closer stops, typically every 200 metres. This accords with research showing that for disabled people bus use falls off sharply if the distance exceeds 200m (250m for non-disabled people). <i>[section 6]</i></p>

The key points are paraphrased from the source documents, and some nuances may have been omitted for brevity. Square brackets [thus] denote the relevant location within the source document, and any comments by the authors of this paper.

Local Transport Note 1/97 'Keeping Buses Moving' (DETR, 1997) does not include guidance on bus stop spacing.

4.2 Commentary

The guidance is expressed in a range of ways:

- It sometimes refers to the walk distance to a stop, sometimes the stop spacing, and sometimes both. There may or may not be a flow-through between the two.
- Some distances are 'recommended', and others are 'typical'.
- Some documents quote from earlier ones.
- Much of the recent guidance is in the context of new developments, where the 'right' spacing can be designed-in from scratch with fewer constraints than in an existing urban area. But the principles are relevant anywhere.

A common starting point is the 1973 government circular (Department of the Environment, 1973) which set out a 400m recommended maximum walking distance to a bus stop, equivalent to a 5-minute walk. This is explicitly referenced in some of the subsequent guidance documents and may also be the basis of the same figure appearing in other documents.

Subsequent guidance documents then develop this 400m figure by variously:

- Seeing it as a guideline, not a precise compliance standard, and that effective bus routing is more important than the exact figure; and/or
- Adding nuances related to gradient; and/or
- Varying it (or inviting consideration of doing so) according to the type of service, local demographics, and/or the type of area it serves (e.g., town

centres). There is little commonality in these variations, except perhaps around a closer spacing in town/city centres.

- In particular, the treatment of residential areas varies. Some guidance documents explicitly adopt 400m for these areas, but others say that the distance should be less for some or all residential areas.

The documents then go on to consider the spacing of bus stops, usually in terms of spacing along a route and sometimes also in terms of spacing between routes.

The spacing along the route is in some cases explicitly related to the walk distance. In others, it is not, but might implicitly be so. The documents do not coalesce on a single figure but are within the range of 200-400m. Again, there are references to variations by type of service, area and demographics.

Spacing between routes is less often covered, at least explicitly. Of the list in Table 2, only the 2018 CIHT guidance and the 2012 TfL guidance do so explicitly.

The guidance says less about BRT, light rail and rail stop spacing. Where it does, the general approach is that these modes should have a greater walking catchment and/or wider spacing than conventional bus routes. There is a degree of consensus around an 800m walk distance, compared to 400m for bus stops.

4.3 Summary

Taking the body of guidance as a whole, the position can be summarised as follows.

Bus stop walking catchment:

- There is a long-standing acceptance of a 400m walk catchment for a bus stop as a headline figure or starting point.
- However, this is subject to a range of other physical, demographic and land-use factors. Different guidance documents highlight different factors in this respect. There have been conflicting approaches as to whether some or all residential areas should follow the 400m figure or use a lower figure. The greatest challenge to the 400m figure has been from the 2018 CIHT guidance which suggests a wholly new set of figures for different circumstances (see below).
- Guidance is consistent that the walk distance figure should be applied pragmatically to secure efficient bus movement.

Bus stop spacing:

- Some guidance only covers the walking catchment – in which cases, the spacing can be seen as being inferred from the catchment.
- Other guidance gives spacing figures in the 200-400m range. These may be (more or less explicitly) derived from acceptable walk distances.
- Again, different guidance documents highlight different factors leading to increasing or decreasing the appropriate spacing.

Other public transport modes:

- Some guidance exists, with various figures for walk distance and spacing. It coalesces around the principle that faster / longer / more frequent routes have longer acceptable walk distances and hence wider acceptable stop/station spacings.

The CIHT (2018) guidance can be seen as the state of the art, drawing out two key factors.

Firstly, it sets out the logic that bus stop spacing should suit the real-world catchment or walk distance, rather than being fixed. The acceptable walk distance is applied to the real-world street layout to give actual catchment areas. The spacing should then suit these catchments (and could vary along a route as the urban form and characteristics change). The spacing of parallel or adjacent bus routes should also reflect the catchment. In new developments (the focus of the CIHT guidance) the stop spacing along a route should be planned, then the housing/street layout designed to be within the required walk distance.

Secondly, it looks critically at the traditional 400m walk distance and seeks a more rigorous approach to catchment planning, due to:

- Changes in the competitive position of bus versus car and the need for mode shift.
- Recognising that total journey time matters, not just the walk time; therefore, people will accept longer walks to better services.
- An increasing proportion of elderly people.
- The needs of people with children, buggies and heavy shopping.
- Lower acceptable walking distances in town centres compared to residential areas.
- The quality of the walking route may affect the acceptable distance.

This leads to the recommended set of walk distances for different situations, as summarised in Table 2.

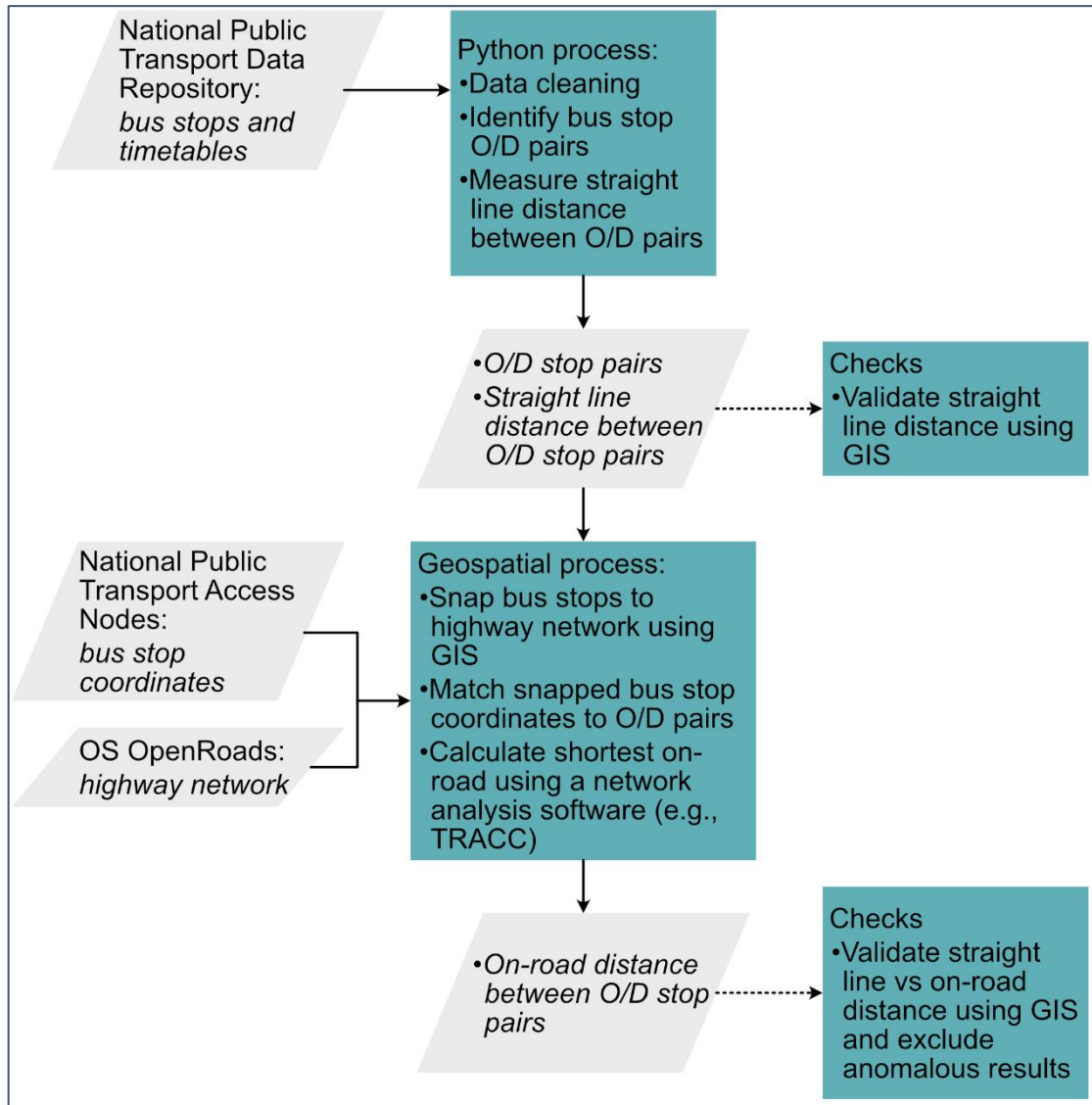
5 A METHOD AND CASE STUDIES IN ASSESSING CURRENT STOP SPACING

We have developed a method for assessing current stop spacing, and validated it on case study data.

5.1 Method

The process is summarised in Figure 4.

Figure 4: methodology process diagram



The following open-source datasets were used:

- National Public Transport Data Repository (NPTDR): timetables (extracted for a defined district boundary).
- National Public Transport Access Nodes (NaPTAN): bus stop coordinates (extracted for the defined district boundary).
- OS OpenRoads: highway network (extracted for the defined district boundary plus 2km buffer).

Identifying consecutive stops, and the distances between them

A Python script was produced to clean and process the NPTDR data, identify pairs of consecutive bus stops (O/D pairs), and calculate a straight line distance within each O/D pair.

Since the straight line distance between stops would not account for the nuances of the road network, a network analysis process (using Basemap TRACC accessibility

modelling software) was set up to estimate the on-road distance between each O/D pair. Bus stop coordinates from the NaPTAN dataset were snapped to the OS OpenRoads highway network to minimise erroneous routing. Then the Basemap TRACC O/D network analysis tool was used to estimate the shortest on-road distance between each O/D pair.

A number of checks were carried out:

- A random sample of straight line distances calculated by the Python process was checked using a GIS straight line distance tool.
- The straight line and on-road distances were compared; the routes with the greatest variation were individually extracted from TRACC and validated. In most cases, the large variation was due to severance (for example, caused by a river, railway line or large land use). The small number of cases where TRACC assigned an erroneous route were excluded from the subsequent analysis.

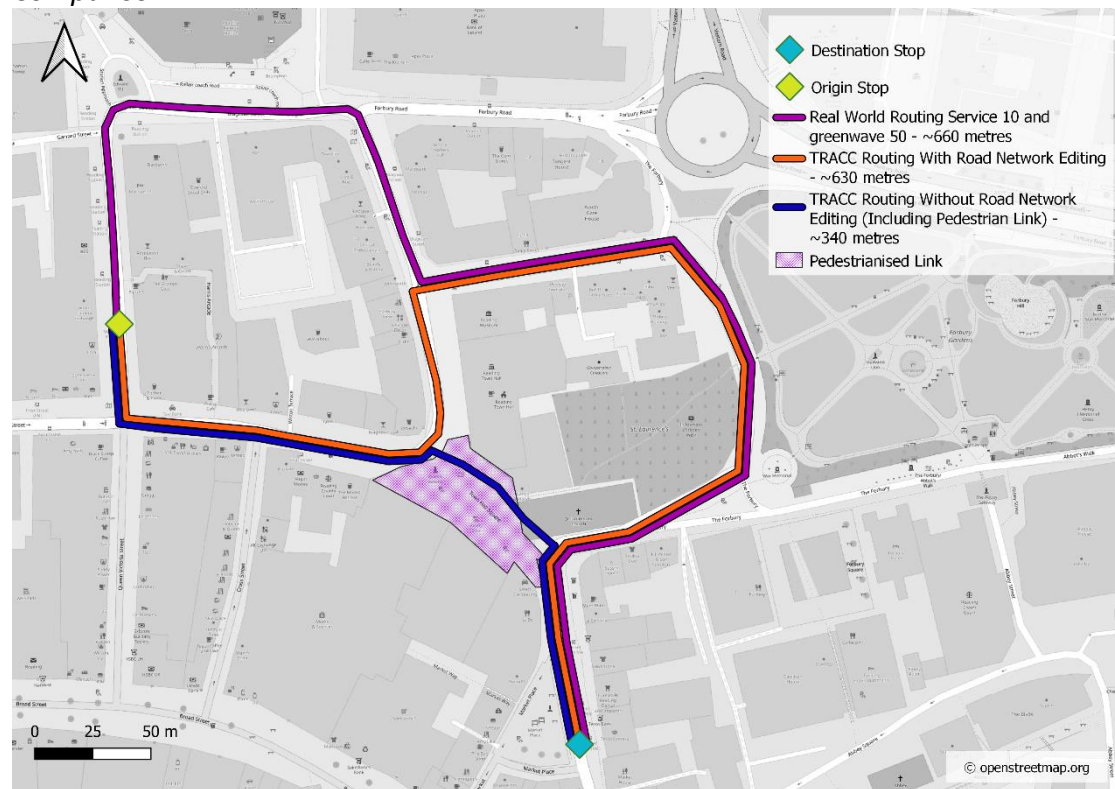
The following assumptions were made, to simplify the process:

- Data obtained from NPTDR, NaPTAN and OS OpenRoads is accurate and up-to-date.
- Buses take the shortest on-road route between origin and destination stop pairs excluding motorways, (i.e., the route assigned by TRACC is reflective of the real-world route taken by buses). Motorways have been excluded due to routing restrictions within TRACC and therefore, it is assumed that bus services do not use motorways. A future refinement could be to exclude any roads from the OS OpenRoads network which are not used by buses. See below.
- NaPTAN bus stops are located on the nearest road link. See below.

Challenges with measuring on-road distance

While the on-road distance measured is generally likely to be an accurate reflection of real-world distance between stops, there are limitations, particularly in town/city centres. Here bus movements are more complex, with bus-only infrastructure such as bus stations, one-way traffic restrictions and streets that are not necessarily suitable for buses. These complexities are not reflected in the OS Open Roads network and therefore not accounted for in this simplified methodology. Additionally, some pedestrianised links are included within the OS Open Roads network. As a result, some on-road distances within town and city centres are likely to be underestimated. Figure 5 shows an example of these limitations.

Figure 5: Reading – Real World and OS Open Roads Network Analysis Tool Route Comparison



A potential solution would be to use a more detailed road network such as OS Mastermap (free to the public sector) which includes directional information, or, to edit the road network to show only useable bus links (more accurate but time-consuming).

Not all NaPTAN stops are located near the road link they are on in the real world. As a result, the bus stops had sometimes snapped to another link such as a nearby residential street. This could increase the measured on-road distance compared to the actual distance.

Additional analysis

Following the estimation of straight line and on-road distance between adjacent stop pairs, potential relationships between the characteristics of an area and its stop spacings were investigated. We then carried out exploratory analysis of local data and compared this to the bus stop spacing. In particular, we considered:

- Bus service frequency: Quarter 4 2022 National Public Transport Data Repository timetables.
- Population density: 2021 Census, TS006 – Population density. Calculations were based on output area population weighted centroids within 400m of the relevant stop.
- Percentage of population over 65: 2021 Census, TS007a – Age by five-year age bands. Calculations were based on output area population weighted centroids within 400m of the relevant stop.

- Town/city centre: Examining stops within town/city centres. Boundaries were created using professional judgement and informed by current town/city centre maps.

Correlation

For each of the factors listed above we calculated the Pearson correlation coefficient to measure the strength of any correlation between two sets of variables. The Pearson correlation coefficient, defined below, returns a score between -1 and 1. A large positive result indicates a strong direct correlation, a large negative result indicates a strong inverse correlation, and values close to zero demonstrate a lack of correlation. The Pearson correlation coefficient (r) is defined below where n is the sample size and x & y are the two variables being compared,

$$r = \frac{n\sum xy - (\sum x * \sum y)}{\sqrt{(n\sum(x^2) - (\sum x)^2)(n\sum(y^2) - (\sum y)^2)}}$$

5.2 Case study locations

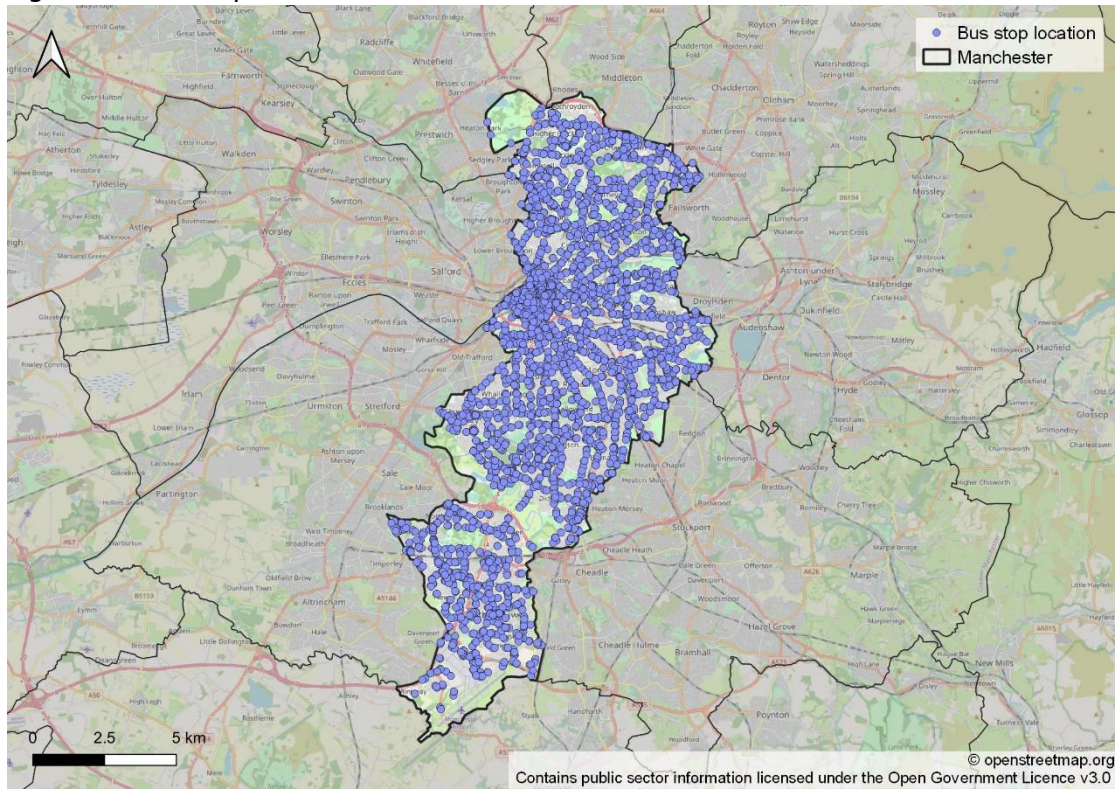
Four case study locations were selected. For consistency and simplicity, we have used the December 2022 Local Authority District boundaries as a proxy for the city and town boundaries. Figure 6 to Figure 9 show the locations of bus stops in each case study area. The map scales are consistent to enable comparison and to highlight the differences between the areas. Future work could consider refining these boundaries to better reflect the cities' urban areas.

Manchester

Manchester was selected as it is located in one of England's largest conurbations and the largest travel to work area (TTWA) by population outside of London. Within Greater Manchester, in the year up to March 2022, there were 121 million bus passenger journeys (Department for Transport, 2022b). It also has a well-established tram system (Metrolink) which, in the same year, carried 26 million passenger journeys (Department for Transport, 2022c).

Figure 6 demonstrates that Manchester district covers just part of the continuous urban area (for example, it does not include area such as Salford and Sale which are included within other districts), but also extends south beyond the M60 to the airport.

Figure 6 – bus stop locations in Manchester district

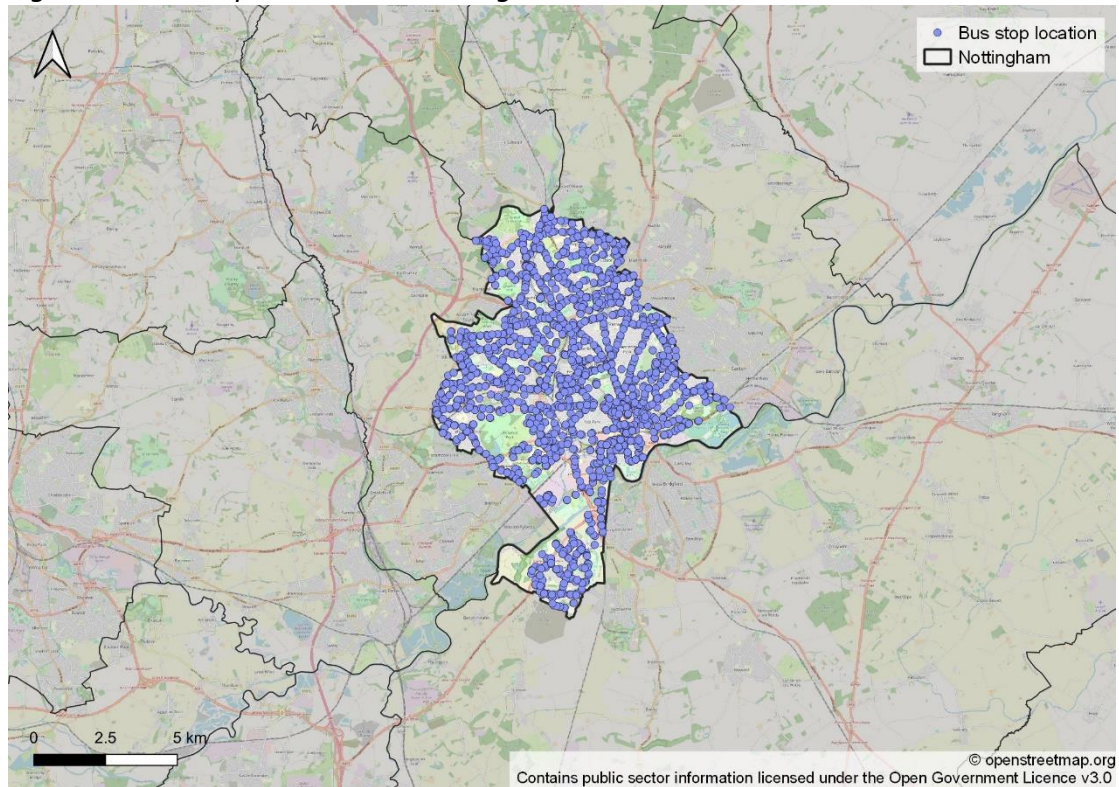


Nottingham

Nottingham is a smaller city that also has a tram network; Nottingham Express Transit saw 9.1 million passenger journeys in the year up to March 2022 (Department for Transport, 2022c). Nottingham’s bus network had 30 million passenger journeys in the same year (Department for Transport, 2022b). The majority of services are operated by Nottingham City Transport, a majority local authority owned bus company. Although not directly explored in this paper, this raises questions of how this different operating model impacts bus service operations.

The district boundary excludes the West Bridgford and Beeston areas, as shown in Figure 7.

Figure 7 – bus stop locations in Nottingham district

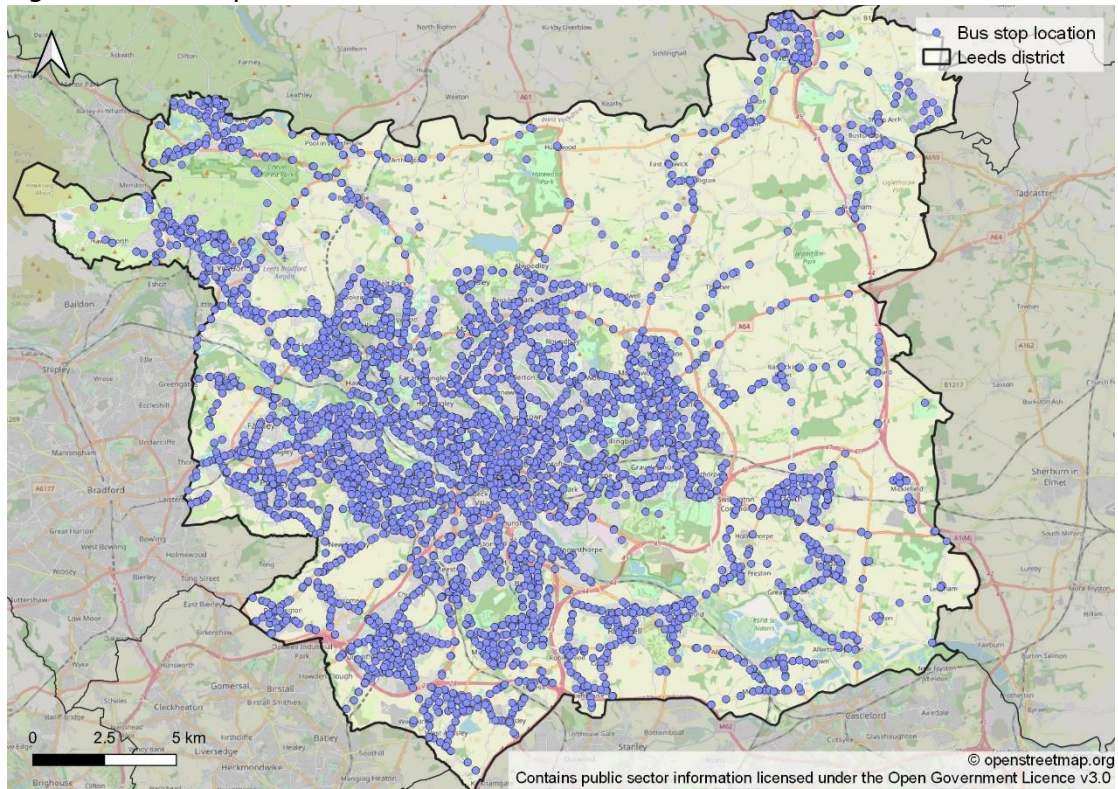


Leeds

Leeds is widely quoted as being the largest UK city without a mass transit network. Residents rely on its bus network for local public transport, alongside the limited local rail services. Across the whole of West Yorkshire, 92 million bus passenger journeys occurred in the year up to March 2022 (Department for Transport, 2022b).

Figure 8 shows that the district boundary contains the city's main urban area as well as a significant suburban / rural perimeter.

Figure 8 – bus stop locations in Leeds district



Reading

Reading is a large town with no tram system. There were 14 million bus journeys in Reading in the year up to March 2022 (Department for Transport, 2022b). Similar to Nottingham, the majority of bus services are operated by Reading Buses which is owned by Reading Borough Council.

Figure 9 shows that there are significant gaps in the urban area within the district boundary which relate to agricultural land water meadows. The district boundary does not include surrounding built-up areas such as Calcot, Sonning, Woodley and Earley.

Figure 9 – bus stop locations in Reading district

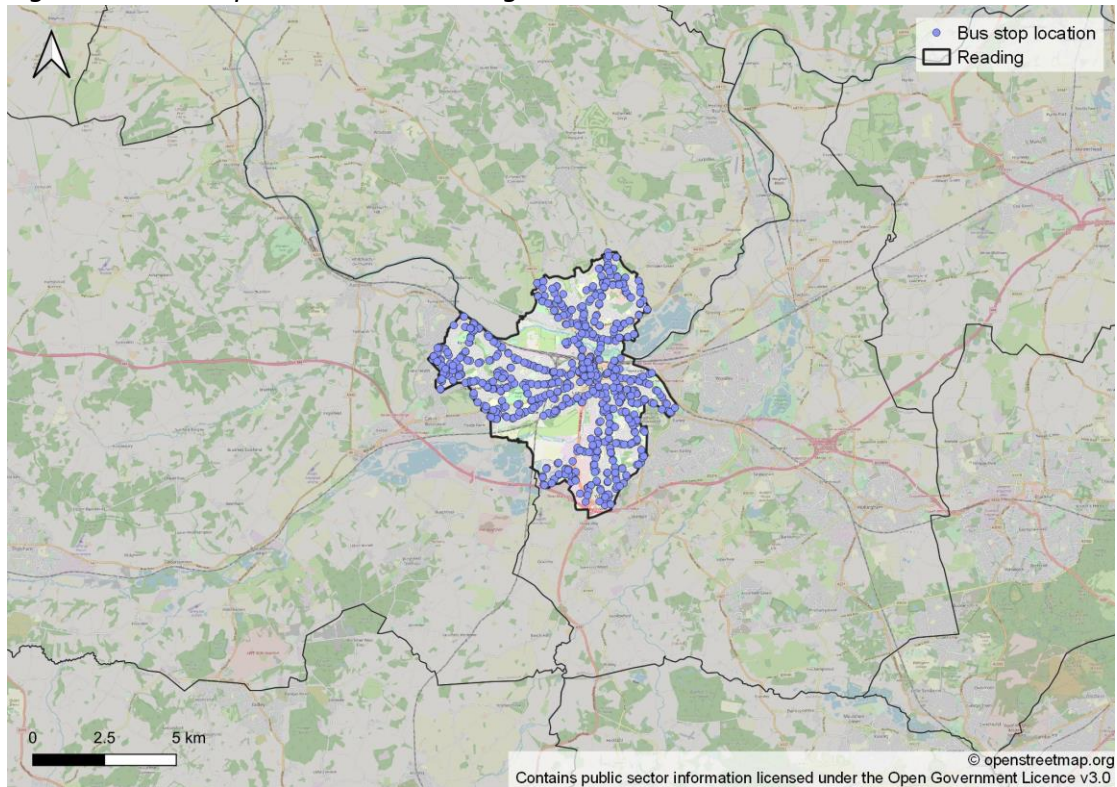
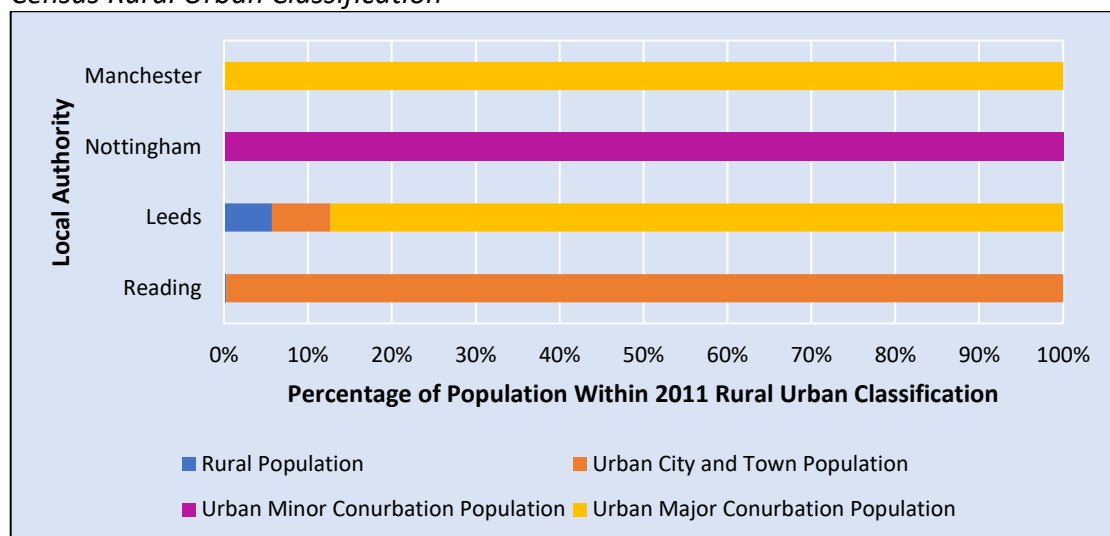


Figure 10 provides further evidence on the urban characteristics of the Local Authority districts analysed. The entire population of Manchester and Nottingham is classified within a single classification: major conurbation and minor conurbation respectively. Reading is almost entirely classified as a city or town, with less than 1% of the population residing in areas classed as rural. Most of Leeds’s population resides within the Leeds urban area but a small proportion are classified within rural areas and other cities/towns. The more rural nature of areas of Leeds may potentially lead to more stops with larger spacing.

Figure 10 – Percentage of Local Authority District Population Within Each 2011 Census Rural Urban Classification



5.3 Results

Figure 11 and Figure 12 show respectively the distribution of straight line and on-road bus stop spacing between consecutive stops, for each of the four locations. Consecutive stops which are more than 1km apart have been omitted from these figures – these cases are likely to represent express services or more rural services with gaps between settlements. For both the straight-line and on-road measures, the distance between stop-pairs most commonly falls between 100m and 400m across all cities as evidenced by the histogram peaks shown below.

While the same general trend emerges in each city, there is some variation between them. The mode stop spacing is lowest in Nottingham and highest in Reading. Reading also shows the least variance in spacing, while Leeds has the highest. As discussed in section 5.2, the high variation in bus stop spacing observed in Leeds is likely a reflection of the district boundary and the greater rurality compared to the other locations analysed.

Table 3 shows the percentage of consecutive stops which are separated by less than 200m, 200-400m, 400m-600m, or more than 600m – highlighting the observations discussed above.

Between 56-61% of bus stop pairs have spacing within the 200-400m range suggested in the guidance; 14-23% have spacing of less than 200m, and 20-30% have spacing of greater than 400m.

Figure 11: Smoothed histogram of straight-line distance (m) between bus stop pairs

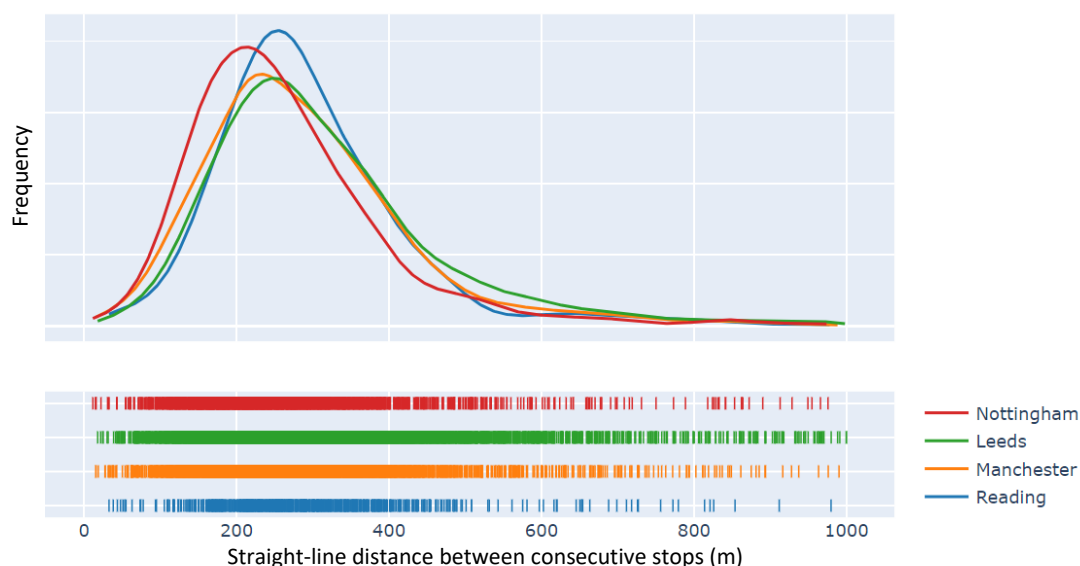


Figure 12: Smoothed histogram of on-road distance (m) between bus stop pairs

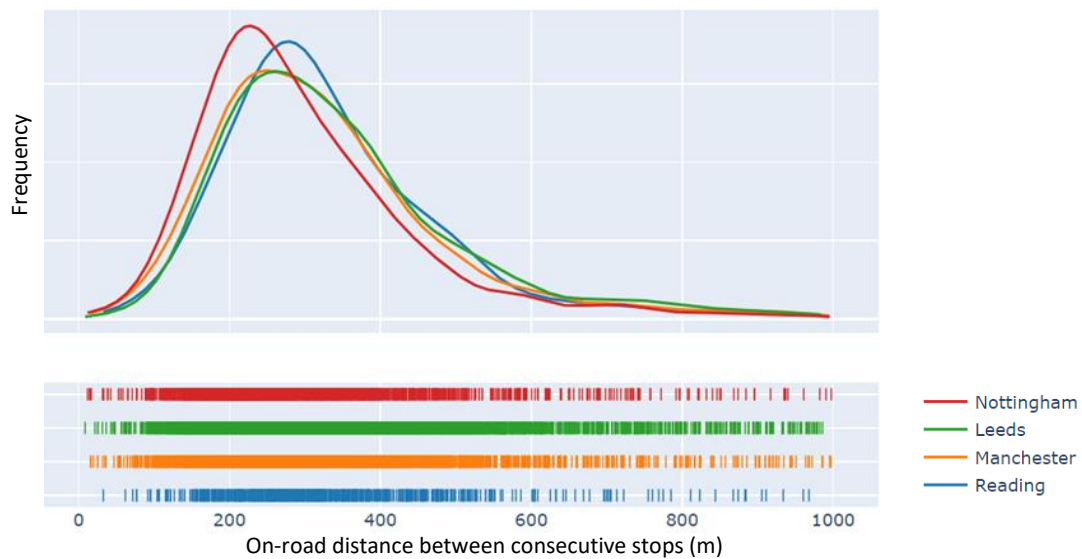


Table 3: Summary of on-road bus stop spacing by 200m distance bins

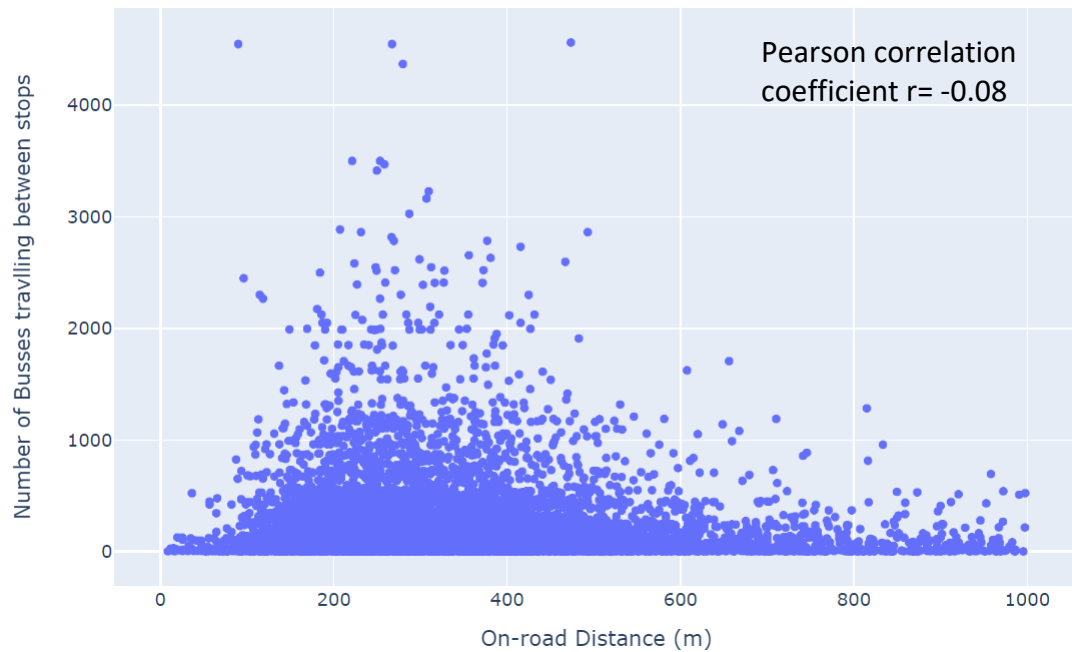
	Percentage of bus stops with on-road spacing of:			
	0-200m	200-400m	400-600m	>600m
Leeds	14.5%	55.8%	19.2%	10.5%
Manchester	18.4%	56.3%	17.1%	8.2%
Nottingham	22.8%	57.7%	12.8%	6.7%
Reading	13.6%	60.5%	18.8%	7.5%

As noted in Table 2, existing guidance suggests that there are a number of factors which might be expected to influence bus stop spacing. The following subsections summarise our findings with respect to bus service frequency, population density, proportion of elderly population and location in a town/city centre.

Bus service frequency

Figure 13 plots bus frequency against bus stop spacing. Guidance suggests that people may be willing to walk further to services with a higher frequency, potentially leading to a need for fewer bus stops and therefore wider spacing. However, we found no correlation between frequency and spacing in the case study locations.

Figure 13: Scatterplot of bus frequency against distance between stop pairs for all cities



Population density

Figure 14 shows the relationship between population density and on-road distance between bus stops across all four case study locations. Again, there is no correlation between the two features. Figure 15 to Figure 18 show the population density (by 2021 Census output area) overlaid with the bus stop locations.

While the data does not show any clear overall correlation relating to *spacing between consecutive bus stops*, it is evident from the maps that there are very few bus stops in the least populated areas.

Figure 14: Scatterplot of population density against distance between stop pairs for all cities

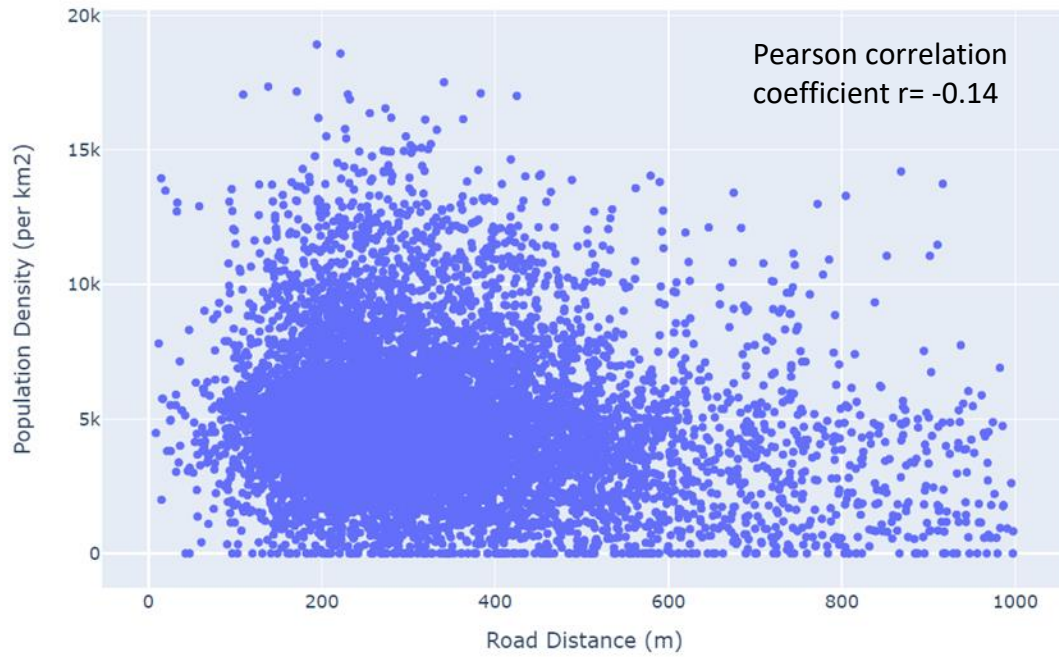


Figure 15: Leeds – population density and bus stop locations



Figure 16: Manchester – population density and bus stop locations

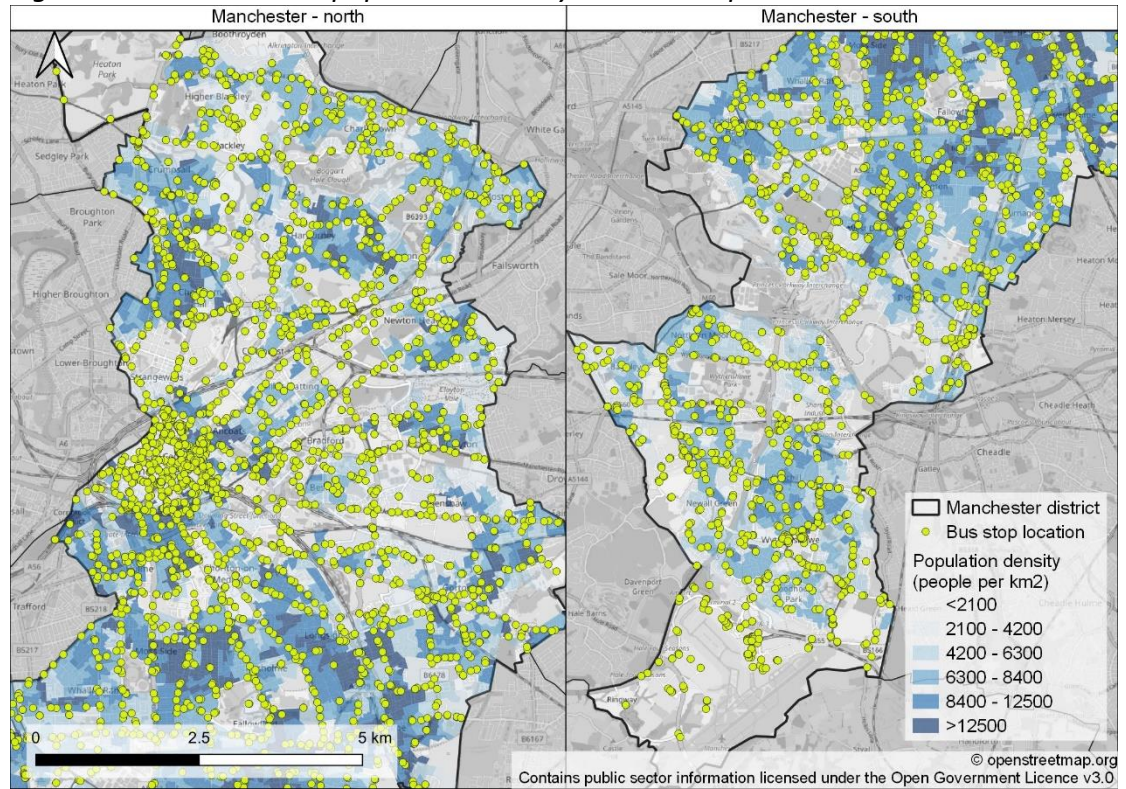


Figure 17: Nottingham – population density and bus stop locations

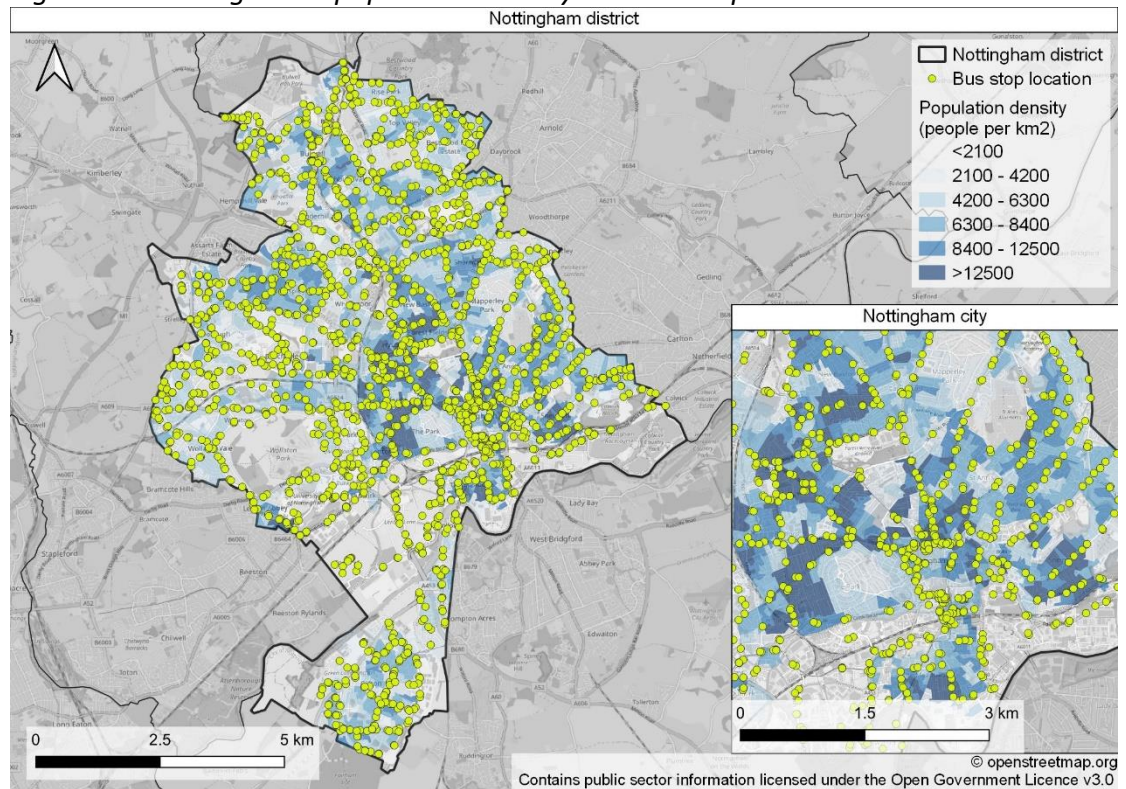
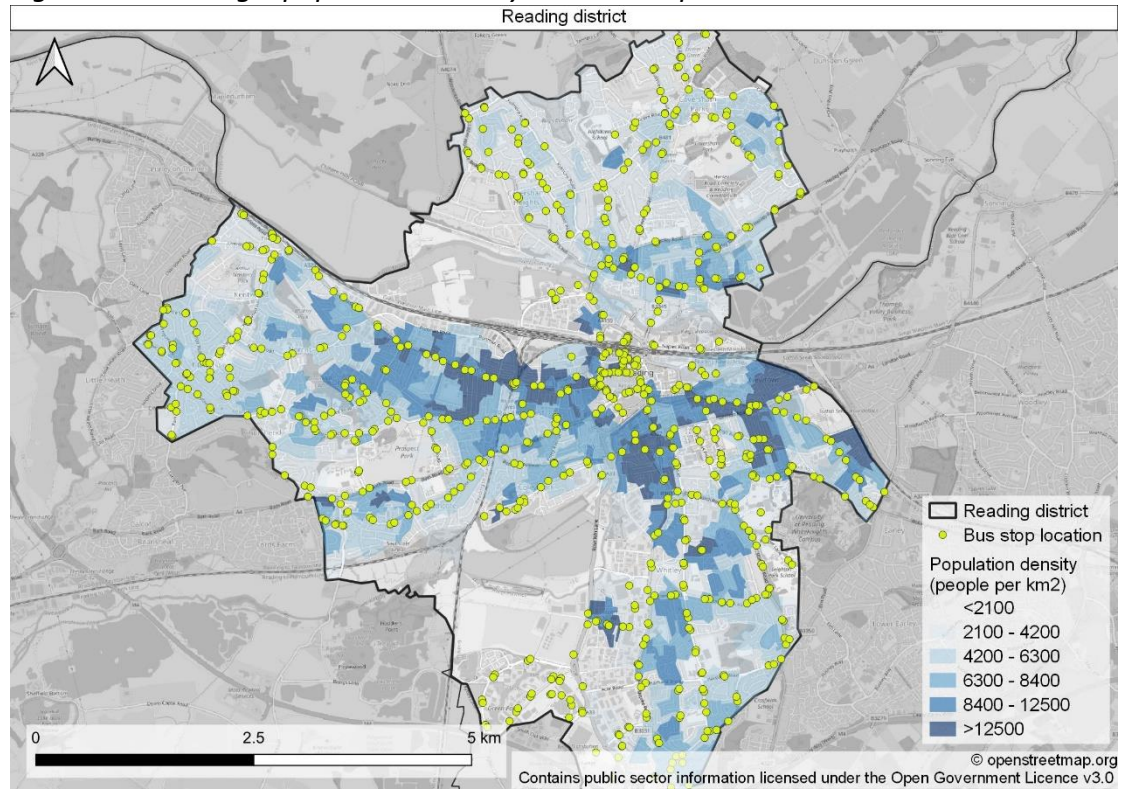


Figure 18: Reading – population density and bus stop locations



Proportion of elderly population

Figure 19 shows the relationship between the proportion of the population over 65 years old and on-road distance between bus stops across the four case study locations. Again, there is no evidence of correlation.

Figure 20 to Figure 23 show the percentage of over-65s (by 2021 output area) overlaid with the bus stop locations. Across all four case study locations, the proportion of over-65s appears to be higher on the outskirts of the town / city. When comparing to the population density maps, it can be seen that these areas with higher proportions of over-65s often have lower population densities.

Figure 19: Scatterplot of elderly population against distance between stop pairs for all cities



Figure 20: Leeds – elderly population density and bus stop locations

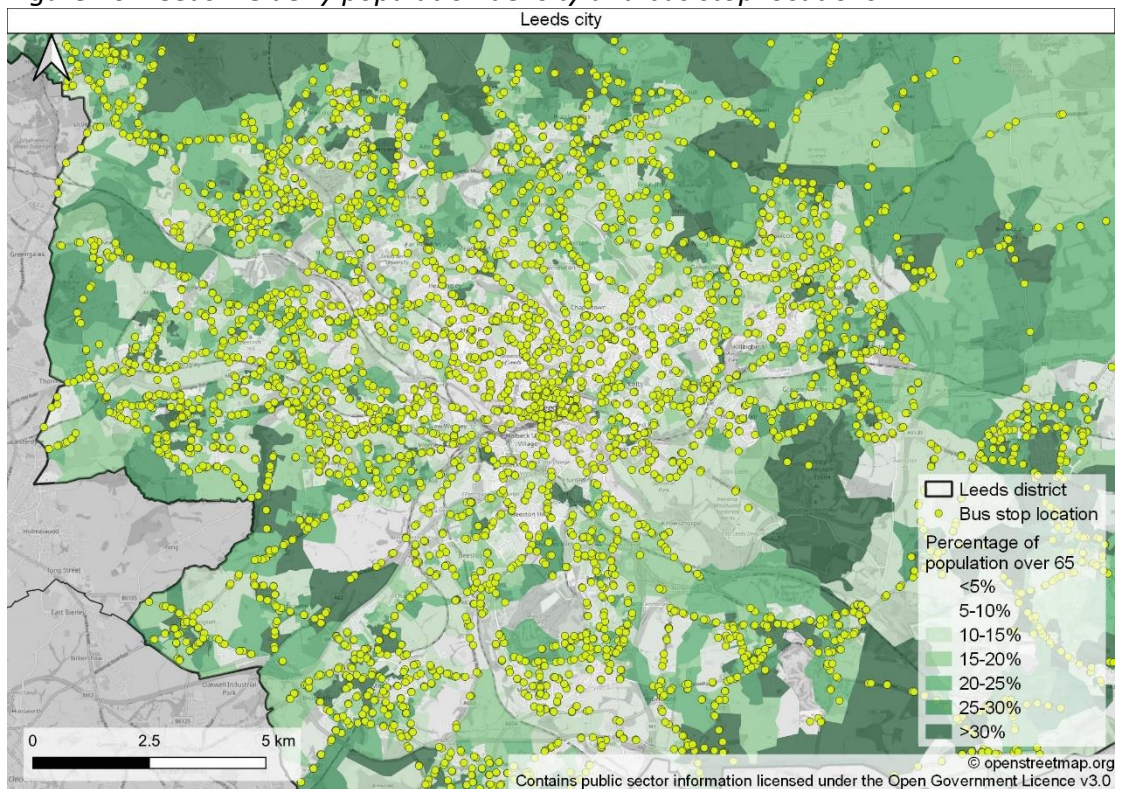


Figure 21: Manchester – elderly population density and bus stop locations

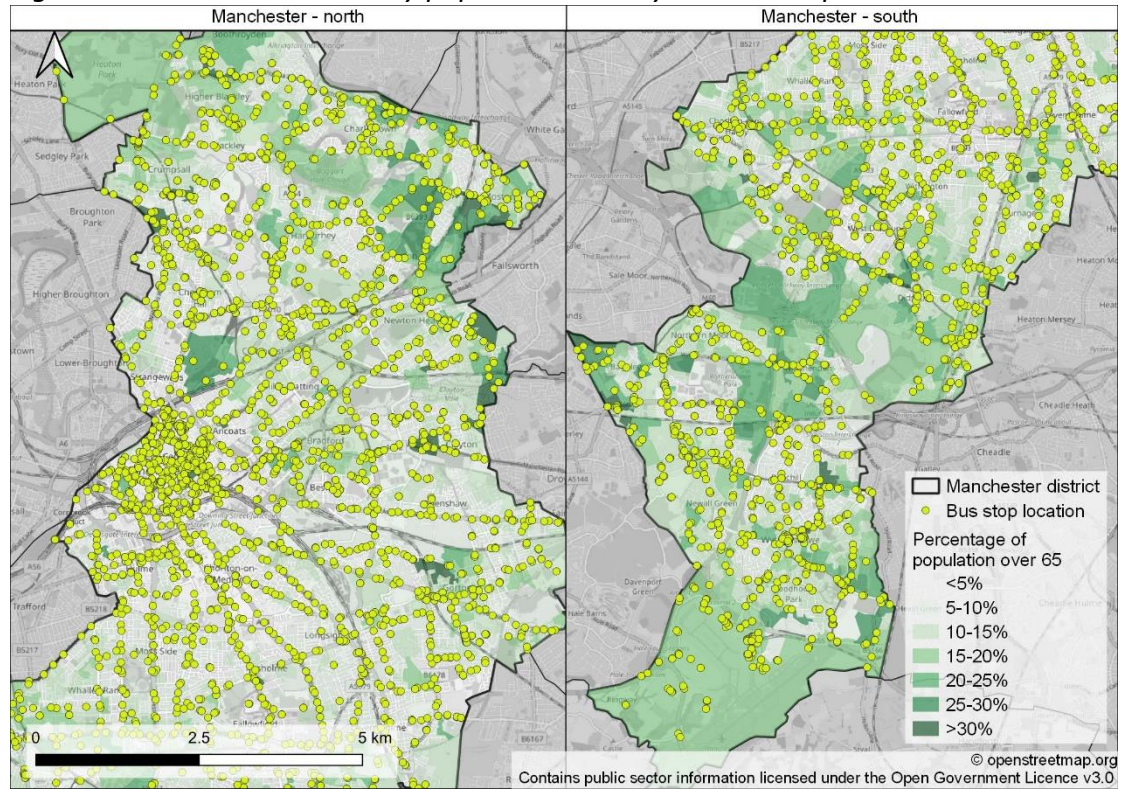


Figure 22: Nottingham – elderly population density and bus stop locations

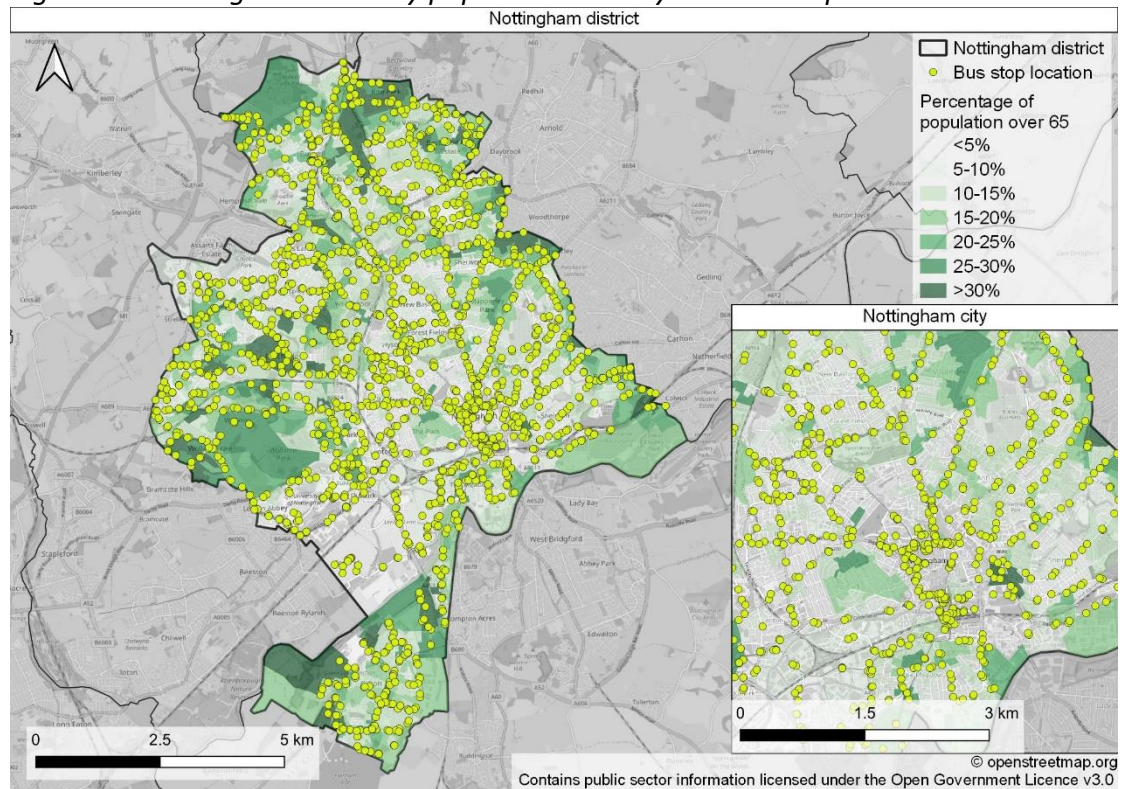
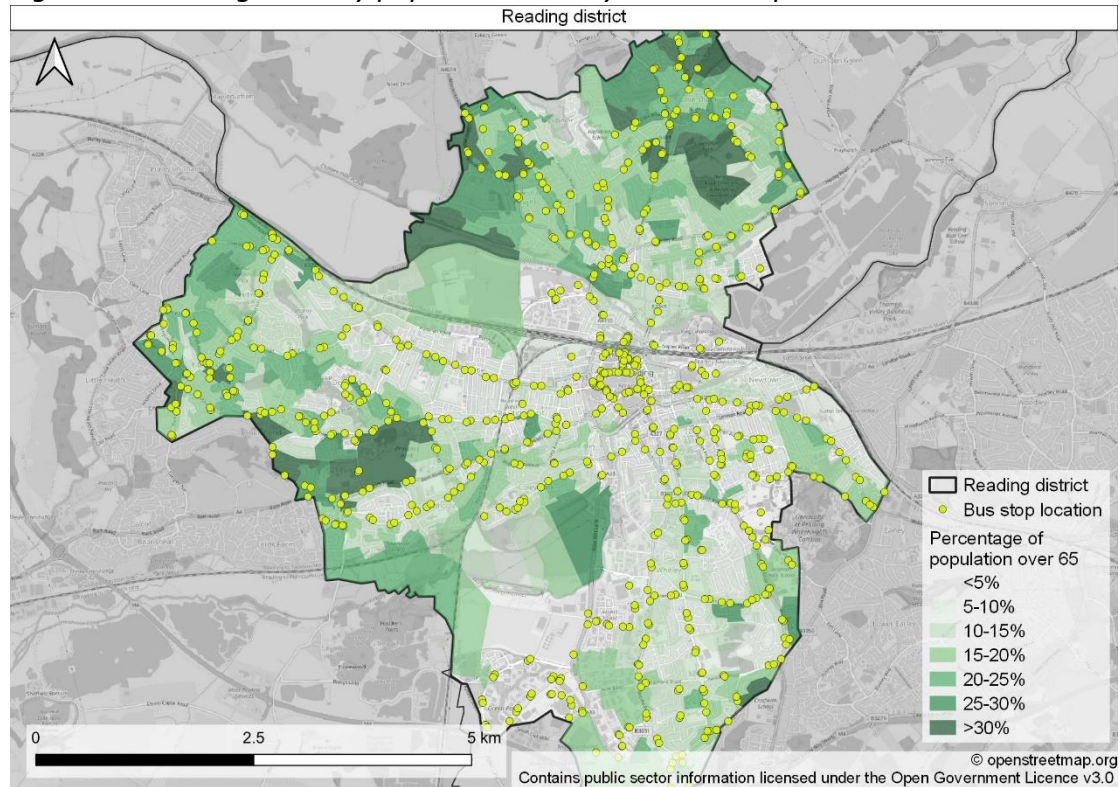


Figure 23: Reading – elderly population density and bus stop locations



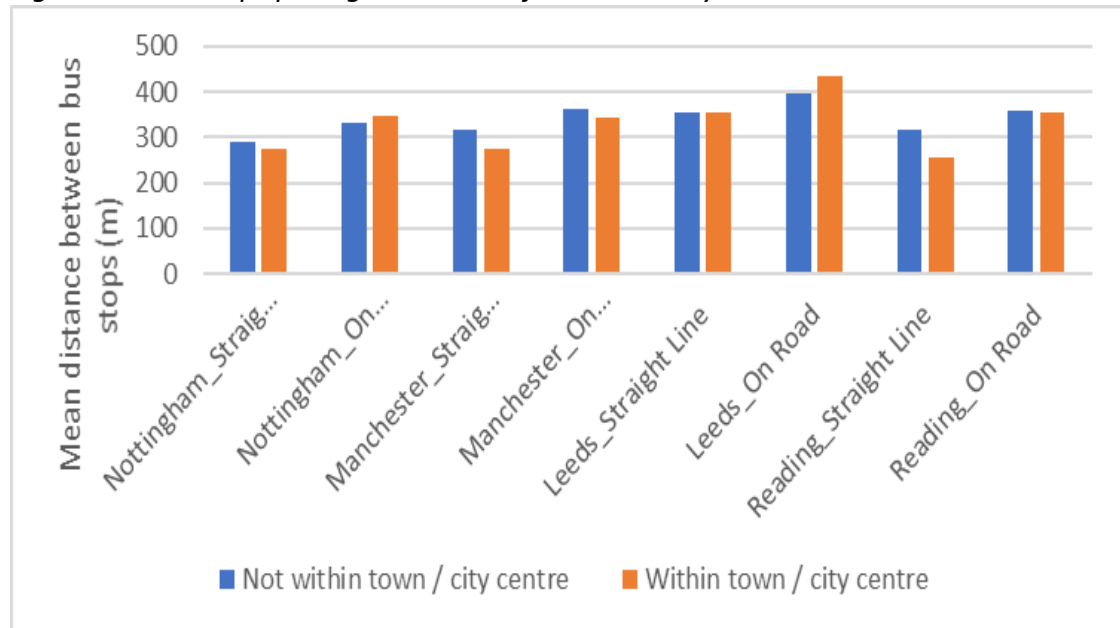
Town or city centre location

Guidance advises that it may be appropriate to space bus stops more closely in town and city centres, given the higher levels of demand and larger density of potential trip attractors.

Figure 24 compares the distance between adjacent bus stops for town/city centre versus non-town/city centre areas. Considering straight line distance only, it would appear that bus stops may be generally slightly closer together in our case study town/city centres. Guidance suggests that spacing should be closer in town/city centres, with only *Transport in the Urban Environment* (The Institution of Highways & Transportation, 1997) specifying a spacing recommendation (no more than 300m). The mean straight line distance for consecutive stops in Nottingham, Manchester and Reading centres is indeed below 300m. There does not appear to be any difference in straight line distance between consecutive bus stops within Leeds city centre compared the rest of the district.

However, when considering on-road distance, bus stops appear to be spaced further apart in two out of the four case study town/city centre locations, and the mean spacing is above the recommended 300m in all cases. This is likely to be related to methodological challenges with estimating on-road distance described in section 5.1, outlined in Figure 5 and the subsequent discussion as well as the complex nature of bus routes within town/city centres.

Figure 24: Bus stop spacing in and out of town and city centres

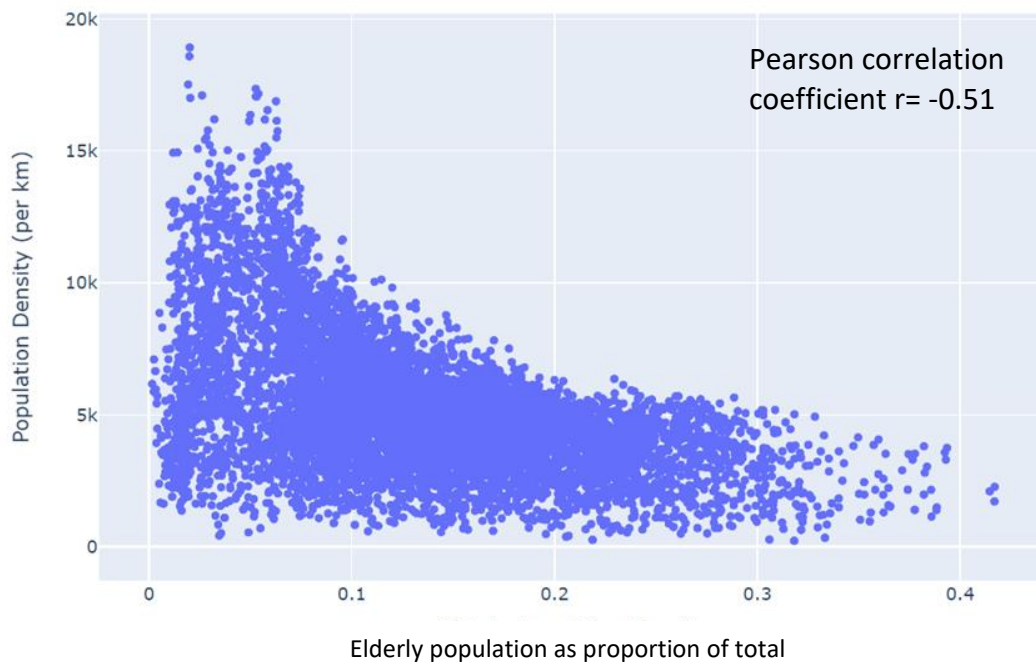


6 DISCUSSION

Our results demonstrate several things. Firstly, for each of the cities we have studied, between 56-61% of bus stop pairs have spacing within the 200-400m range suggested in the guidance; 14-23% have spacing of less than 200m, and 20-30% have spacing of greater than 400m. The same patterns emerge across each of our case studies – despite the inherent differences between each.

Additionally, for each continuous feature we studied – bus frequency, population density and elderly population rates – there is no observable correlation. This highlights the complexity of the real-world situation. In particular, there are interactions between the factors considered which all, in theory, could result in a need for a higher density of bus stops. For example, the proportion of elderly population appears to be higher in areas which are generally lower in overall population density. This is demonstrated in Figure 25 below – the only statistically significant correlation of this study appears in this case.

Figure 25: Scatterplot of elderly population density against overall population density



This raises an interesting question for bus stop spacing: if an area has a low population density but high proportion of elderly residents – as is often the case – which of these factors takes priority? Our research suggests that the situation is complex with competing priorities at play. There is no clear overall winner. There may be some instances where, for example, a high proportion of elderly population drives the need for closer bus stop spacing, but this is not evident over a whole city.

7 CONCLUSION

This paper summarises the existing guidance relating to bus stop spacing in England. The recommended spacing generally falls within the 200-400m range, although different guidance documents highlight different factors which may contribute to a need flex this acceptable range in either direction.

We have developed a methodology for determining whether current practice reflects the guidance, and used this method to assess four case study locations. The results show that between 55% and 60% of bus stops in each of the four case study locations have an on-road distance of between 200-400m, and the majority of the remainder have spacing either between 100-200m or 400-600m; less than 11% are more than 600m apart. We have looked into how some key factors highlighted in the guidance (service frequency, high population density, high percentage of elderly people and location in a town/city centre) may currently be affecting bus stop spacing. Of these factors, only location in a town/city centre appeared to be significantly affecting the spacing.

Decisions around bus stop spacing are influenced by the need to strike a balance between:

- minimising walking distance and maximising accessibility – pushing towards a greater number of more closely spaced stops, and
- improving bus journey times – pushing towards fewer, more spread out stops.

As outlined earlier in this paper, this is a pertinent issue; at least two UK cities have recently looked at reducing the number of bus stops in order to improve in-vehicle journey times, reliability and viability of bus services. Local bus networks are key to mobility; in light of the climate emergency and growing awareness of social inequalities, they are becoming increasingly important. As transport planners endeavour to shift the public's reliance on private cars onto more sustainable modes, we must consider how to improve public transport's accessibility, attractiveness and efficiency.

The methodology set out in this paper could be used as a starting point for transport authorities, operators or other stakeholders to identify potential areas for intervention. For example, it could be used to highlight areas where bus stops are located further apart than average and therefore may be missing out on catchments. Conversely, it could be used to identify areas where there may be scope to reduce the number of bus stops with minimal impact on accessibility, and drive improvements to in-vehicle journey times and bus reliability.

7.1 Further questions for practitioners and researchers

We invite practitioners and researchers to use and build upon this method, to investigate stop spacing in other urban areas, and extend the work to other public transport modes. We also invite them to consider the wider questions set out below:

Practice

- Do other urban areas show similar results to our case studies?
- Do different places have different patterns of stop spacing? If so, how and why?
- Do different types of area have different patterns? If so, how and why? Can these be traced back to different urban forms, or different philosophies / guidance at different eras of development?
- Overall, what is the national picture, and how closely does current spacing match current guidance?
- To what extent have the nuances of departing from the traditional 'headline' 400m walk distance fed into practice?

The theory and the guidance

- Is there a consensus on best practice?
- To what extent does the guidance *reflect* practice or *lead* it?
- To what extent is the CIHT 2018 guidance – particularly its range of acceptable walk distances in different situations – accepted in the

profession? Does it reflect current practice, or point towards a change in practice?

- What is the strength of the evidence or analytical base for the guidance – both the ‘headline’ figures such as the 400m walk distance, and nuances such as having a closer stop spacing in more densely populated areas?
- To what extent have local highway and transport authorities followed the national guidance or developed their own, differing guidance?
- How does English guidance and practice compare with other UK nations and internationally?
- What are the implications of the earlier research on actual walk distances, described in section 2.1? Do people walk further than they would like, or would consider acceptable, because of where the stops are?

Reasons

- What is the impact of urban form, street layout and pedestrian permeability? What stop spacing (linear or mesh) would be needed to ensure dwellings are within the target walk distance of stops, in different types of neighbourhood? Does practice reflect this?
- To what extent do other highway design considerations influence bus stop spacing, or vice versa?
- What impact does the local highway authority's role have in bus stop spacing? Do different areas have different policies or historical inheritances?
- Are people willing to walk further to a light rail stop than a bus stop and, if so, why? Does this match the guidance?
- Does having a dense rail network affect bus stop spacing?
- If it is acceptable or preferable for a network to have more widely-spaced but more frequent routes, is it equally acceptable to have more widely-spaced stops along each route? Or does a close stop spacing help to make a wide route-spacing acceptable?

Potential change

- Are there certain types of area where the *siting* constraints are so great as to in effect dictate the actual *spacing*, or at least make it difficult to change? If so, how would this affect any potential review of spacing?
- Do contemporary expectations on bus stop accessibility and amenities point towards ‘fewer, better’ stops, as a matter of practicality in a time of limited budgets and competing demands for kerb and footway space? Or is more attention required to the needs of people who can only walk short distances?
- Is there a general need to review existing bus stop spacing, in the way that was identified in Birmingham, Edinburgh and Belfast (section 2.1)? If so, does this apply to any types of area in particular?
- If there is such a need, is it because practice has departed from the correct balance, or because the correct balance has changed?

- If there is such a need, what would be the value of doing so, relative to other priorities? How deliverable would any change be, and what would be the scale of the value compared to the cost?
- Is an updated analytical assessment needed of the best spacing for different circumstances, to confirm or amend current guidance?

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