National Infrastructure Commission

Cambridge-Milton Keynes-Oxford Corridor

Transport workstream

Report

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Metro Dynamics

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Executive Summary

In March 2016, the former Chancellor of the Exchequer asked the National Infrastructure Commission (NIC) to:

> "… make recommendations to maximise the potential of the Cambridge–Milton Keynes–Oxford corridor as a single, knowledge intensive cluster that competes on the global stage, whilst protecting the area's high quality environment and securing the homes and jobs the area needs.
>
> The Commission will look at the priority infrastructure improvements needed and assess the economic case for which investments would generate the most growth."

The Commission organised a Call for Evidence on the subject during the summer of 2016, and received responses from Local Enterprise Partnerships, local authorities, universities and other organisations. Following this, Arup, Savills and MetroDynamics were commissioned to investigate transportation infrastructure and its interaction with housing, finance and economic activity (for which Cambridge Econometrics were engaged by the Commission), across the Cambridge–Milton Keynes–Oxford corridor (the CaMkOx corridor, or the study area). We were asked to produce a contextual overview of:

- Current transport use.
- Mapping of the strategic and economic cases for transport investment in the corridor, and a reflection on how these cases meet the identified challenges.
- Beyond the immediate investments, a view of a future transport package for the corridor which includes "incremental" and "transformational" outcomes.
- A focus on the contribution that transport can make to unlocking housing sites, and the opportunities for agglomeration benefits.

The timescales for the investment packages was determined by the NIC to be the period to 2050. We reported our draft findings in November 2016, ahead of the publication of the Commission's own report. This document represents our final report.

Current transport use

There are presently four relatively self-contained labour market areas within the study area (Swindon, Oxford, the central area of Milton Keynes – Northampton – Bedford – Wellingborough, and Cambridge), with Swindon the most distant in geographical terms, and in terms of its economic interaction with the others. Oxford and Cambridge have particularly knowledge-based economies. Separately, there is a degree of interaction with the London labour market, with the towns to the south of the study area having a stronger inter-relationship with London than those to the north.

This limited labour market interaction across the Corridor appears to be due in part to the physical distances, the size of the towns and the poor quality of orbital

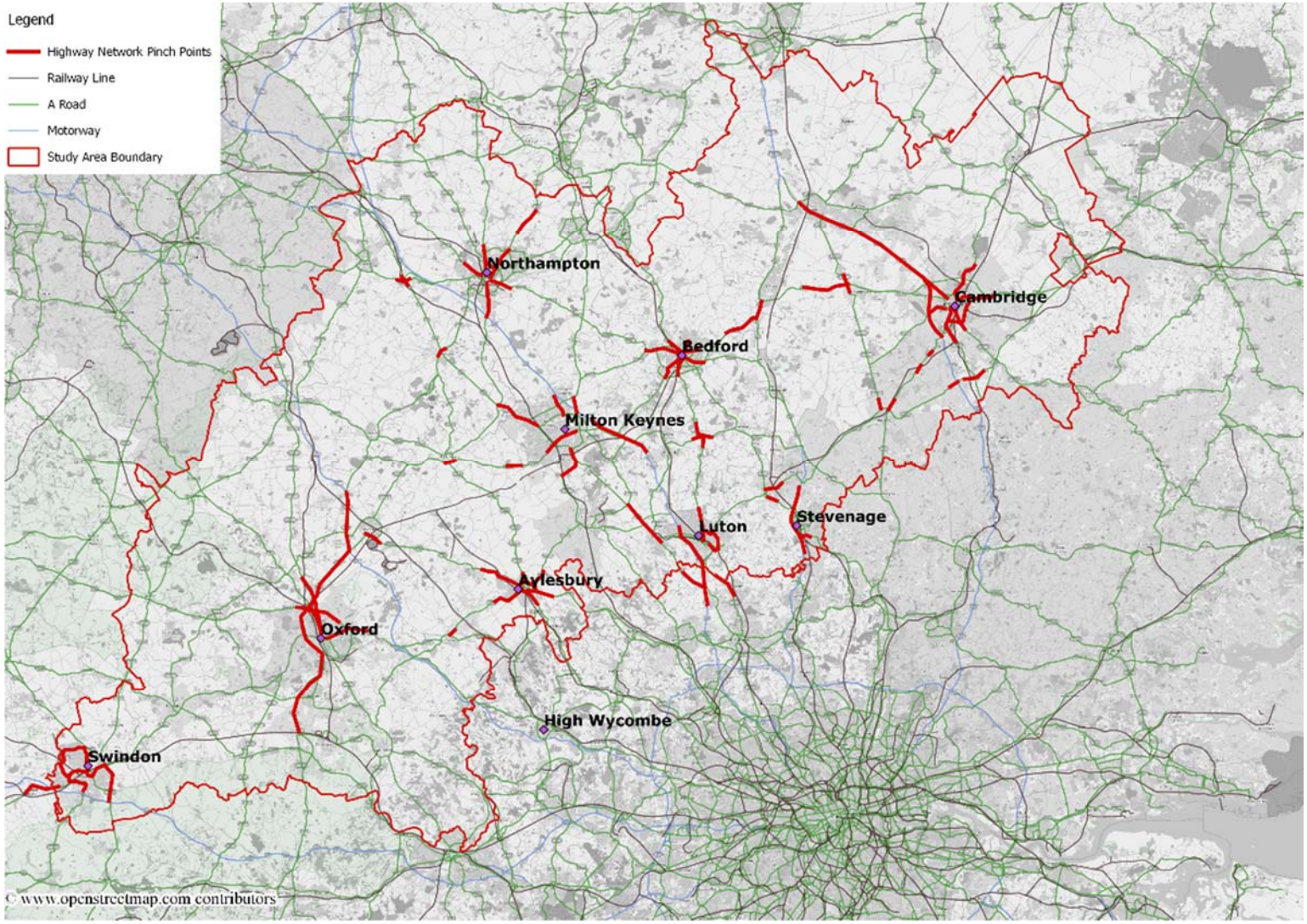
links. For example, many road links have relatively little separation of local and interurban traffic with long journey times as a result. Furthermore, although the western leg of East West Rail is under construction, there is presently no direct rail link across the corridor. Many rail journeys are therefore best undertaken via London or via interchanges in locations to the north of the corridor. By contrast, the transport links between the towns within the corridor and London are of relatively higher quality, and have higher-than-average speeds, but suffer from overcrowding and congestion.

These factors help to explain why urban areas draw most of their labour from the immediately surrounding vicinities. The most concentrated catchment areas are around the knowledge-based clusters of Oxford and Cambridge, which are both tightly bounded and currently perceived as overheating. The Milton Keynes – Northampton – Bedford – Wellingborough area is larger and has more labour market interaction between its major settlements, reflective of the better transport links between those towns.

In common with many other towns and cities, journeys from suburb to centre within the study area suffer from road congestion, which is at its worst at the points where the intra-urban road network meets the inter-urban road network. Whilst the bus network in the towns, particularly in Oxford and Cambridge, is well used, the limited segregation from general traffic means that it is often susceptible to delays.

Some of the consultation responses received by the NIC suggest that congestion is becoming a threat to economic investment, as well as to air quality and to quality of life. Together with the poor interurban links, it is also potentially a threat to creating a single knowledge intensive cluster, as envisioned by the former Chancellor. In this way, further economic growth may be limited by the increasing demand placed on transport links and the need for good quality housing provision that is affordable and in the right places, connected to job opportunities and sustainable communities.

Figure 1: Highway network peak time pinch points



Source: Open street map, Arup, Local Transport Plans, DfT

Drivers for change

Future employment, housing and population growth are likely to place additional strain on existing transport infrastructure in the period to 2050. In a similar way, provision of transport infrastructure will create economic opportunities and will contribute to unlocking housing sites. We worked iteratively with Cambridge Econometrics and Savills to understand the future patterns of economic activity, job creation, population and housing growth - and developed transport packages that support, enable and respond to the challenges of these potential futures.

Future job growth is projected to be focussed on Milton Keynes, as well as the knowledge based centres of Cambridge and Oxford, suggesting that areas approaching town centres are likely to become particularly congested if left unchecked. The transformational case suggests additional pressure on commuting routes arising from an increase in movements of up to 61% compared to the existing situation, and will need to respond to this (with the highest growth is in the Milton Keynes area).

Table 1: Commuting Projections to 2050 – sub regions and study area

Transformational scenario	2011 Commuting movements	2050 Projected movements	2050 (% increase on 2011)
Oxford-Swindon area	723,000	1,079,000	**49%**
Greater Northampton area	369,000	538,000	**46%**
Greater Cambridge-Northern Hertfordshire area	612,000	939,000	**53%**
Milton Keynes-Bedfordshire-Aylesbury Vale area	794,000	1,275,000	**61%**
Total	**2,498,000**	**3,831,000**	**53%**

Source: Arup, ONS

There is also a need to improve capacity and connectivity to underpin further employment growth – both generally and specifically in higher productivity and higher value added knowledge intensive sectors.

Investment must also ensure that transport infrastructure is in place to allow for housing growth at existing sites and at new locations. Finally, there is a need for improving the capacity of the transport system to cope with associated with movement at a national scale.

Future transport packages

The observation that inter-urban links are poor does not necessarily lead to a conclusion that significant upgrades would have significant economic benefits. Whilst previous evidence suggests that transport is most likely to deliver catalytic change when it assists in unlocking identified constraints to growth, our work examining the current transport situation suggests that the worst pinch points are on urban networks, with less evidence of problems on inter-urban routes (although journey times remain long, and so the lack of congestion may be partially

reflective of a lack of use). As such, it is challenging to determine what the economic interactions might look like if new transport links were provided.

Nevertheless, our strategies suggest focussing on lifting the major constraints to the extent possible – this means targeting existing urban transport pinch points first, to create better access to the future employment opportunities in the major town centres, together with transport investments that open up housing and employment land opportunities (the most obvious constraints, and the building blocks for growth). The prioritisation of the unlocking of existing constraints (links to employment opportunities and deliver housing at scale) would be expected to deliver the fastest benefits. This is backed up by our quantitative assessment which suggests that intra-urban investments within economically successful areas, and extra-urban investments between centres that are more close together have the potential to generate significant agglomeration benefits.

The scenarios have been determined cumulatively, which means the costs in the incremental scenario include those from the baseline scenario as well as those unique to the incremental schemes, and the costs in the transformational scenario include those from both the baseline and incremental scenarios, as well as those from transformational schemes. A summary of the split between national and local spending on transport schemes, and of the scenarios, is provided below in Table 2.

Table 2: Summary of transport capital costs, by scenario

Transport investment package - Summary	Cost (£ bn)	Cumulative Cost (£ bn)
Baseline scenario	12.5	12.5
of which national schemes	10.5	10.5
local schemes	2.0	2.0
Incremental scenario	+44.1	56.7
of which national schemes (including Crossrail 2)	41.8	52.3
local schemes	2.3	4.3
Transformational scenario	+56.6	113.2
of which national schemes (including HS2)	55.4	107.7
local schemes	1.2	5.5

Source: Arup

Baseline scenario

The schemes identified as part of this scenario represent a prospective future in which a minimum level of transport intervention is delivered to improve the corridor's infrastructure provision required to enable and service from the baseline population and jobs growth. These schemes have already been committed in local and regional plans, strategies and other documents, and they will go some way towards freeing existing constraints and encouraging housing investment in the corridor. This includes road improvements and other small schemes targeted at pinch points on the network. Transport spending in the region of £13 billion would provide this infrastructure. Later in our report, the interventions are disaggregated to packages for the key urban centres to respond to the housing and

employment projections, as well as an inter-urban package and a package for radial routes to support economic growth across the corridor. Transport spending of just under £13 billion[1] would provide this infrastructure of which national schemes account for c. £10.5 billion (84%) and local schemes the remaining £2.0 billion (16%).

Incremental scenario

The incremental scenario has population in the study area growing faster than the national rate. Current plans go some way to alleviating transport issues in certain areas but there is an infrastructure gap associated with the delivery of current plans. Given our high level analysis there appear to be sound strategic cases for going above the baseline level of investment to provide infrastructure that underpins local employment and residential site development opportunities. Housing and transport infrastructure provision in the corridor is therefore expected to relieve or reduce several of the key employment constraints without representing a major shift in labour productivity or the economic geography of the corridor.

Our incremental scenario addresses this; by focussing on the areas of growth (the major towns and cities, and particularly Milton Keynes) we provide access to current and future employment opportunities and maximising labour agglomeration impacts of growth. We also include East West Rail's central section, the Expressway and bus-based rapid transit schemes in the larger towns and cities. In order to address traffic congestion more aggressively and to secure new journey opportunities, economic growth, housing delivery at higher rates than assumed in the baseline. The transport package responds to and enables faster rates of employment and population growth with a further £12 billion investment (plus a further £32 billion for Crossrail 2), to a total of some £57 billion (only a portion of the Crossrail 2 spending and benefits would apply to the region). Of the additional c£12 billion, c£9.8bn (81%) has been classed as national scheme expenditure. Local schemes account for the remaining £2.2bn. Cumulatively, national schemes account for 92% of the costs in the incremental scenario, with local schemes accounting for 8%.

Transformational scenario

The transformational scenario addresses the idea that the corridor is a globally competitive knowledge cluster with excellent connectivity, moderate to high levels of commuting and collaboration, all while reducing the gravitational pull of London. This would require radical levels of transport investment, including a focus on urban mass transit and further upgrades to East West Rail, to a metro-style service.

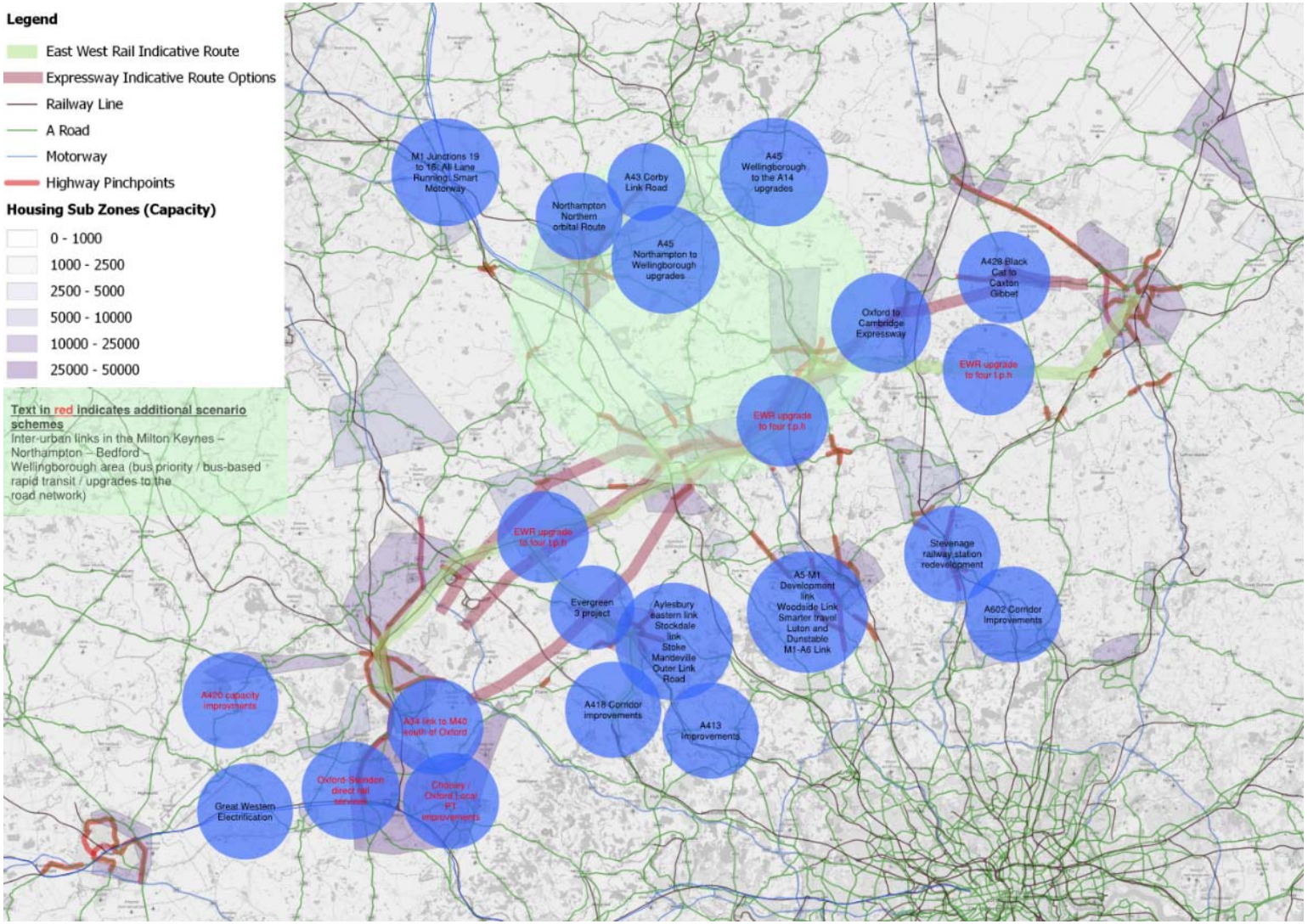
Our assessment suggests that the level of spend within the corridor that would be needed to realise its transformational potential is a focus on responding to and enabling the faster rate of growth through more significant mass transit

[1] Costs are typically assumed to be in 2015/16 prices. However due to the nature of some of the sources used, estimates throughout this report should be considered to be no more than indicative not least because in some instances base years may differ from 2015/16 (eg where no year was cited in source documentation).

interventions. The investment required is significant at a further £1.6 billion (plus the cost of the capacity release on HS2, the total scheme cost of which is £55 billion), to a total of some £113 billion in transport (although only a portion of the costs and benefits of HS2 would apply to the corridor). In order to fully realise the benefits of this, potentially higher levels of investment may be required in other sectors. This package would go some way to achieving the former Chancellor's ambition of a single, knowledge-intensive cluster that competes on a global stage.

In the transformational scenario it is envisaged that the corridor becomes a globally competitive knowledge cluster enjoying excellent connectivity, including further investments in rapid transit and further upgrades to East West Rail to offer a metro-style service. Our assessment suggests that the level of expenditure on local projects is some £1.2 billion (£1.4bn if East West upgrades are considered to be local). This is before consideration of HS2 (which has an estimated cost of £55bn). In total, 95% of all cumulative, transformational costs are for national schemes, with local schemes accounting for 5% of costs.

Figure 2: Transformational scenario – Inter-urban schemes (not all local, or radial schemes shown)



Source: Open street map, Savills, Arup

Table 3: Summary of transport capital costs, by scenario

Transport investment package - Summary	Cost (£bn)	Cumulative Cost (£bn)
Baseline scenario	12.5	12.5
Incremental scenario	+44.1	56.7
of which crossrail 2	32.0	32.0
net of crossrail 2	12.1	24.7
Transformational scenario	+56.6	113.2
of which HS2 and associated capacity release	55.0	55.0
net of HS2 and associated capacity release	1.6	58.2
net of both Crossrail 2 and HS2	1.6	58.2

Source: Arup

Wider benefits of transport investments

Schemes that improve connectivity within and between places in the study area are likely to lead to some benefits from agglomeration. These benefits are likely to be positively correlated with the size of the towns, their proximity to each other and the level of sectoral synergies between them. The distances between many places in the Cambridge-Milton Keynes-Oxford Corridor is over 50 kilometres, which could limit the potential level of agglomeration benefits (which decay with distance).

However, places in the centre of the Corridor such as Milton Keynes, Northampton, Bedford and Wellingborough are closer together and there is evidence that the labour markets in these areas already overlap. Transport schemes which reduce travel times between the latter places would be likely to lead to high agglomeration benefits through further enhancing existing mutual relationships and widening labour market catchments.

There are potentially significant benefits from improving links across the Corridor, albeit with substantially higher costs, and to fully realise potential benefits would require significant changes to the current trip patterns in the study area (i.e. dynamic land use effects). This highlights the importance of ensuring that transformational investments have a twin focus on unlocking new housing and access to jobs and on delivering new transport linkages between knowledge intensive jobs in Oxford and Cambridge.

Housing and transport

Arup and Savills carried out joint analysis that identified housing sites that have the potential to be brought forward through investment in transport infrastructure. We undertook work to sift the transport schemes within each scenario to determine those that have an impact on unlocking land for housing use. Our joint work with Savills listed the transport schemes identified in the incremental and the transformational scenarios, by sub area, and the number of houses they are collectively and individually thought to unlock.

On the 301 large housing sites identified, there is the potential capacity for around 400,000 units. There are 207 transport schemes that could have an impact on bringing forward these housing sites (of which 59 could have a "high" impact). The spending for these 59 schemes is around £44.5 billion inclusive of HS2 and Crossrail 2, and around £12.5 billion net of HS2 and Crossrail 2. The number of schemes in the table sums to 255; this is because some schemes have an impact on multiple housing sites.

Table 4: Cost and number of transport schemes by impact on housing

Impact on housing	Number of transport schemes	Cost (£m)	
		Incl. HS2/Crossrail2	Net of HS2/Crossrail2
Very Low	41	1,204	1,204
Low	24	369	369
Mid	63	64,002	9,002
Medium-High	68	3,163	3,163
High	59	44,503	12,503
Grand Total	**255 (207)**	**113,240**	**26,240**

Source: Arup, Savills

Conclusions

The corridor is already a net contributor to the Exchequer, and plays an important role in the national transport story through hosting several of the main road and rail links, and well as the forthcoming HS2. Whilst local in nature, the investment packages that we have identified have significant national benefits. And in return, many national schemes are creating a good opportunity to yield local benefits. We have also identified investments that would potentially free up sites for housing development, which in addition to fulfilling other policy needs would potentially generate a source of additional funding for the infrastructure plan.

Our joint work with Savills suggests that the long term housing strategy for the corridor is partially dependent on options for east-west connectivity. There are locations along the East West Rail line and the Expressway where housing sites are unlocked. In addition, other methods of connectivity, within the urban areas, and on a north-south axis, also open up additional housing. The latter could be particularly important in accommodating some of London's growth.

A number of these short term enhancements to transport could help bring forward current plans for housing. There is "low hanging fruit" in other areas as well - whilst the long term strategy for growth should not focus exclusively on east-west connectivity across the whole corridor, there are segments of it, particularly in between Milton Keynes and Cambridge that could support growth in specific locations.

Areas of the corridor have enjoyed economic success, particularly in the knowledge based industries, which is coupled with a perceived high quality of life. In its response to the NIC's call for evidence, the joint response from the

Local Enterprise Partnerships highlighted that whilst some of these strengths build on a history of success, future success should not be taken for granted, and similarly, the corridor has huge potential for further growth.

1 Introduction

1.1 Study drivers

In March 2016, the then Chancellor of the Exchequer asked the National Infrastructure Commission (NIC) to:

> "… make recommendations to maximise the potential of the Cambridge–Milton Keynes–Oxford corridor as a single, knowledge intensive cluster that competes on the global stage, whilst protecting the area's high quality environment and securing the homes and jobs the area needs.
>
> "The Commission will look at the priority infrastructure improvements needed and assess the economic case for which investments would generate the most growth."[2]

The Commission organised a Call for Evidence on the subject during summer 2016 and received responses from Local Enterprise Partnerships, local authorities, universities and other organisations. Arup, Savills and Metro Dynamics were then commissioned to investigate transportation infrastructure, and its interaction with housing, finance and economic activity (for which Cambridge Econometrics were engaged by the Commission) across the Cambridge–Milton Keynes–Oxford corridor (the CaMkOx corridor - the study area).

The four firms have been working together, sharing data, establishing baseline, incremental and transformational scenarios and coordinating case studies and other cross-cutting matters.

The NIC's overarching objective was for its consultants to help identify a set of infrastructure proposals that - if delivered - would unlock significant economic growth across the corridor through the interlinked provision of new transport links, jobs, housing and improved productivity. The timescales for the investment packages was determined by the NIC to be the period to 2050.

The objectives for the transport workstream were to provide:

- A contextual overview of current transport infrastructure use and arrangements across the corridor including a description of where the principal transport infrastructure pinch points and challenges sit, including an assessment of commuter flows and identification of areas where existing infrastructure is under strain from congestion or overcrowding.
- Mapping of the strategic and economic cases for transport investment in the corridor, including current investments, proposed investments and priorities

[2]National Infrastructure Commission: Cambridge-Milton Keynes-Oxford: 'growth corridor' call for evidence. Available from: https://www.gov.uk/government/consultations/cambridge-milton-keynes-oxford-growth-corridor-call-for-evidence/cambridge-milton-keynes-oxford-growth-corridor-call-for-evidence

identified through the NIC's call for evidence, as well as a reflection on how these cases meet the identified challenges.

- A considered view of what future transport packages for the corridor could look like, including provision required to support a more ambitious approach to growth.
- A focus on the contribution that transport could make to unlocking housing sites and an analysis of the agglomeration benefits of better connectivity between urban centres on the corridor and shorter journey times within them.

1.2 This document

This document forms the final report for the transport workstream. It sets out the following analysis and synthesis of evidence, the report is structured as follows;

- Section 1 provides an introduction.
- Section 2 covers transport patterns in the growth corridor today – including an overview of the study area's transport provision. This provides a starting point from where to conduct a gap analysis of what interventions are required across the corridor. The main different modes of transport are discussed as well as specific and general travel patterns and congestion points.
- Section 3 looks at drivers for change – three scenarios are discussed here in some detail. They inform the levels of demand that transport infrastructure could aim to meet at different points to 2050.
- Section 4 looks at future transport packages. We develop a list of schemes of national importance and schemes as part of packages for five subareas; Oxford, Cambridge, Milton Keynes – Northampton, Inter-Urban corridors plus radial links with London.
- Section 5 covers housing, and the wider benefits of transport investment. This section focuses on the importance of the transport schemes in unlocking housing growth across the corridor, as well as implications for productivity growth through agglomeration benefits and the wider strategic case for investment.
- Section 6: is where we summarise our conclusions.
- Appendices – we include as appendices the full list of candidate schemes; our scheme evaluation results; congestion maps; bus journey isochrones; commuting patterns; a literature review of agglomeration impacts; a productivity assessment; analysis of future transport trends; and more background on the baseline, incremental and transformational scenarios.

1.3 Study area

The Arup, Savills and Metro Dynamics consortium, with Cambridge Econometrics, agreed with the NIC a spatial definition of the corridor to allow us to focus our work on data collection and analysis. As can be seen in Figure 3 at the end of this section, the CaMkOx study area is a "corridor" in the UK to the

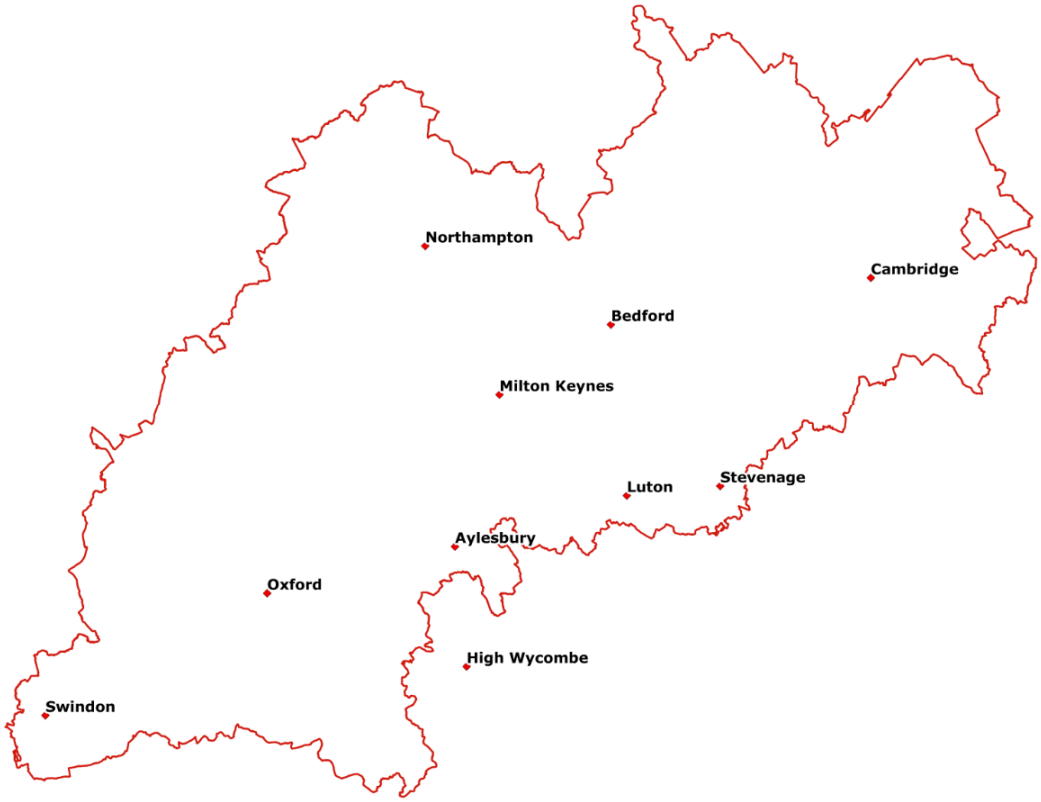
north-west of London, with Swindon at its western point and Cambridge at its eastern edge. The study area includes the major towns and cities of Cambridge, Milton Keynes, Northampton, Bedford, Wellingborough, Oxford and Luton and further west, Swindon. These centres are supported by a number of smaller towns and settlements spread across Cambridgeshire, Central Bedfordshire, Bedford, Milton Keynes, Luton, Hertfordshire, Buckinghamshire, Oxfordshire, Northamptonshire and Swindon.

The study area is home to three of the highest performing economies in the south-east, and a higher than average concentration of knowledge based jobs. The areas around Oxford and Cambridge have a very high concentration of these. The Cambridge Econometrics report for the economics workstream identified that two of the three economies (Oxford and Cambridge) may be perceived as "overheating" for a number of reasons including greenbelt constraints. These factors, together with the projected growth in population of Milton Keynes and Northampton and the demand from London residents for "overspill" housing are putting pressure on the local and regional transport network. Across the corridor, quality of life is threatened by increasing congestion on transport links. In addition, there is a need for good quality housing provision that is affordable, in the right places and connected to job opportunities and sustainable communities.

The study area differs across its geography; from its demographic and socio-economic characteristics to its infrastructure provision and governance structures. This has important implications for both drawing out investment and implementing coherent proposals for investment over the medium to long term.

In addition, the four relatively self-contained labour market areas within the study area (Swindon, Oxford, the central area of Milton Keynes – Northampton – Bedford – Wellingborough, and Cambridge), and the degree of interaction with the London labour market, perhaps indicates that more could be done to enable the area to function as a corridor. The degree of interaction in the central Milton Keynes – Northampton – Bedford – Wellingborough "constellation", arguably reflects the better transport links between those towns. This suggests that better, more transformational transport links may open up new opportunities in the corridor. Major interventions have therefore been looked at alongside smaller schemes that relieve pinch points.

Figure 3: Study area



Source: Open street map, Arup

2 Transport patterns in the growth corridor today

2.1 Summary

The map overleaf illustrates an overview of the strategic highway and rail network across the corridor. The location of the corridor, between London and the midlands, means that it sits astride many north-south routes. Connectivity along the east-west axis is more limited.

There are presently four relatively self-contained labour market areas within the study area (Swindon, Oxford, the central area of Milton Keynes – Northampton – Bedford – Wellingborough, and Cambridge), with Swindon the most distant in geographical terms and in terms of its economic interaction with the others. Oxford and Cambridge have particularly knowledge-based economies. There is a degree of interaction with the London labour market, with the towns to the south of the study area having a more significant interrelationship with London than those to the north.

This limited labour market interaction across the corridor appears to be due in part to the physical distances and the size of the towns and the comparatively poor quality of orbital links. Many road links have relatively little separation of local and interurban traffic with long journey times as a result. Furthermore, although the western leg of the East West Rail is under construction, there is presently no comprehensive direct rail link across the corridor. Many rail journeys are therefore best undertaken via London or via interchanges in locations to the north of the study area. By contrast, the transport links between the towns within the corridor and London are of higher quality, and have higher-than-average speeds. However they tend to suffer from overcrowding and congestion.

These factors perhaps help to explain why urban areas in the corridor tend draw most of their labour from immediately surrounding vicinities. The most concentrated catchment areas are around the knowledge-based clusters of Oxford and Cambridge, which are both tightly bounded and currently perceived as overheating. The Milton Keynes – Northampton – Bedford – Wellingborough area is larger and has more labour market interaction between its major settlements, reflective of the better transport links between those towns.

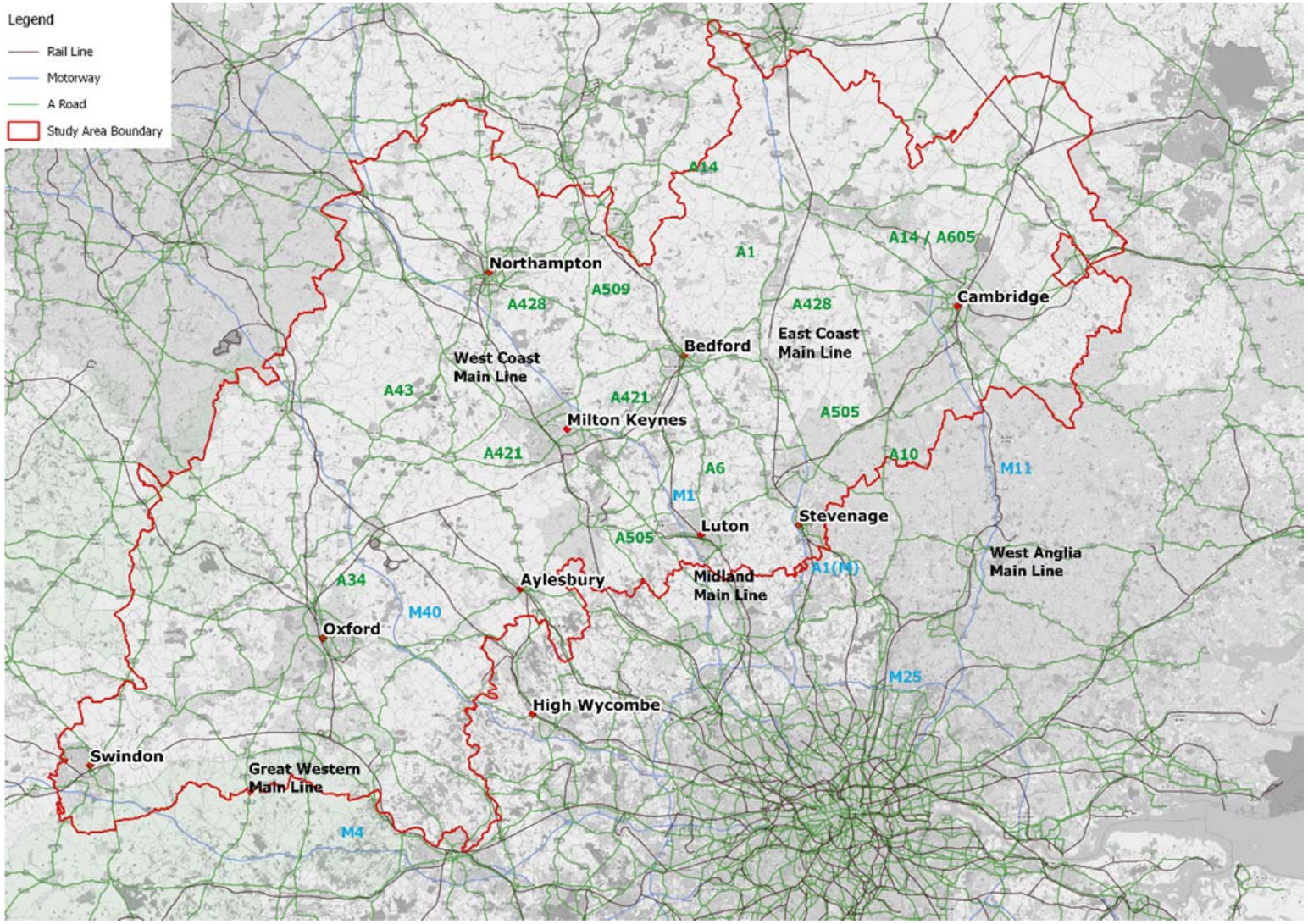
As with many parts of Britain and indeed Europe, the study area suffers from congestion, particularly on approaches to its town centres, and where the strategic road network interacts with the local road network. Congestion, is often at its worst where the intra-urban road network meets the inter-urban road network. Whilst the bus network in towns, particularly in Oxford and Cambridge, is often well used, limited segregation from general traffic means that it is often susceptible to delays.

Some of the consultation responses received by the NIC suggest that congestion is becoming a threat to economic investment, as well as to air quality and to quality of life. Together with the poor interurban links, it is also potentially an impediment to creating a single knowledge intensive cluster, as envisioned by the

last Chancellor. In this way, further economic growth may be limited by the increasing demand placed on transport links and the need for good quality housing provision that is affordable and in the right places, connected to job opportunities and sustainable communities.

This suggests that there may be benefits to be gained from enhancing orbital connectivity, and (as suggested by the Local Enterprise Partnerships in their response to the NIC consultation) complementing investment in strategic infrastructure with 'first mile/last mile' connectivity across all modes. This may also unlock housing sites and deliver growth and employment in a successful part of the economy.

Figure 4: Strategic highway and rail networks



Source: Open street map, Arup

2.2 Road

2.2.1 Connections

Despite the observations noted above, in some ways, the CaMkOx area is well served by the strategic transport network. This forms mainly radial routes (running north-south). The strategic routes of the M11, A1(M), M1, M40 and M4, managed by Highways England form the strategic road network fanning out from the M25 orbital route around Greater London. As can be seen from Figure 4, the A34, A43, A45 and A14 form an outer orbital route between the radial routes. The A428 and A421 form a partial orbital route connecting Cambridge, Bedford and Milton Keynes.

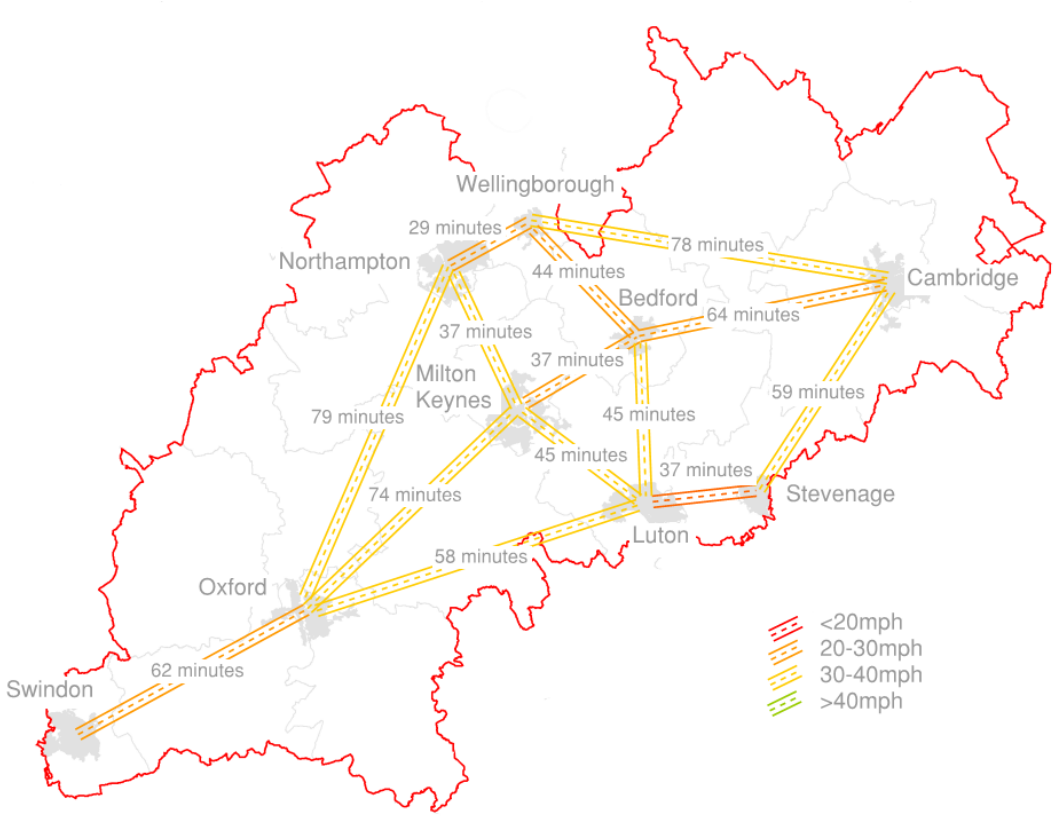
Connections between Milton Keynes and Oxford are formed by the local strategic highway network managed by local highway authorities. The A420 connects Swindon and Oxford but connections between Oxford and Milton Keynes are less direct. The A34 and A421 provide a route via Buckingham and the A318 and A4146 provide a route via Aylesbury. Complementing the strategic network is a network of local routes, which is at its most dense in the city and town centres.

2.2.2 Journey times

AM peak hour journey times between urban centres in the study area, as shown in Figure 5, indicate marginally higher speeds north-south than east-west reflecting the radial routes passing through the study area. Orbital road links have less separation of local and interurban traffic, and longer journey times as a result.

Speeds vary between approximately 20 and 40 mph throughout the study area with north-south routes generally being slightly faster (30-40mph) than east west routes (20-30mph), particularly to Swindon, Oxford, Luton, Stevenage, reflecting the motorway infrastructure. Local road layout may also be a factor. For example the connectivity provided between Oxford and interurban traffic is less congested than around Cambridge (which A14 investment is aiming to address). Congestion is examined in more detail in a later section and in Appendix B.

Figure 5: AM peak period average journey times – centre to centre



Source: Open street map, Google maps journey planner, Arup

2.3 Rail

2.3.1 Connectivity

The rail corridors including the Great Western, West Coast, East Coast, West Anglia and Midland main lines provide radial routes through the study area.

The Chiltern railway provides a route between Oxford and Bicester (and now on to London), the London Midland line provides a connection between Bletchley and Bedford and the Great Northern line connects Cambridge and Stevenage. Whilst there is a commitment to build the Western Section of East West Rail, and the Central Section is under consideration (see later sections of this report) there is currently no continuous rail route that spans the study area.

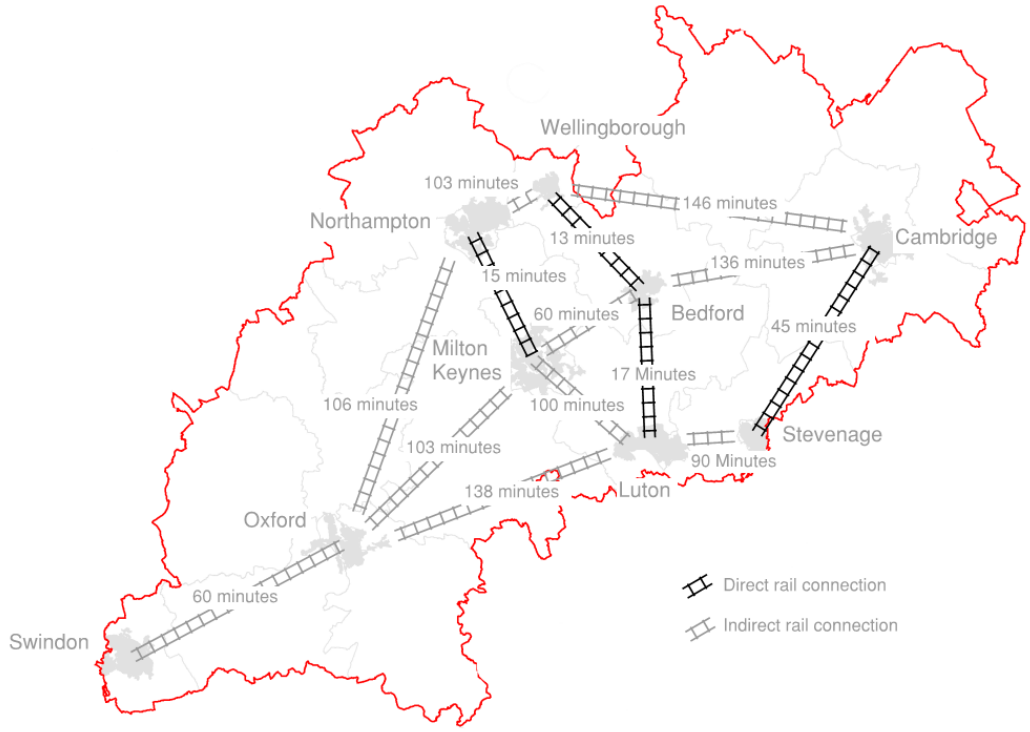
2.3.2 Journey times

Rail journey times in the study area are comparatively good for radial movements. For example Milton Keynes to London takes 35 minutes and enjoys a frequency of eight trains per hour. However orbital links are poorer, with many journeys having to be made via London or other destinations (with an interchange) (see Figure 6). For example:

- The quickest route from Oxford to Milton Keynes is via Coventry and takes at least 80 minutes with one train per hour;

- The quickest route from Milton Keynes to Cambridge is via London and takes 120 minutes (two hours) with three trains per hour;
- The quickest route from Oxford to Cambridge is via London and takes 170 minutes (over two and a half hours); and
- The quickest route from Northampton to Cambridge is via London and takes 150 minutes (two and a half hours) with three trains per hour. This is a journey of over twice the distance (around 130 miles via London for a 60 mile journey).

Figure 6: AM peak hour average journey time – station to station



Source: National Rail Enquiries, Arup

Where there are direct, frequent, rail services (between Milton Keynes and Northampton and between Wellingborough and Bedford), the journey times compare favourably to highway journey times. But many other rail routes are typically not competitive when compared with journey times by road. The majority of the orbital routes do not have direct connections and require a change within CaMkOx (Swindon-Oxford via Didcot) or outside (e.g. Oxford – Milton Keynes via London or Coventry) which is reflected in the journey times shown. As a result, for many people, the car is often the most logical mode of transport within the study area. The East West Rail scheme (discussed further on in this report) is aimed in part at addressing this poorer connectivity.

2.4 Bus

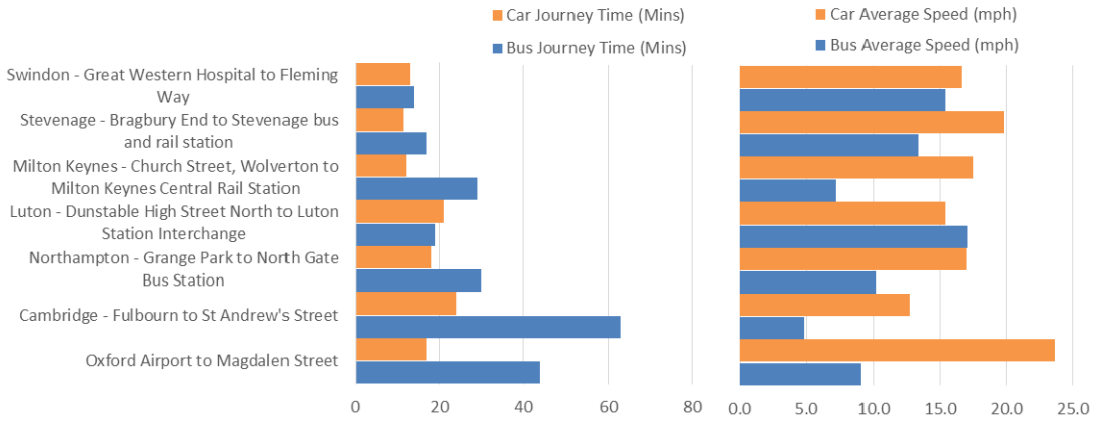
The lack of metro systems, and orbital rail connections leaves an opportunity for fast direct bus services. But too often these services are at the mercy of traffic congestion and slow road speeds and so journey times are lengthy. For example

the X5 service between Oxford and Cambridge has a timetabled journey time of three hours and 40 minutes (equivalent to an average speed of 23mph) from city centre to city centre. The 66 service between Swindon and Oxford has a timetabled journey time of 85 minutes, equivalent to an average speed of 14mph.

Nevertheless, a number of the towns and cities in the study area benefit from dedicated bus lanes. For example, the Cambridgeshire guided bus way that links Cambridge, St Ives and Huntingdon opened on the route of an old railway line in 2011 and provides a dedicated route for modified buses.

Buses more generally are often caught in congestion present on the local road network. As such, sometimes suffer from comparatively poor journey times (see Figure 7 below). (Congestion is examined in more detail in Appendix B.)

Figure 7: Bus journey time comparison – selected suburb to centre routes



Source: Bus timetables, Google maps journey planner, Arup

The time taken to travel by bus to each of the town / city centres is mapped in Appendix C. These indicate relatively good accessibility by bus in close proximity to urban centres but this declines between centres in the corridor. Capital investment may be required over the medium to long term to tackle this.

2.5 Commuting patterns

We have undertaken an analysis of the 2011 Census journey to work data for this study. Commuting patterns in the study area tend to be localised. Our analysis is summarised below and is shown in more detail in Appendix D.

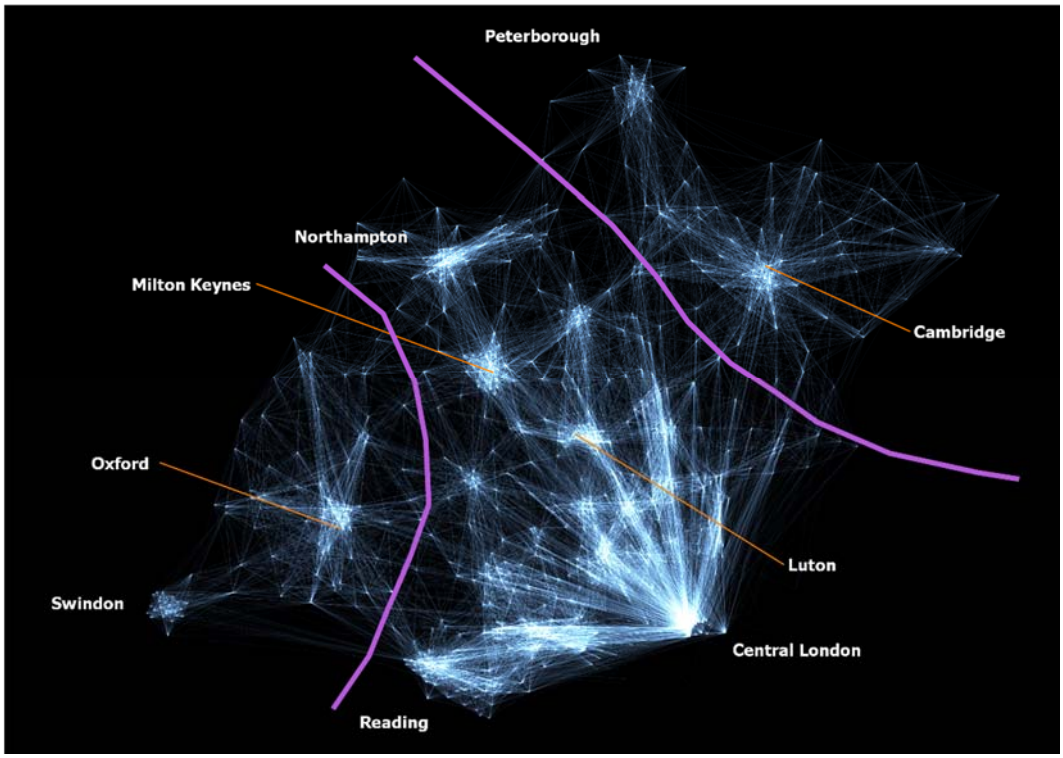
The southern portion of the area (e.g. between London and Luton) has significant commuting interaction with London. For the more distant centres such as Northampton, Peterborough, Cambridge and Oxford, interaction is less pronounced.

Whilst there is significant commuting interaction between central locations, such as Milton Keynes, Northampton, Bedford and Luton, there is much less interaction between these centres and Oxford and Cambridge and Swindon. As noted earlier, this reflects the poor orbital connections between these areas.

This relative isolation of Oxford and Cambridge from the central towns of the study area is highlighted in the journey to work catchment area plots (in Figure 8, and Figure 9 below and in detail in Appendix D). These maps show connectivity flows rather than volume of individual commuter flows.

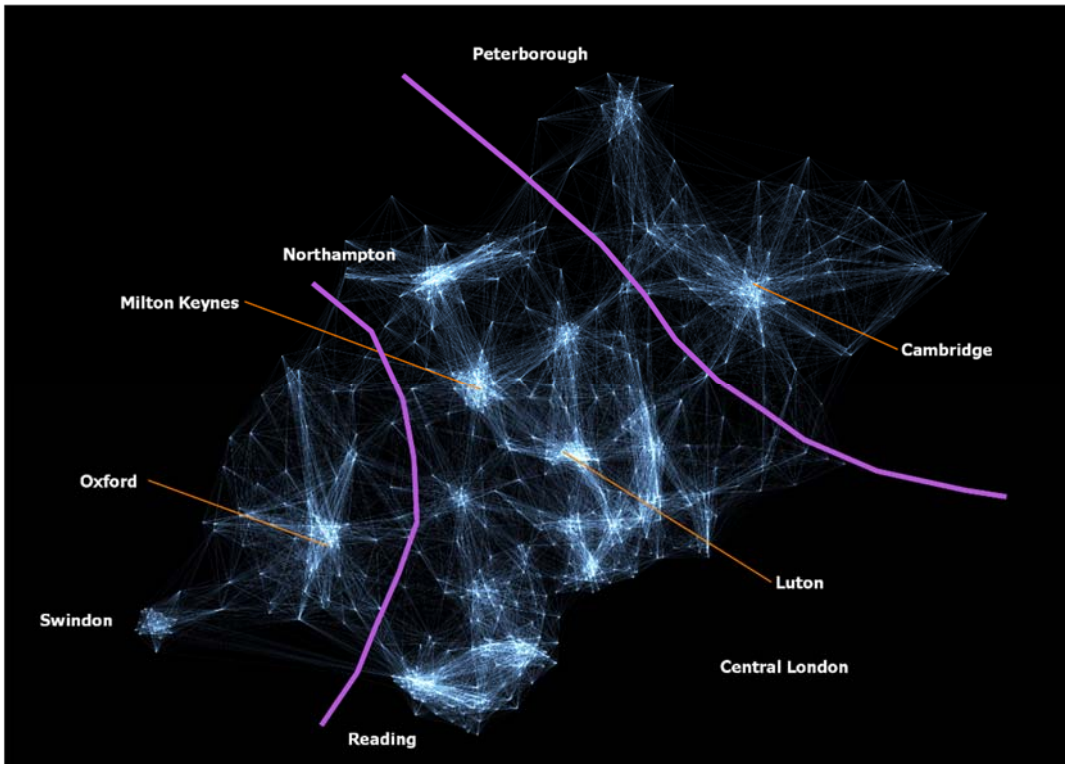
In the Milton Keynes / Northampton / Bedford / Wellingborough area, travelling to work in neighbouring towns is relatively common (all these towns have strong links with Milton Keynes, but weaker links with each other). Oxford and Cambridge have a wide catchment area of hinterland to centre movement, but less interaction with other major towns in the study area. This arguably reflects the geographical location of the employment centres, as well as the quality of the transport links between them.

Figure 8: Connectivity flows with London (7-10 am, Monday to Friday)



Source: ONS 2011 Census Local Authority Areas, Open street map, Arup

Figure 9: Connectivity flows without London (7-10 am, Monday to Friday)



Source: ONS 2011 Census Local Authority Areas, Open street map, Arup
Note: these diagrams show levels of connectivity and not necessarily volumes of movement; purple lines are simply designed to highlight the three principal areas of activity.

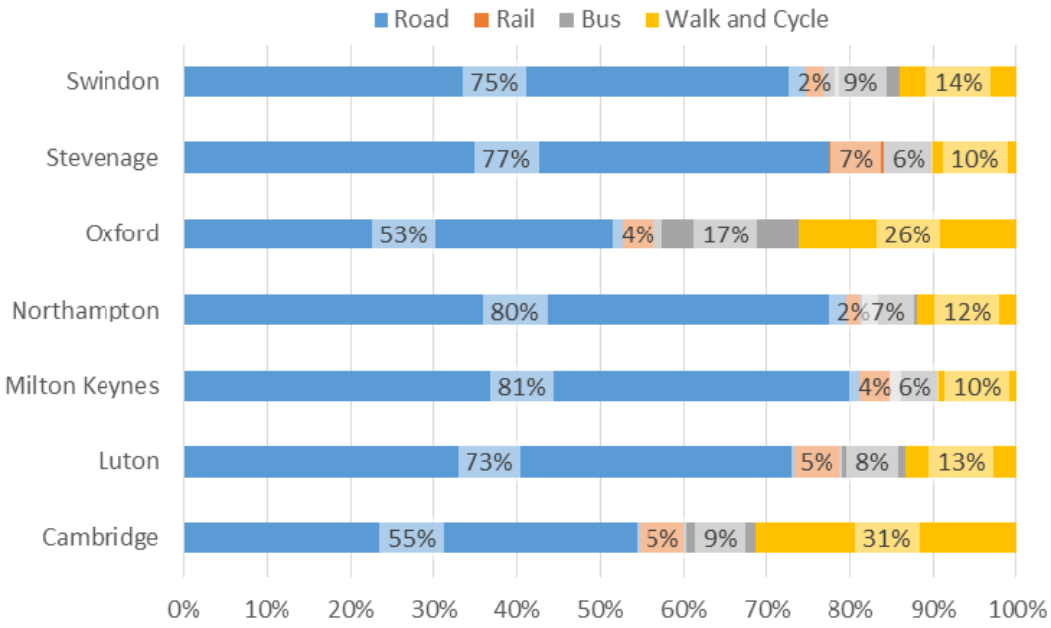
2.6 Mode share

2.6.1 Overall

The dominant mode of transport in the study area is car. This is particularly the case in Stevenage, Northampton and Milton Keynes, where 2011 Census data indicates that it accounts for around 77%, 80% and 81% of trips respectively.

- The mode shares for Oxford and Cambridge differ from the rest of the study area, with walking and cycle trips playing a more significant role in commuting patterns and in Oxford's case in particular, bus plays a pivotal role.
- The greater role of public transport, cycling and walking reflects the restricted availability of car parking space provision in the two historical cities, the high levels of road congestion, the quality of cycling infrastructure and local transport policies as well as geographical factors such as the compact nature of the cities. Newer towns have more availability of parking at central locations and larger less compact employment sites.

Figure 10: Urban centres commuting mode shares (combined origin and destination share)



Source: ONS 2011 Census Local Authority Areas, Arup

2.7 Congestion

2.7.1 Town centre congestion

Journeys from suburb to centre within the study area suffer from common problems of road congestion, which is at its worst at the points where the intra-urban road network meets the inter-urban road network. This is made worse in the centre of some towns, where the historical urban centres suffer from congestion that arise partially from the nature of their street networks. The consultation responses received by the NIC suggest that congestion is becoming a threat to economic investment, as well as to air quality and to quality of life.

For more details on town centre congestion, see Appendix B.

2.7.2 Inter-urban routes

The inter-urban routes are comprised of roads managed by Highways England and the local highway authorities. Journey time reliability on the strategic road network is measured by Highways England and expressed in terms of the percentage of journeys which are on time (with journeys are defined as travel between adjacent junctions on the network and an on time journey is one which is completed within a set reference time drawn from historical data). The percentage of journeys on time is thus a measure of relative congestion. Generally speaking, the links with the lowest proportions of journeys on time (see Appendix B for a detailed breakdown) are those that have the closest connections to the urban centres, and have been identified by local planning authorities through their local transport plans.

Average speeds on the 'A' roads managed by the local highway authorities for the weekday morning peak display a similar pattern: orbital routes across the CaMkOx corridor, and radial routes into the urban centres have the lowest speeds. The routes which connect smaller urban centres or centres connected by the strategic network have the higher average speeds.

The pinch points identified by the Local Planning Authorities' Local Transport Plans are identified in Figure 11.

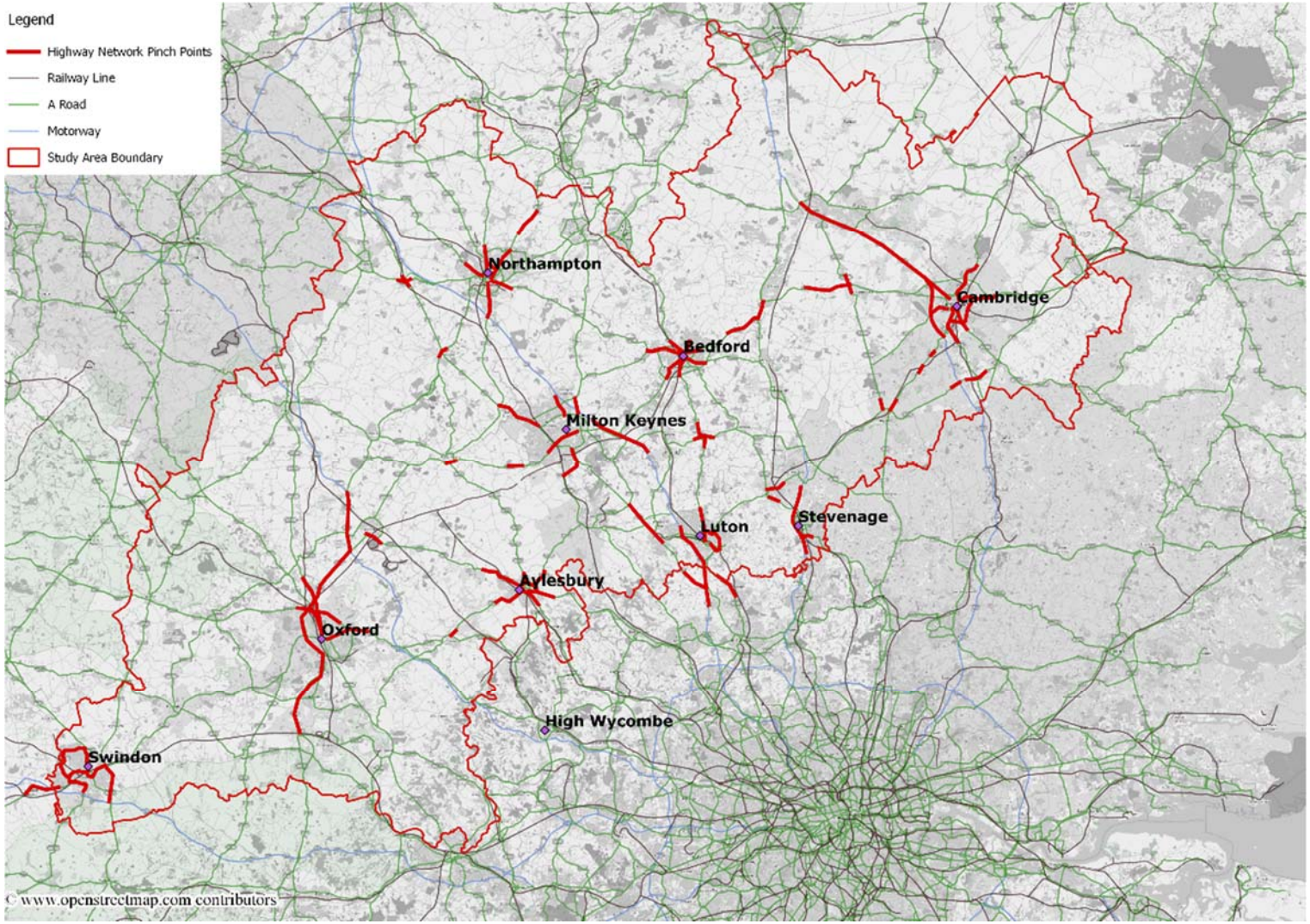
2.7.3 Rail network congestion

The radial rail network often experiences high load factors. The LEPs across the growth corridor recognised this in their collective response. For example they state that "travel times to London may be quick but many lines are capacity constrained and subject to delays and uncertainty over journey times." These are well documented in other studies[3] and as such are not included as the focus of this report. Nevertheless, the main capacity issues on the rail network can be broadly summarised as:

- Crowding on rail services into London including peak hour services, to/from London Paddington and Oxford and Swindon, and services into Farringdon and Moorgate; and
- Crowding at busy rail stations including Oxford, Cambridge, Bedford, Banbury and Milton Keynes.

[3] Including the Long Term Planning Process: London and South East Market Study, *Network Rail, October 2013* and previously, Network Rail's Route Utilisation Studies.

Figure 11: Highway network peak time pinch points



Source: Open street map, Arup, Local Transport Plans, DfT

3 Drivers for change

3.1 Summary

Arup worked iteratively with Cambridge Econometrics and Savills to understand possible future patterns of economic activity, job creation, population and housing growth in the period to 2050 for the study area. We then developed transport packages that support, enable and respond to the challenges of future scenarios. For details please refer to their individual reports.

Future job growth is projected to be focused on Milton Keynes, as well as the knowledge based centres of Cambridge and Oxford. Areas close to town centres are likely to become particularly congested if left unchecked. The transformational scenario (and the most ambitious of the three we have evaluated) suggests increases of between 42% and 61% for sub-areas compared to 2011 baseline data.

3.2 Planning for growth

The factors which form the case transport interventions and investment in the study area include immediate local challenges such as:

- Dealing with the day to day problems of congestion that lead to delay, unreliable journeys and associated environmental impacts;
- Tackling the related problems of a lack of capacity on transport infrastructure which in turn leads to delays and costs for users (and non-users alike);
- Addressing “missing links” to accessibility and connectivity (such as east - west); and
- Catering for background increases in demand for trips that may occur within the study area if people’s propensity to travel increases over time.

There are then a number of more regional factors that form part of the case for change. These include:

- Improving capacity and connectivity to underpin employment growth; both generally and specifically in higher productivity/higher value added knowledge-intensive sectors. Schemes are aimed at reinforcing and delivering agglomeration benefits both within the study area and in relation to London;
- Ensuring that transport infrastructure is in place to allow for housing growth at existing sites and also for housing growth at new locations. These may even provide some modest provision to accommodate demand from London; and
- Improving the capacity of the transport system to cope with anticipated population growth but also associated with movement at a national scale. There is therefore a case for projects which generate national strategic benefits to be included. Not only do these help to ensure that transport benefits are

being delivered to other parts of the country but with careful planning and integration with more local schemes, they can provide a platform of infrastructure to underpin transformational levels of movement employment and housing opportunities within the study area.

We worked iteratively with Cambridge Econometrics and Savills to understand the future patterns of economic activity, job creation, population and housing growth - and developed transport packages that support, enable and respond to the challenges that come with them. We adopted three scenarios, informed by other consultants' work. This was informed by understanding past and future economic trends, starting with population and employment growth, and their implications for housing and productivity (GVA).

3.3 Baseline scenario

This scenario is informed by, enables and responds to Cambridge Econometrics' report, in which population is assumed to grow at the Office for National Statistic's central principal projections. Employment was estimated using Cambridge Econometrics' Local Economy Forecasting Model, which distributes sectoral employment and GVA across the 406 local authority districts in the UK. The anticipated population growth is expected to be around 0.7% per annum, which equates to just under 1 million more people living across the corridor by 2050 compared with a baseline year of 2014.

Housing delivery estimates were estimated by Savills using Cambridge Econometrics' population projections. Based on these, as well as current local plan targets, market conditions, and government policies, Savills have concluded some 510,000 homes need to be built by 2050.

An increase of 15,000 homes per annum is anticipated. The transport schemes identified as part of this scenario are already committed, and represent broadly the level of transport intervention that is considered needed to respond to population, GVA and housing growth rates in the baseline case. They go some way towards freeing existing constraints and encouraging housing investment in the corridor. In places, they also improve the corridor's infrastructure provision from today.

In response to the baseline levels of growth, there is therefore more of an emphasis on schemes that deliver benefits and reduce costs associated with existing patterns of activity, rather than create new opportunities for movement. Projects to remove pinch points, improve junctions and improve public transport journey times have been included. These often form part of more significant projects that are included in full in the other scenarios. A good example is the East West Rail scheme, anticipated to be constructed in three stages. Finally, given the comparatively low level of growth in the baseline case, we consider that some projects should perhaps be phased later in the timescale to 2050 compared to the other higher growth cases.

3.4 Incremental scenario

Our work on transport again responds to Cambridge Econometrics work on this scenario. Future patterns of population growth have been estimated within this

scenario using the ONS high migration projections. These project an additional 191,000 of population on top of the baseline forecast to 2050 (from a baseline year of 2014), with the corridor growing faster than the UK national rate. KBS employment is expected to grow at historical 1990 – 2014 rates in the Cambridge and Oxford sub areas. Non-KBS employment is be driven by both increased population growth and KBS employment, through increased demand for services and supply chain effects.

The projections for housing in the incremental scenario have been based on the local plan targets in addition to recent Strategic Housing Market Assessment (SHMA) targets. Savills' target is 20,000 homes per year to 2050 across the corridor.

In responding to the levels of population, housing and employment in this scenario, transport investment is carried over from the baseline scenario, and coupled with further investment. Some of this is aimed at reinforcing the connectivity between locations that already enjoy a degree of economic interaction. Schemes are also included that are designed to connect more of the workforce with employment opportunities in the three main labour market areas of Milton Keynes – Northampton – Bedford – Wellingborough, plus Cambridge and Oxford sub area and in doing so, to ensure support for the more knowledge based and hi tech labour markets. These areas are ones that Cambridge Econometrics consider are likely to grow most substantially to 2050.
In the incremental scenario, investment in strategic projects also takes place. Some improvements in links to London are also included.

3.5 Transformational scenario

The transformational scenario population projections derived by Cambridge Econometrics uses above ONS "high migration" figures to generate additional demand for employment beyond that of the incremental scenario. The transport response to this addresses the idea that the corridor is a globally competitive knowledge cluster with excellent connectivity, moderate to high levels of commuting and collaboration, while reducing some of the economic "pull" of London. To achieve the high levels of growth within the transformational scenario would, in our view, require radical levels of transport investment, including East West Rail and the Oxford – Cambridge Expressway. Knowledge Intensive Business services (KIBs) would, in this scenario, and partially in response to transport investment, maintain their historic rates of employment growth, which are extrapolated forward to 2050. Again, non-KIBS employment is driven by both increased population growth and employment, through increased demand for services and supply chain effects.

There are two dependencies for additional housing need in the transformational scenario. Firstly, the study area should take an economically efficient share of national housing need. Secondly, the study area should meet need from economically connected areas in which it is not possible to meet housing need. In overall terms just over 1 million homes are built equivalent to a combined annual rate of just over 30,000 homes per annum to 2050.

3.6 Interaction between scenarios

The assumptions adopted by Cambridge Econometrics, Savills and Arup for the economics, housing and transport workstreams are broadly consistent and represent the results of iterative work. However, there is inevitably a degree of variability and uncertainty associated with them. There is also a degree of iteration – especially in relation to the economic case (i.e. a "chicken and egg" relationship between transport investment, projects, housing and growth). As a result, they should be treated as indicative of the scale of impact and or opportunity that the study area might be capable of delivering rather than a set of forecasts that will be achieved with a high degree of certainty.

3.7 Commuting patterns projections

We used the projections for population and employment levels by local authority to develop an equilibrium model that could be used to guide projections on future patterns of commuting[4]. It uses the employment growth centres as attractors and centres of population growth as originators to provide an estimate of the number of commuting trips by local authority for each scenario in the period to 2050. Note that this model is indicative only, and in particular it does not include an allowance for changed commuting patterns as a result of the transport investments in our packages.

Baseline case

As we have already noted, the combination of even modest rates of growth with the current sub-optimal performance of significant parts of the transport network would, without substantial intervention lead to deteriorating traffic speeds, increased delays, less reliable journey times, increased congestion and environmental harm and a loss of productive economic output. The already constrained radial routes into the principal towns would be placed under greater pressure as journeys within these areas increase and more trips are drawn in from the sub regions around them.

[4] AM weekday peak (7-10 am). Commuting movements are measured on a "gross" basis. So for example, if they pass through more than one local authority area they might be more than once.

Table 5: Commuting projections to 2050 – sub regions and total for the study area (to nearest thousand)

Baseline scenario	2011 Commuting movements	2050 Projected movements	2050 (% increase on 2011)
Oxford-Swindon area	723,000	857,000	**19%**
Greater Northampton area	369,000	440,000	**19%**
Greater Cambridge-Northern Hertfordshire area	612,000	763,000	**25%**
Milton Keynes-Bedfordshire-Aylesbury Vale area	794,000	1,032,000	**30%**
Total	**2,498,000**	**3,092,000**	**24%**

Source: Arup, ONS

Incremental case

Commuting movements are projected to grow by at least 30% in each of the sub regions (see Table 6 below). This is particularly the case with Oxford and Cambridge which are projected to see some of the highest percentage increases of housing, and employment, productivity and consequently GVA gains. Milton Keynes sees the largest increase in population in both absolute and percentage terms. The area's importance as a location for increased housing means that transport interventions must ensure that it can perform its function as not only a centre of employment and one of accommodation.

Table 6: Commuting Projections to 2050 – sub regions and study area (to nearest thousand)

Incremental scenario	2011 Commuting movements	2050 Projected movements	2050 (% increase on 2011)
Oxford-Swindon area	723,000	959,000	**33%**
Greater Northampton area	369,000	483,000	**31%**
Greater Cambridge-Northern Hertfordshire area	612,000	851,000	**39%**
Milton Keynes-Bedfordshire-Aylesbury Vale area	794,000	1,134,000	**43%**
Total	**2,498,000**	**3,427,000**	**37%**

Source: Arup, ONS

Transformational case

The transformational case suggests additional pressure on commuting routes arising from an increase in movements of up to 61% compared to the existing situation, and will need to respond to this. Again, the highest growth is in the Milton Keynes area.

Table 7: Commuting Projections to 2050 – sub regions and study area

Transformational scenario	2011 Commuting movements	2050 Projected movements	2050 (% increase on 2011)
Oxford-Swindon area	723,000	1,079,000	**49%**
Greater Northampton area	369,000	538,000	**46%**
Greater Cambridge-Northern Hertfordshire area	612,000	939,000	**53%**
Milton Keynes-Bedfordshire-Aylesbury Vale area	794,000	1,275,000	**61%**
Total	**2,498,000**	**3,831,000**	**53%**

Source: Arup

4 Future transport packages for the corridor

4.1 Summary

Our strategies focus on lifting constraints to growth. This may mean targeting existing urban transport pinch points first, to create better access to (future) employment opportunities in major town centres, together with transport investment that opens up housing and employment land opportunities. The prioritisation of the unlocking of existing constraints (links to employment opportunities and delivery of housing at scale) can be expected to deliver benefits most quickly.

The baseline scenario includes road improvements and other small schemes targeted at pinch points on the network. Transport spending of just under £13 billion[5] would provide this infrastructure of which national schemes account for c. £10.5 billion (84%) and local schemes the remaining £2.0 billion (16%).

The incremental scenario continues to focus on areas of growth (the major towns and cities and particularly Milton Keynes). We make provision for access to current and future employment opportunities and maximising labour agglomeration impacts of growth. We also include East West Rail's central section, the Expressway and bus-based rapid transit schemes in the larger towns and cities. The incremental scenario provides for an additional £12 billion of investment compared to the baseline case (before £32 billion for Crossrail 2[6]). Of the additional c£12 billion, c£9.8bn (81%) has been classed as national scheme expenditure. Local schemes account for the remaining £2.2bn. Cumulatively, national schemes account for 92% of the costs in the incremental scenario, with local schemes accounting for 8%.

In the transformational scenario it is envisaged that the corridor becomes a globally competitive knowledge cluster enjoying excellent connectivity, including further investments in rapid transit and further upgrades to East West Rail to offer a metro-style service. Our assessment suggests that the level of expenditure on local projects is some £1.2 billion (£1.4bn if East West upgrades are considered to be local). This is before consideration of HS2 (which has an estimated cost of £55bn). In total, 95% of all cumulative, transformational costs are for national schemes, with local schemes accounting for 5% of costs.

In order to fully realise the benefits of this, potentially higher levels of investment may be required in other sectors.

[5] Costs are typically assumed to be in 2015/16 prices. However due to the nature of some of the sources used, estimates throughout this report should be considered to be no more than indicative not least because in some instances base years may differ from 2015/16 (eg where no year was cited in source documentation).
[6] 2014 prices

4.2 Assessment of schemes

4.2.1 Sift criteria

To select schemes for investment, we developed evaluation criteria from a set of overarching objectives for the study. These prioritise infrastructure that would:

- **Improve connectivity** across the corridor, within and between the areas, towns and cities, tackling congestion, including public transport and a consideration of the interdependencies with social infrastructure requirements;
- **Improve employment and productivity** to create more and higher value jobs, drive the regeneration of communities, spread the benefits of economic growth along (and beyond) the corridor and ensure effective links with related hubs. It would also support and stimulate growth, through opening up new economic opportunities and journey patterns.
- **Act as a catalyst for bringing forward new sites for housing** to meet existing and expected housing need (including on public sector land), create new developments which are sustainable and provide commercial space for existing companies and inward investment;
- **Maintain and protect the environment** ensuring new infrastructure is of a high quality, maintains and/or protects the area's environment and cultural assets (including valued parts of the green belt).

We also included criteria on the practical aspects of delivery of projects, such as value for money, affordability and timescale.

The markings for the evaluation criteria categories were on a five point scale (from the lowest mark of zero – for a low, or negative contribution, to the highest mark of five – for a very positive contribution). In this way, a scheme that (for example) freed up a housing site and contributed to reducing congestion in a particular area would score more highly than one which just freed up a housing site.

The assessment drew on publicly available data and was moderated through both peer review and workshops. The evaluation in the housing category was undertaken through joint working between Arup and Savills (and is included in more detail in Section 5 of this report).

We applied the sift criteria to a list of schemes on an area by area basis, together with a further set of schemes corresponding to improving interregional links.

4.2.2 Identification of schemes

The schemes themselves were pieced together from those already planned, those being developed and our own list of potential transport improvements that would yield benefits.

The schemes assessed as part of this process have been positioned as those which support, enable, and respond to the projected changes in population, employment, and subsequent housing growth in the study area.

We identified the schemes that have been committed to the area but have not yet been built. To supplement this, we have also identified the planned schemes that address transport issues in the study area, obtaining this information from statutory bodies, including, Network Rail, Highways England, local authorities and packages of schemes from Growth Deal 3 Project Bids (including from the Buckinghamshire Thames Valley LEP, Cambridge City Deal, Greater Cambridgeshire Greater Peterborough LEP, Hertfordshire LEP, Northamptonshire LEP, Oxfordshire LEP, and South East Midlands LEP). Many of these authorities have a planning horizon of up to ten years, with some major schemes being planned up to twenty years in advance. Where no firm plans exist, we supplemented this with suggestions for addressing these gaps in response to the specific issues identified in earlier sections of this report.[7]

Our list of potential schemes stretches to over 200, with a capital cost of £113bn – when all national schemes (including HS2, Crossrail etc are included). A full list of these schemes appears in Appendix A.

4.2.3 Principal schemes of national importance

Some national schemes are likely to have a significant impact on travel patterns in the study area when and if they are implemented. These are discussed below.

East West Rail Western Section (committed)

The development of this section of railway will result in the introduction of direct rail passenger services from Oxford to Bedford; Milton Keynes to Oxford; and Milton Keynes to London (Marylebone) via Aylesbury. Work on Phase 1, Bicester to Oxford, was completed in December 2016, with services between Oxford and London (Marylebone) via Bicester. Work on Phase 2, Bedford to Bicester, and Milton Keynes to Princes Risborough – is underway with preliminary designs being developed further following public consultation.

Local impacts: New station at Winslow, potential new station at Steeple Clayton. The East West Rail consortium has proposed three new passenger trains per hour in each direction, bringing Oxford to Milton Keynes in 40 minutes; Reading to Milton Keynes in 84 minutes; Oxford to Bedford in 60 minutes; Reading to Bedford in 106 minutes; Milton Keynes to Aylesbury in 33 minutes; and High Wycombe to Milton Keynes in 63 minutes[8], in many cases negating the need to change trains in London. This scheme potentially frees up land for housing development (see later section). It is estimated to generate a local GVA impact of £399m, with a direct GDP impact of £183m.

National impacts: East West Rail would have a national as well as local impact.[9] The national impacts would include construction spend and the wider impacts generated by the running of through services including Cross Country services and freight traffic from Southampton to midlands northern intermodal terminals.

[7] In some cases, versions of these schemes are being promoted by organisations or individuals.
[8] East West Rail Wider Economic Case: Refresh, *Rail Expertise, 2015*
[9] East West Rail Economic Case Refresh, *Arup, 2014*

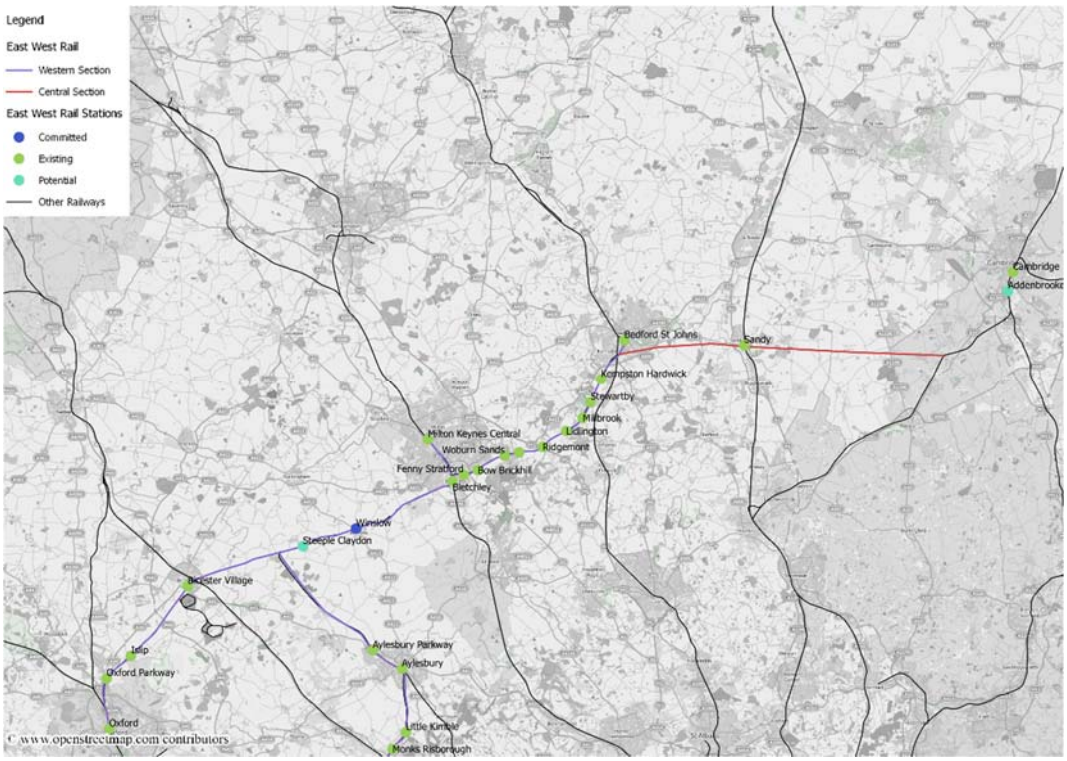
National GVA impact of £1,140m has been estimated alongside national direct GDP impacts of £522m.

Scheme cost: £734 million (Phase 1 £332 million, Phase 2 £402 million)[10].

Timeline: A target completion date for Phase 2 is expected to be confirmed by early 2017. Train services could start operating in the early 2020s, subject to securing the necessary approvals.

Current Status: Phase 1 is under construction.

Figure 12: East West Rail Western and Central Sections



Source: Open street map, Arup

East West Rail Central Section (planned)

The East West Rail Consortium is currently identifying a route to extend the Western Section to Cambridge, thus enabling train services to operate between Oxford and Cambridge, and eventually on to Norfolk and Suffolk. Part of the former railway alignment has been developed, and is therefore the most difficult and costly part of the route to reinstate. A preferred corridor via Sandy was announced in March 2016.

Local impacts: Through trains would become possible between Oxford and Cambridge. Indicative journey times between Bedford and Cambridge are 64 minutes with fast services and 77 minutes with semi-fast services[11]. The scheme

[10] East West Rail: A strategic railway connecting the Thames Valley with the South East Midlands and East Anglia, *Oxfordshire County Council, 2015*
[11] East West Rail Central Section Engineering Summary Report, *Jacobs, 2016*

provides opportunities for business to business travel by rail.[12] It also potentially frees up land for housing development (see later section), especially in the Sandy area.

Scheme cost: £1.4 billion[13]

Timeline: Under design development, possible completion in the early 2030s.

Current status: Network Rail proposes to work with the East West Rail Consortium, the Department for Transport and industry partners to establish potential funding sources for remaining development stages and construction. However the Secretary of State for Transport recently announced his intention that the line should be procured using a private sector procurement mechanism.[14]

Oxford – Cambridge Expressway (planned)

An Oxford to Cambridge Expressway Strategic Study was launched by the Government in autumn 2015. The interim report found that a new link will improve journey times by up to 30 minutes along the length of the route and support economic growth in the towns and cities on the Expressway. The new road would benefit commuters and businesses in Cambridge, Oxford, and Milton Keynes. The study is part of the government's next phase of road improvements, which will get underway from 2020 in the next road investment period (the current Road Investment Strategy period covers 2015-2020)[15].

Local impacts: This includes faster and more reliable journeys across the corridor (travel between Oxford - Milton Keynes and Cambridge - Milton Keynes in around 45 minutes) and local commuter routes into town and city centres. According to the Strategic Study, the Expressway will act as an enabler for the delivery of new jobs, homes and wider economic benefits, directly supporting the growth aspirations of the LEPs and local authorities (see later section).

National impacts: Links the strategic route network across the corridor including M1, A1, A14 and M11. Significant link to national freight routes (linking the southern ports with the M4 and M40).

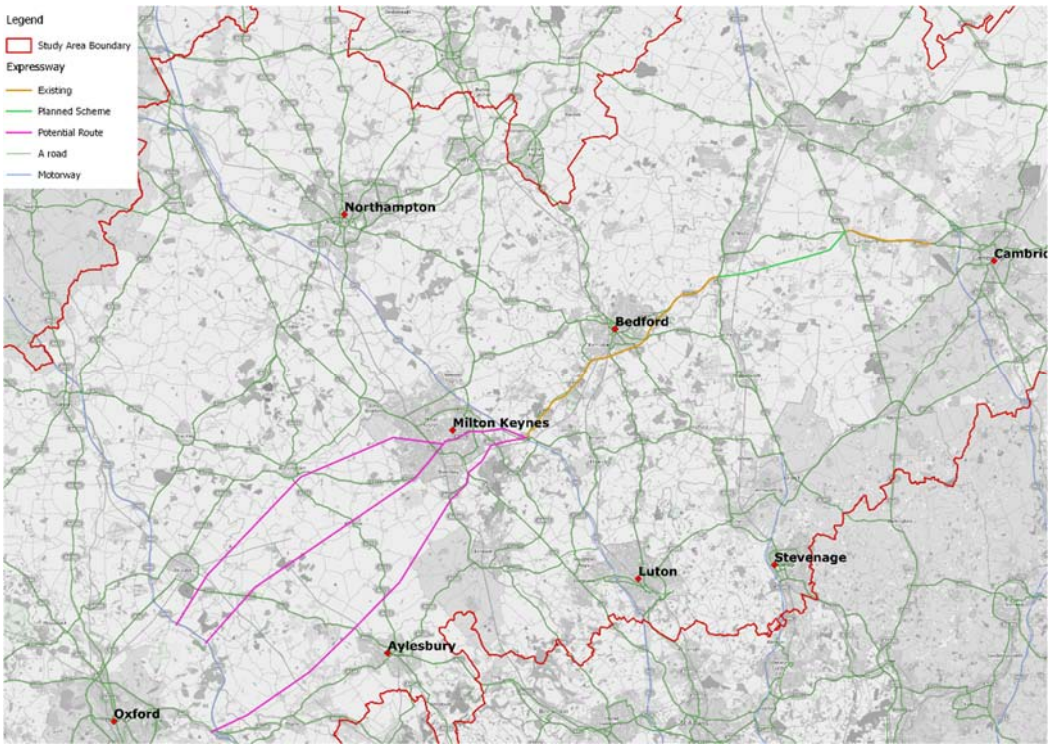
Scheme cost: £3.5bn[16].

Timeline: Interim report (a strategic case) for the Strategic Study are now available online. The study is due to be completed by late 2016.

Current status: Further proposals on the route of the Expressway are now being developed.

[12] East West Rail - Central Section Conditional Outputs Statement, *Atkins, 2014*
[13] East West Rail Central Section Engineering Summary Report, *Jacobs, 2016*
[14] The Guardian: Chris Grayling unveils plans for fully privatised rail line, *2016.* Available from: https://www.theguardian.com/uk-news/2016/dec/06/new-fully-privatised-rail-line-chris-grayling-plans-oxford-cambridge
[15] Oxford to Cambridge Expressway Strategic Study Interim Report, *WSP et al, 2016*
[16] Oxford to Cambridge Expressway Strategic Study Stage 3 Report, *DfT and Highways England, 2016*

Figure 13: Oxford - Cambridge Expressway



Source: Open street map, Arup

High Speed 2 West Coast Main Line Capacity Improvements (planned)

HS2 will relieve pressure on the West Coast Main Line which will enable local and regional services to be improved, providing increased capacity to support growth in the long distance, freight and suburban markets, alongside improvements to the service quality in terms of journey time, connectivity and frequency. To support this level of service a number of high-cost infrastructure enhancements are required.

Local and national impacts: According to the Department for Transport[17], HS2 offers the potential to operate around 60-70 per cent additional inter-city services, many of which could stop in the region. For example, there is the possibility of 12 "fast line" stops in Milton Keynes in each hour, up from around 8 per hour today, potentially offering improved links to London and national destinations. This would accommodate the increase in demand that will be generated by any improvements to journey time. At least one extra freight train per hour in each direction.

Scheme cost: £55 billion[18].

Timeline: post-2026.

Current status: Planning stage.

[17] Supplement to the October 2013 Strategic Case for HS2, *DfT, 2015*
[18] This is the cost of the HS2 scheme itself. The HS2 scheme costs enable West Coast Main Line capacity release.

Crossrail 2 (planned)

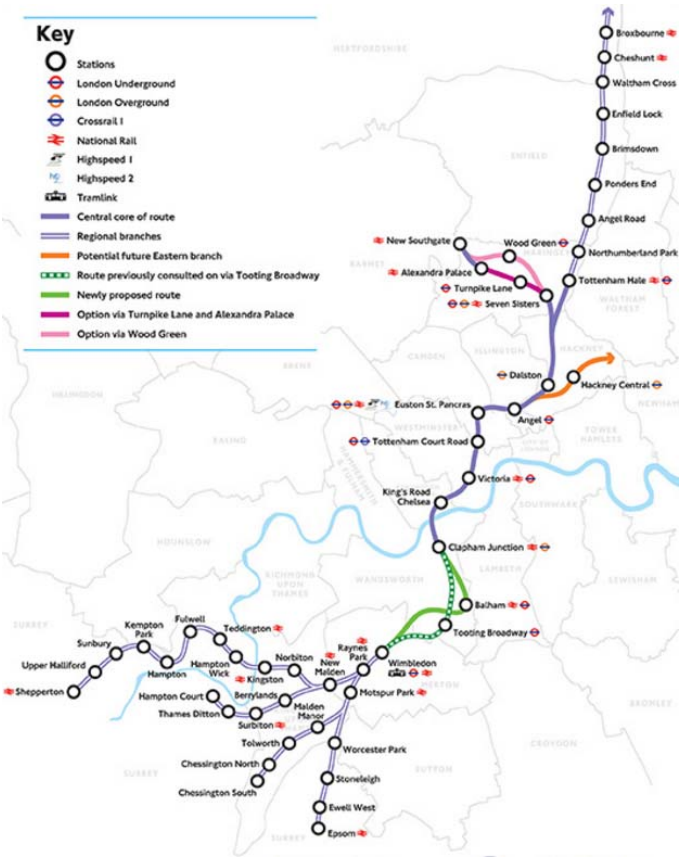
As a new railway on a north east – south west axis, Crossrail 2 will connect National Rail networks in Surrey and Hertfordshire with stations in London, including Wimbledon, Tottenham Hale, Angel, Tottenham Court Road, Victoria, Clapham Junction and Balham. Journey times across the axis will be reduced, the need to change from National Rail to London Underground (for some journeys) should decline, and capacity will be added to the central London and regional rail network. In terms of economic impacts, the scheme will support around 200,000 jobs and the delivery of 200,000 new homes.[19]

Local Impacts: The scheme is predominantly out of the study area but it will be vital in the unlocking of around 10,000 homes in East Hertfordshire, with housing sites in areas such as Broxbourne and Cheshunt likely to be brought forward. Crossrail 2 will provide new capacity for up to 270,000 more people travelling into London in peak periods. This will relieve crowding and congestion on the current network, and in particular on the West Anglia Main Line which serves Cambridge.

Scheme Cost: Up to £32 billion.[20]

Timeline: Potentially operational by 2030.

Figure 14: Crossrail 2 route



Source: http://crossrail2.co.uk/

[19] From http://crossrail2.co.uk/
[20] Ibid

4.3 Future transport packages

This section presents the transport infrastructure investment to unlock growth, jobs and housing within the Cambridge-Milton Keynes-Oxford study area over the period to 2050. The packages are presented by sub-area aligned with the housing and employment forecasts. Two sets of packages, focused on inter-urban connectivity and radial routes to London are also outlined. The future transport packages are assembled for the baseline, incremental, and transformational scenarios.

The full results of the assessment of schemes against the sift criteria is shown in Appendix A.

Table 8: Summary of transport capital costs, by scenario

Transport investment package - Summary	Cost (£m)	Cumulative Cost (£m)
Baseline scenario	**12,534**	**12,534**
of which national schemes	10,548	10,548
local schemes	1,985	1,985
Incremental scenario	**+44,127**	**56,660**
of which national schemes (including Crossrail 2)	41,778	52,326
local schemes	2,349	4,334
Transformational scenario	**+56,580**	**113,240**
of which national schemes (including HS2)	55,400	107,726
local schemes	1,180	5,514

Source: Arup

The transport strategy works across all three scenarios. The speed of delivery alters according to the scenario chosen, with the baseline scenario representing the slowest rate of build, and transformational representing the fastest. From a national perspective it was important to assess the combined schemes potential impact to drive economic growth outside of London and to alleviate development pressures and unmet demand where that exists in residential or employment land and to contribute to delivery of a coherent transport and growth strategy.

By applying the sift evaluation process, packages support better connectivity for existing and new areas of housing with increased growth in jobs in the three main labour market areas of the central area of Milton Keynes – Northampton – Bedford – Wellingborough, Cambridge, and Oxford. These are areas that are forecast to grow most substantially over the coming years. This results in an infrastructure investment strategy in the period to 2050, in broad order of priority:

- **Intra-urban networks in the major urban centres** of Cambridge, Milton Keynes, Northampton and Oxford.

  This includes packages of improvements to reduce congestion and increase access to the labour market, with the centrepiece being integrated and high quality rapid transit systems. Given the anticipated fast growth in population and jobs, there is a case for making Milton Keynes, Northampton and

Cambridge the overall priorities for investment (the city of Montpellier and other cities, provide examples of an effective transport scheme operating in a historic university city with a high concentration of knowledge based jobs – see case study in Section 4).

- **Investment in inter-urban links in the Milton Keynes – Northampton – Bedford – Wellingborough area** to strengthen its functioning as a single labour market.

  This includes supporting new housing development sites in Northampton, Daventry and Wellingborough with improved road connections and improvements to bus services on the main corridor linking the three centres.

  This is in the strategy because of the potential for wider economic benefits through servicing the central area, the high levels of congestion on the approaches to central area towns, and the high levels of housing and jobs growth expected in Milton Keynes and Northampton.

- To **provide effective orbital links** it is essential to commit to some higher value transformational schemes including East West Rail and the Expressway.

  These are important to provide opportunities for specialisation benefits by linking centres with similar business sectors and to free up additional land for housing schemes on strategic sites between centres, for example around stations.

  Both the Oxford-Cambridge Expressway, and the East West Rail scheme will have environmental impacts, and knock on effects on the wider transport network. These will need to be considered in a full project appraisal. The section of the Expressway that links Milton Keynes to Cambridge is already committed under RIS1.

With all of the above schemes, it is likely that effective network management based on data analytics will be required as part of a wider transport strategy to manage transport infrastructure to eliminate congestion and enable seamless connected journeys.

The transport packages proposed in this section reflect current policy on housing and jobs growth in the area. If a significant shift in housing policy towards a new town, or an increase in London-centric growth, or a significant change in London housing policy becomes apparent, the strategies will need to be re-examined as part of this alternative transformational scenario.

4.3.1 Sub Area Packages

Greater Cambridge-Northern Hertfordshire area

Baseline

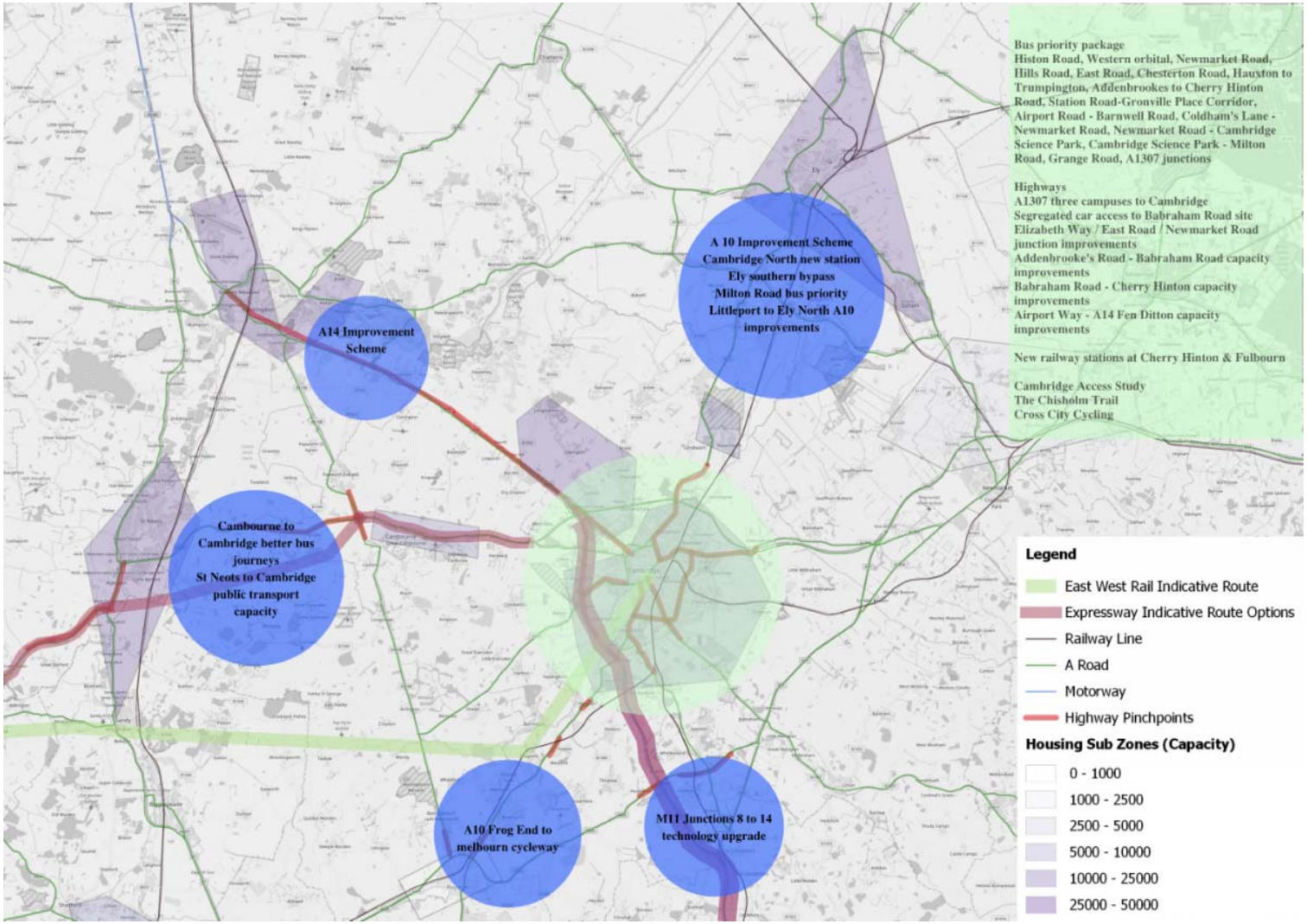
The baseline transport interventions support projected population and employment growth of just under 246,000 and around 86,000 respectively by 2050 (from a

baseline of 2016) in the Greater Cambridge and Northern Hertfordshire sub area. The interventions include a significant number of already committed schemes adding up to investment of just over £1.9bn. This includes £1.2bn for the A14 Cambridge-Huntingdon improvement scheme which enables significant development along the corridor. The remaining £0.7bn is for a mixture of road improvements, public transport schemes and cycling infrastructure, which are for the most part, part of the Cambridge City Deal, required to support the planned growth in employment and population in the sub area. The capital expenditure:

- Enables housing sites along the A14 corridor between Huntingdon and Cambridge by alleviating existing congestion, whilst also improving safety, providing better pedestrian facilities and minimising effects on the local environment and community;
- Tackles road congestion in Ely with the southern bypass, improving accessibility and journey times to support housing growth north of Cambridge;
- Reduces congestion on the M11 through improved incident detection and automatic signalling to improve journey time reliability;
- Delivers Cambridge North Station to alleviates pressure at Cambridge rail station, improve access to the science and business parks from the City and provide access from new housing north and south of Cambridge.

The baseline scenario for Cambridge is illustrated in Figure 15 and the package of interventions to enable the forecast growth is summarised in Table 9.

Figure 15: Baseline scenario –Cambridge



Source: Open street map, Savills, Arup

Table 9: Cambridge – Baseline schemes

BASELINE SCENARIO – transport investment package - Cambridge	Cost (£m)
A14 Cambridge to Huntingdon Improvement Scheme	1,200.0
Cambridge North New Station	50.0
Ely Southern Bypass	35.0
M11 Junctions 8 -14 Technology Upgrade	30.0
St Neots to Cambridge PT capacity	3.5
Madingley Road Bus priority	34.6
A428 to M11 segregated bus route / A428 corridor Park & Ride	24.5
The Chisholm Trail	8.4
Cross City Cycling - five projects north east and south of Cambridge - key links to cycle routes across the city	22.6
Milton road bus priority scheme	23.0
Histon road bus priority scheme	4.3
Cambridge access study - eight-point plan to tackle congestion	2.6
Western Orbital - bus priority scheme	9.0
A1307, three campuses to Cambridge	39.0
Improve accessibility of Babraham Road site through provision of segregated car access	1.5
Consideration of a new railway station at Cherry Hinton	50.0
Consideration of a new railway station at Fulbourn	50.0
Newmarket Road bus priority scheme	11.9
Hills road bus priority scheme	25.8
Chesterton Road bus priority scheme	10.0
East Road bus priority scheme	10.0
Hauxton to Trumpington bus priority scheme	15.8
Busway between new Hauxton P&R site and Trumpington P&R	33.1
Inbound bus lane between Addenbrooke's and Cherry Hinton Road	18.7
Comprehensive bus priority between Station road and Gonville Place	5.0
Busway between Airport Way and Barnwell Road	5.0
Busway parallel to M11 corridor	5.0
Busway linking Coldham's lane to Newmarket road	18.7
Busway linking Newmarket road to Cambridge science park station	64.7
Busway linking Cambridge science park station to Milton road	5.0
Highway capacity between Addenbrooke's Road and Babraham Road	4.0
Higway capacity between Babraham road and cherry hinton - including tunnel under the Gogs	4.0
Highway capacity between Airport Way and the A14 Fen Ditton Junction	4.0

BASELINE SCENARIO – transport investment package - Cambridge	Cost (£m)
Elizabeth Way - East Road - Newmarket Road junction, remodelling to improve priority for buses, cyclists and pedestrians at grade	10.0
Grange Road bus priority	10.0
Bus priority at key congestion points on A1307	36.0
Royston Rail Crossing	0.0
A428 Trunk Road	3.5
A505 - A11 - A1304 route	3.5
Bourn Airfield	0.0
A10 Growth Corridor Littleport to Ely North	30.0
A10 South Cycle Super Highway	3.7
Subtotal Cambridge	**1,925.4**

Incremental

The housing supply in the Greater Cambridge-Northern Hertfordshire area grows by just over 169,000 units and employment grows by c.197,00 jobs in 2050 (from 2016). The incremental scenario includes £474 million additional capital expenditure on transport infrastructure to support the higher rate of house building and respond to the higher rate of economic growth.

The incremental scenario supports the higher rate of housing growth by unlocking development at additional locations within the sub area. The additional expenditure responds to employment growth by enhancing connections to employment growth areas. In particular the expenditure supports:

- Improved connectivity in Cambridge south with the provision of Addenbrooke rail station, relieving congestion and supporting the development of nearly 10,000 new homes;
- Improved capacity north of Cambridge with the Ely-Soham rail track doubling to enable more capacity for rail services to serve the additional demand from Soham station and its surrounding development; and
- Relieves rail overcrowding in the peak hour between Kings Lynn and Cambridge, particularly between Ely and Cambridge through the Kings Lynn-Cambridge 8-car project, thus improving journey time reliability and supporting housing growth of around 4,000 units around Soham station.

The need for investment

Additional transport investment within Cambridge and its employment hinterland would help to overcome the constraints of existing road congestion and poor public transport connectivity. It would also better link its job opportunities to residential areas. This has the effect of increasing the labour catchment that businesses can recruit from and thus supporting growth and productivity improvements. This will support the high forecast knowledge-based jobs growth in Cambridge.

The importance of this approach is highlighted in many of the call for evidence submissions, which identified the benefits of investment to target pinch-points at key junctions around the cities of Cambridge and Oxford to better connect them with their local housing and employment markets. They highlighted that some deprived areas around growth hubs such as Cambridge would also benefit from such investment.

The responses also point out the need for local upgrades to complement more strategic improvements which will better connect the existing local housing and employment markets and play an essential part in realising the full benefits of increased connectivity along the corridor.

The England's Economic Heartland position statement highlighted that better transport interchanges and strategic 'first mile/last mile' connectivity will allow transport systems to work as proper networks, providing improved connectivity to other major centres of growth for all localities throughout the area. It recommended that shorter distance journeys are catered for through a combination of local infrastructure schemes unlocking urban congestion hotspots and the promotion of sustainable transport and smarter choices measures.

Incremental scenario transport package

The significant number of schemes delivered in the baseline scenario will go some way to addressing current road pinch points and to improving bus services at specific locations by implementing segregated busway sections, although it does not provide infrastructure at all potential new housing and employment sites. Additional growth in the incremental scenario in Cambridge will put additional pressure on the transport system and require additional infrastructure.

With limited space in the city, environmental constraints and a sensitive historic centre there is little scope to provide additional road capacity into the city's employment centres to connect more people to knowledge based jobs.

The experience of cities overseas such as Montpellier suggests that this can be overcome, and can generate positive impacts on employment, housing and city image – as shown in the case study below.

Case study: Montpellier

Example: Transportation systems in historic cities - Montpellier

Background

Montpellier is a little larger than both Oxford and Cambridge, with around 250,000 inhabitants. With 8% population growth between 2008 and 2013, this young[21] city is one of the fastest growing of France, attracting people for its quality of life and environment. Montpellier's local economic structure is dominated by the service sector which counts almost 90% of the total employment. Its local economy is characterised by a high level of SMEs and a well-developed health services cluster. Montpellier also has a large university, digital economy (including French Tech and other digital clusters), bio-industries and agriculture, and cultural, tourism and sports industries.

Montpellier's inner city transport provision in the early 2000 was similar to the ones of Oxford and Cambridge today. Montpellier's historic city centre was congested by cars and buses, and suburban towns were poorly connected to the city centre, which created particular congestion on the main city entrances. There was an unmet demand for housing due to the fast growing rates of the city, and some areas were suffering from social segregation. Launched by the flamboyant and controversial former mayor of the city, Georges Freches, Montpellier's transport strategy was intended as a lever to address these issues.

Table 10 below provides a comparison of socio-economic statistics for Montpellier, Oxford, Milton Keynes and Cambridge.

Table 10: Socio-economic comparisons; Montpellier and study area

City	Jobs	Knowledge-based jobs	% knowledge-based jobs	Population	Knowledge based jobs as % of pop.
Montpellier	124,765	26,169	21%	272,000	9.6%
Oxford	130,000	82,300	62%	160,000	51%
Milton Keynes	181,000	81,300	45%	262,000	31%
Cambridge	105,000	72,400	69%	131,000	55%

Source: INSEE, 2013 population census; ONS, Annual Population Survey; Cambridge Econometrics

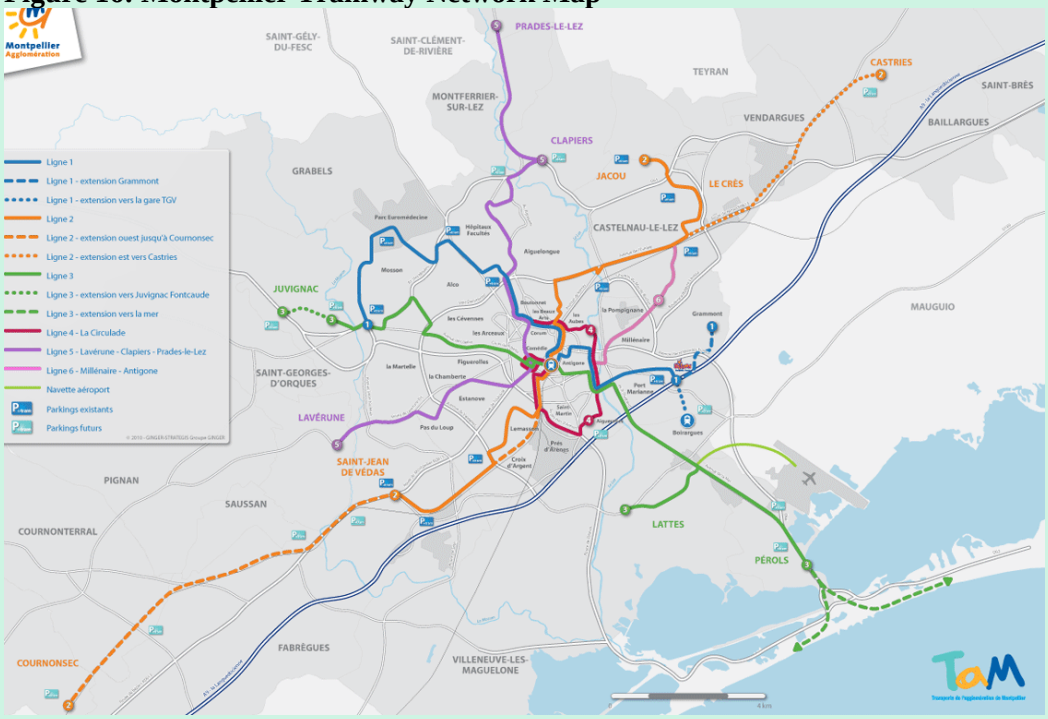
Transport

The Montpellier tram network opened in 2000, and now comprises four lines and 56km of route, with a further seven planned. A recent urban mobility plan highlighted the need for high quality public transport as a reason to stem the dominance of the car[22], and used this to justify, in part, the case for additional tramway extensions. The most recent lines (lines 3 and 4) represented a €530m investment, with over half funded by the city (€369m), and the remainder by the French national state (€83m), the region (€50m) and the regional government (€28m).

[21] Half of the population is below 35 years old
[22] Montpellier Plan de Déplacements Urbain, 2010-2020.

Complementing the tram network are a network of feeder bus lines and bicycle stations. Over 300,000 journeys per day, including 43,000 commuters from outside the metropolitan area, are made on the network. Many of these commutes are long distance, with half of them travelling more than 28km a day, compared to a 9km average travel distance for inhabitants of the metropolitan area.

Figure 16: Montpellier Tramway Network Map



Source: Tam in Perspectives des transports

Impact on economy and housing

The tramway has increased demand for housing along the lines and has reportedly added a +5% value increase per year to properties located nearby stations[23].

The tram has acted as a tool to limit urban sprawl and increase densification[24], supporting the city strategy to increase density along public transportation links. The tram has indeed encouraged the building of large scale new housing developments (Malbosc, Prés d'Arènes) and redevelopment of deprived neighbourhoods (Petit Bard, Mosson) nearby stations. The tramway has also increased connectivity to towns of the metropolitan area and relieved congestion from the main road accesses to the city centre. As such, it is reported to have resulted in a 10% reduction in car use, as well as lower energy consumption resulting in a 23% reduction in greenhouse gas emissions by 2020.

The tram has revitalised the city centre through increasing daily flows by 11% per year between 1997 and 2009 at the entrance of the main shopping mall, near tram line 1 station, compared with the city centre increase of only 1% per year[25] (although there was reported to be a more limited impact after the opening of the second line).

[23] FNAIM de l'Herault.
[24] Montpellier Plan de Déplacements Urbain, 2010-2020.
[25] Direction Etudes & Observatoire Economique *Enquête, 2009,* Chambre de Commerce et d'Industrie de Montpellier, *Elodie Averous, 2010*.

Montpellier shows how investment in transport infrastructure can be undertaken in an historic city centre, and integrated into a broader housing redevelopment and local regeneration strategy.

It is therefore important for the incremental scenario to provide additional public transport capacity into the city. This involves further upgrades to the rail service and delivery of an integrated and high quality rapid transit network across the city to support the additional growth.

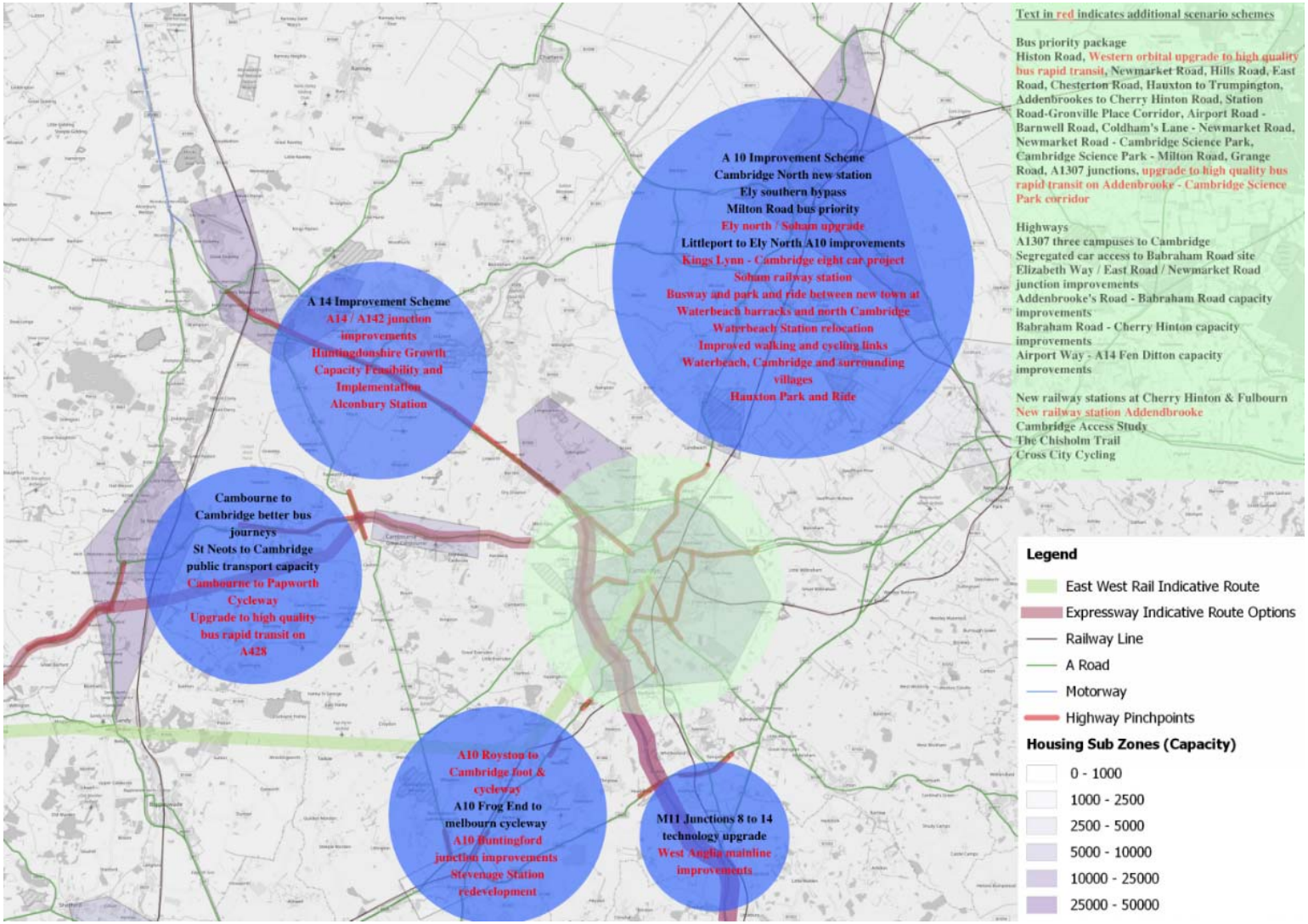
The incremental scenario therefore involves delivery of planned rail improvements that provide additional capacity to support growth. For example, the station at Addenbrooke serves just under 10,000 new homes in the south of the city and the new station at Soham a further c.4,000 homes to the north of the city.

The Ely to Soham doubling and Kings Lynn-Cambridge 8-car project enable the rail services to have additional capacity to carry the additional demand from these stations.

Our further recommendation is to upgrade existing bus services to a bus rapid transit system in line with the principles set out in the example below, to accommodate the additional transport demand in the incremental scenario. For example, just over 19,000 homes could be supported by a good public transport system in the Cambourne corridor that links to jobs in Cambridge city, and nearly 25,000 homes in the western orbital (M11) corridor. This would unlock significant housing development in the city and provide sustainable connections to knowledge based jobs in the city.

The incremental scenario for Cambridge is shown below, with the incremental schemes listed in red to differentiate them from the baseline schemes. The package of schemes is summarised in Table 11.

Figure 17: Incremental scenario - Cambridge



Source: Open street map, Savills, Arup

Table 11: Incremental scenario – Cambridge

INCREMENTAL SCENARIO – transport investment package - Cambridge	Cost (£m)
Baseline schemes Cambridge	1,925.4
A10 Royston to Cambridge foot & cycleway	7.0
A505 transport corridor study	0.9
A14/A142 junction improvements	3.5
Ely North junction/Soham upgrade	10.0
Addenbrooke Railway Station	50.0
Kings Lynn Cambridge 8 car Project	50.0
Soham Railway Station	50.0
Ely area rail improvements GRIP 1-5 studies	10.0
Cambourne to Papworth cycleway	10.0
Busway between new town at Waterbeach barracks and north Cambridge	46.0
A10 Waterbeach park and ride	12.0
Improving cycling and walking links between new town at Waterbeach barracks, Cambridge and surrounding villages	12.0
A10 Hauxton park and ride	17.0
Huntingdonshire Growth Capacity Feasibility and Implementation	11.0
Waterbeach railway station relocate to better serve Waterbeach development	50.0
Alconbury station	50.0
Upgrade to high quality bus rapid transit system on A428 (Cambourne) corridor	35.0
Upgrade to high quality bus rapid transit system on western orbital (M11) corridor	25.0
Upgrade to high quality bus rapid transit system on Addenbrooke to Science Park corridor	25.0
Subtotal Cambridge (inclusive of baseline)	**2,399.8**

Transformational

The transformational scenario supports growth in the Cambridge area of just under 220,000 households and around 284,000 jobs by 2050 (from 2016). Additional investment of £550 million builds upon the committed, planned and new schemes identified in the previous scenarios to support the faster rate of growth. This includes provision for further enhancements to train service frequency between Ely, Waterbeach and Cambridge to provide a metro-style (4 trains per hour) service for passengers, connecting additional housing areas with knowledge based jobs in Cambridge employment zones.

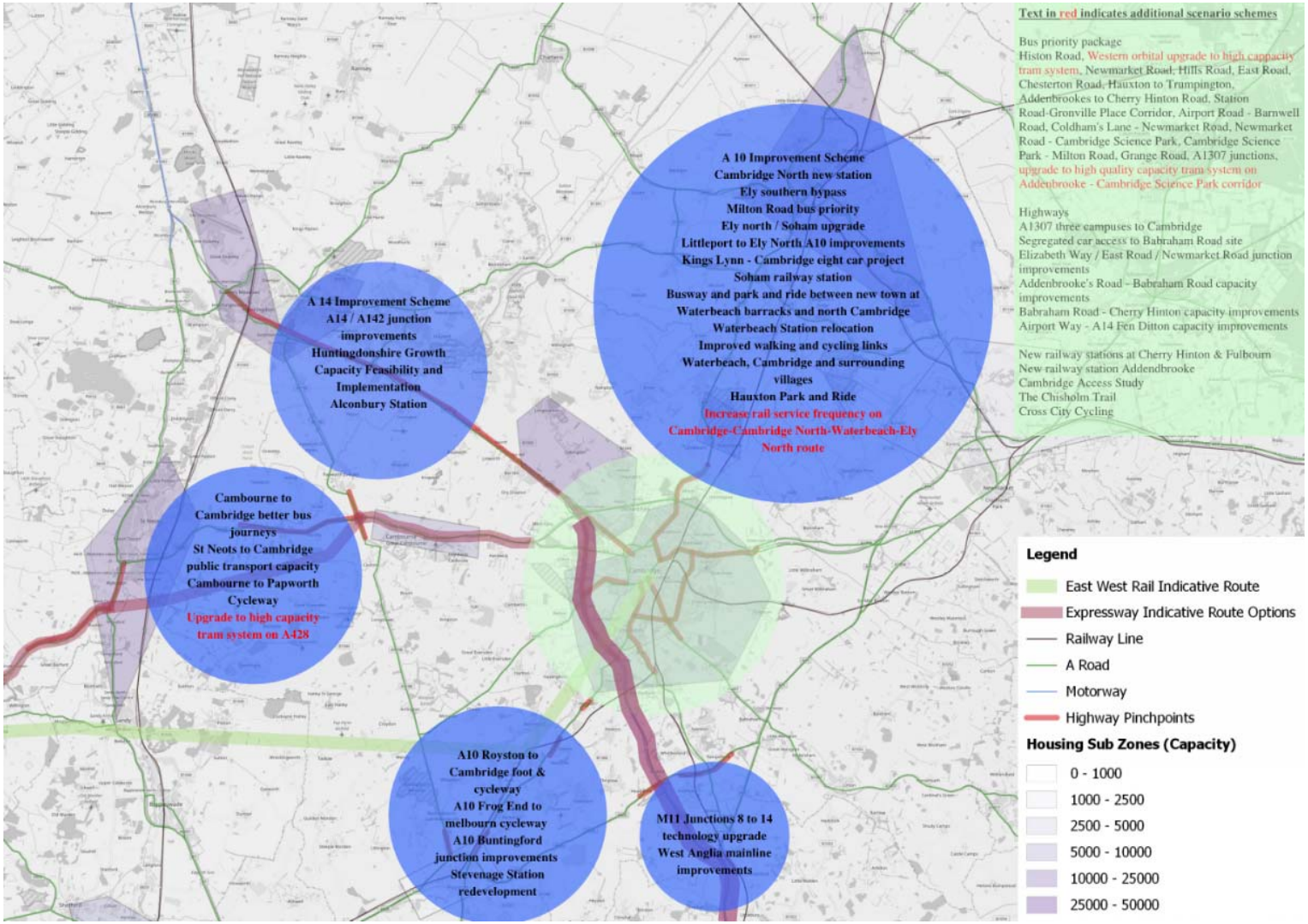
It also includes light rail schemes in place of the bus transit schemes under the incremental growth scenario to respond to the faster growth in demand in the transformational scenario and additional capacity and quality of service as the

implementation of high quality public transport services in the city attracts more ridership.

This will provide a high level of public transport service in and around Cambridge, reducing the need to use a private car and providing equitable access to jobs in the city centre and science park.

The transformational scenario for Cambridge is shown below, with the transformational schemes listed in red to differentiate them from the baseline and incremental schemes. The package of schemes is summarised in Table 12.

Figure 18: Transformational scenario – Cambridge



Source: Open street map, Savills, Arup

Table 12: Transformational scenario - Cambridge

TRANSFORMATIONAL SCENARIO – transport investment package - Cambridge	Cost (£m)
Baseline and incremental schemes Cambridge	2,399.8
Increased rail service frequency on Cambridge-Cambridge North-Waterbeach, Ely North route	200.0
Upgrade to high capacity tram system on A428 (Cambourne) corridor	150.0
Upgrade to high capacity tram system on western orbital (M11) corridor	100.0
Upgrade to high capacity tram system on Addenbrooke to Science Park corridor	100.0
Subtotal Cambridge (inclusive of baseline and incremental)	**2,949.8**

Milton Keynes – Greater Northampton Area

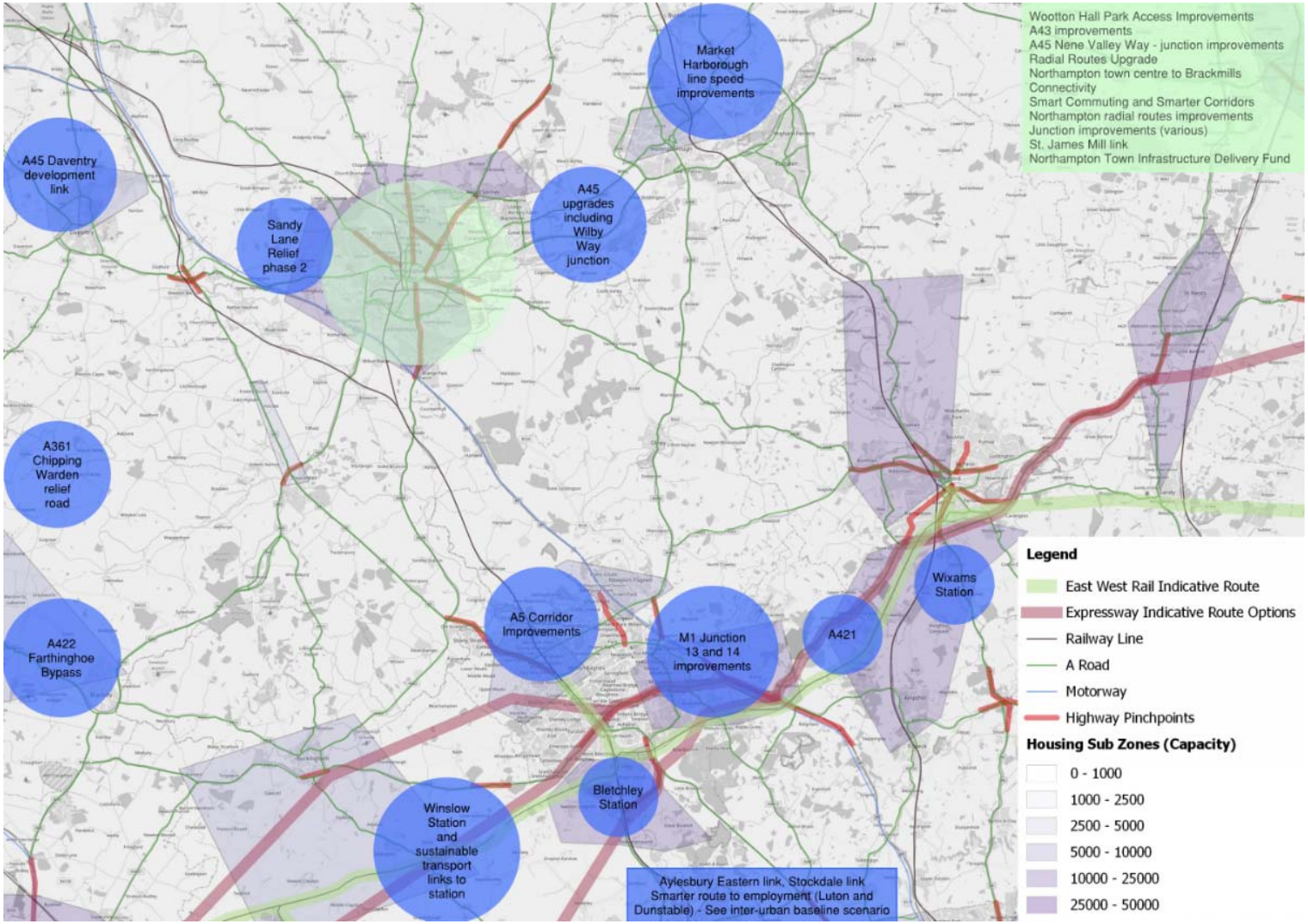
Baseline

The baseline scenario projects growth in the Milton Keynes-Northampton area of around 193,000 households and nearly 104,000 jobs by 2050 (from 2016). Investment in committed schemes adding up to just over £178 million responds to the forecast growth in the baseline scenario. This includes rail improvements, such as the development of a high quality gateway at Bletchley Station to enable access to East West Rail improving access between housing growth in the area and employment growth in the remainder of the corridor, and road schemes including the A45 Daventry link which unlocks major housing development in the area.

The investment also addresses existing pinch points and enhances public transport improvements to improve journey time reliability. The investment supports economic growth in the area and responds to the increased demand for access to employment.

The baseline scenario for Milton Keynes-Northampton is illustrated below, and the package of schemes in summarised in Table 13.

Figure 19: Baseline scenario – Milton Keynes – Greater Northampton



Source: Open street map, Savills, Arup

Table 13: Baseline scenario – Milton Keynes – Greater Northampton

BASELINE SCENARIO – transport investment package – Milton Keynes – Greater Northampton	Cost (£m)
A45 Daventry Development Link Road	32.0
Bletchley Station	1.5
Iver, Taplow and Winslow stations	0.7
Sandy Lane Relief Road Phase 2	5.4
Smart Commuting	2.3
Smart Corridors (Local Sustainable Transport Scheme)	9.0
Wootton Hall Park Access Improvements	2.6
Improvements to the A43 in Northampton	20.8
A361 Chipping Warden relief road	2.0
A422 Farthinghoe Bypass consultation	11.0
A45 Nene Valley Way - junction improvements between Great Billing and M1 J 15	7.8
Upgrade of Northampton radial routes - Lumbertubs Way, Kingsthorpe Corridor and connections through to Dallington Grange / Kings Heath	3.2
Northampton town centre to Brackmills Connectivity	2.0
Abington Street / Kettering Road / Wellingborough Road Gyratory	2.0
Bedford Road / Cliftonville Road	2.0
Bedford Road / Victoria Promenade / Cheyne Walk / York Road / Billing Road	1.0
Billing Road / Alfred Street / Cliftonville Road	2.0
Gas Street Roundabout	2.0
Harlestone Road/Sandy Lane Improvement North	1.0
Kettering Road / Round Spinney	3.0
M1 Junctions	3.5
North Grafton Highway (junction of the A5 and H5/A509)	4.0
Regents Square	1.0
Spencer Bridge Road / St Andrews road / Grafton Street	2.0
The Plough Gyratory	1.2
Towcester Road / St Leonards Road / London Road / Cotton End	2.0
Upton Way / Weedon Road Roundabout	2.0
Weedon Road / Spencer Bridge Road / Harlestone Road	2.0
Wellingborough Road / St Edmunds Street	2.0
Sustainable Transport Links to East West Rail's arrival in Winslow	1.0
Joining up St. James Mill Road	0.6
A45 Northampton to Wellingborough - upgrades including the Wilby Way roundabout	3.2
A43 Abthorpe roundabout improvement scheme	7.0

BASELINE SCENARIO – transport investment package – Milton Keynes – Greater Northampton	Cost (£m)
Aylesbury Eastern Link Road and Stockdale Link	31.0
Northampton Town Infrastructure Delivery Fund	1.0
Smarter Routes to Employment projects in Luton and Dunstable	1.6
Subtotal Milton Keynes and Northampton	**178.3**

Incremental

The incremental scenario projects growth in the Milton Keynes-Northampton area of just over 193,000 housing units and nearly 215,000jobs by 2050 (from 2016). The transport infrastructure and investment to enable faster housing supply, support increase growth in employment opportunities and respond to higher economic growth amounts to an additional £444.4 million investment in the sub area.

The investment brings forward:

The north-west relief road for Northampton to reduce congestion in the north-west of Northampton, particularly relieving congestion in and around the Kingsthorpe Shopping Centre. and improve access to the motorway and other strategic roads from industry at Moulton Park, Round Spinney and Lodge Farm Industrial Estate;

Improvements to the local bus network into Northampton to help public transport provision keep pace with housing growth.

The need for investment

The Milton Keynes, Northampton, Bedford and Wellingborough area has a number of existing road congestion issues and poor public transport connectivity between centres, particularly Northampton and Wellingborough.

The area is identified in the economic analysis as most likely to benefit from transport infrastructure improvements to support planned growth of population and housing. It is an area with strong planned population and employment growth and less environmental constraints on expansion, and there is already significant local travel interaction between these centres, as well as more strategic movements between this area and London due to the existing capacity and capabilities of the north-south transport connectivity. The improvements should build on this interaction to create a strong economic centre for the growth corridor.

Many previous studies have identified this area as the ‘hub’ of the growth corridor or arc. For example, the England’s Economic Heartland Position Statement identifies Milton Keynes, Northampton and Bedford as ‘key hubs’ as they provide a focus for jobs in the local area and have good strategic connections to London.

In the Milton Keynes 2050 Vision document it is proposed to make Milton Keynes the hub of the Cambridge-Milton Keynes-Oxford arc, and suggests that this is already happening. This is supported not only by committed and planned

infrastructure improvements (e.g. East West Rail) but also by non-transport initiatives such as the plans to develop a new university under the MK:IT project.

Our view is that it should be the full Milton Keynes, Northampton, Bedford and Wellingborough box that is developed as the growth engine for the corridor. Rail links between Milton Keynes and Northampton, and between Bedford and Wellingborough already provide quick frequent connections between these centres. The initial focus should therefore be on enhancing the other sides of the box – Milton Keynes and Bedford, and Northampton and Wellingborough.

The former, Milton Keynes-Bedford, is connected by an existing rail service (although this requires travellers to change at Bletchley and incur significant interchange time penalties) as well as the A421 via the M1. East West Rail seeks to enhance the public transport connections between these centres although the proposed two services per hour frequency[26] would not achieve the quality of connection required to support growth focused on the box.

The latter, Northampton-Wellingborough, is connected by the A45 as well as the X4 and X46 bus services which provide three to four buses in each direction in the peak hour, but journey times are long. Enhanced bus provision between the centres and bus priority improvements within the centres are a potential means of achieving the quality of public transport connection required.

The Cambridge guided busway and Luton to Dunstable guided busway, mentioned earlier in this report, demonstrate that segregated off-carriageway running can achieve high frequency reliable connections that bus priority measures alone cannot achieve.

Developing schemes to achieve the same objectives as Oxford and Cambridge in the Milton Keynes – Northampton – Bedford – Wellingborough box is important. These should be high quality, segregated rapid transit schemes serving the high demand corridors to employment centres. The exact corridors and technology – LRT, BRT or bus priority – needs to be studied and developed by each local area, and should be defined by a further investigation of jobs and housing growth areas, and existing movements.

Incremental scenario transport package

To address the infrastructure deficit remaining after the baseline scenario, the incremental scenario for Milton Keynes-Northampton involves a number of planned and new schemes adding up to investment of just under £200m.

The Northampton North West Relief Road and Northampton Transport Strategy are planned schemes with a combined cost of £44m. These schemes address existing pinch points on the approaches to the town which will improve journey times and reliability, and importantly they open up nearly 10,000 homes around Northampton to support growth in the central area of the Corridor.

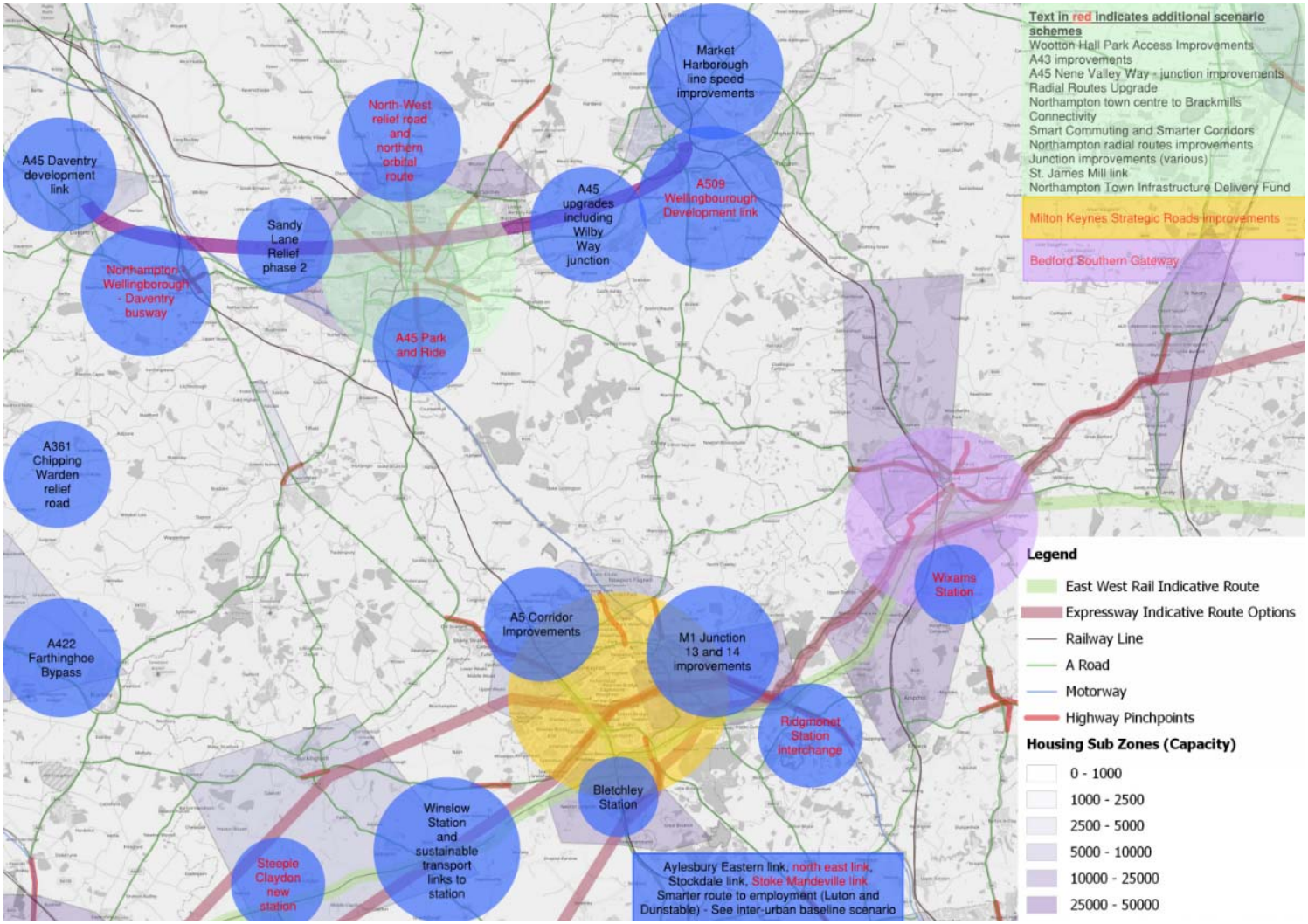
[26] One train per hour East West Rail service plus one train per hour Cross Country service (Bournemouth-Oxford-Milton Keynes-Manchester).

The remaining £155m is for two new schemes proposed by this study. The first is a proposed busway link from Daventry through Northampton to Wellingborough, to support the development of up to 24,000 homes in the area (including the 10,000 in Northampton mentioned above). Public transport provision in this area is currently poor with long journey times, and this scheme is aimed at providing rapid links from these housing areas to jobs in Northampton, and connections beyond to Milton Keynes. The second scheme proposed is to introduce a park and ride service for Northampton from M1 junction 15 to avoid the need for traffic to travel through pinch points into the town.

These schemes will provide additional public transport connectivity to unlock major housing growth opportunity areas, particularly in Daventry and Northampton, and connect them with jobs growth in Northampton and Milton Keynes centres.

The incremental scenario for Milton Keynes-Northampton is shown below, with the incremental schemes listed in red to differentiate them from the baseline schemes. The package is summarised in Table 14.

Figure 20: Incremental scenario – Milton Keynes – Greater Northampton



Source: Open street map, Savills, Arup

Table 14: Incremental scenario - Milton-Keynes-Greater Northampton

INCREMENTAL SCENARIO – transport investment package – Milton Keynes – Greater Northampton	Cost (£m)
Baseline schemes Milton Keynes - Northampton	178.3
Northampton North-West Relief Road	32.0
Northampton Northern Orbital Route	50.0
A509 Wellingborough Development Link	38.5
Milton Keynes Strategic Roads - enabling growth to 2050 and beyond	20.0
Steeple Claydon potential new station	50.0
Bedford Southern Gateway	5.1
Wixams Rail Station	30.2
Northampton-Wellingborough-Daventry Busway	150.0
Ridgmont Station interchange	8.0
PnR – A45 M1 Junction 15 to Northampton Wellingborough service as well along A45	5.0
Stoke Mandeville Outer Link Road (A413 to B4443)	23.4
Aylesbury NE Link Rd (also submitted to Large Local Transport Majors)	25.0
Grand Union Triangle "Greenways to Growth"	7.2
Subtotal Milton Keynes – Greater Northampton (inclusive of baseline)	**622.7**

Transformational

The transformational scenario projects growth in the Milton Keynes-Northampton area of just over 232,000 in housing and some 358,000 jobs by 2050 (from 2016). Investment of an additional £370 million in transport infrastructure is needed to enable new housing sites, support employment growth and respond to the increased interaction between the urban centres in the sub area.

The sub area will benefit from infrastructure schemes recommended in the Inter Urban Corridors section, such as East West Rail and the additional infrastructure investment for the sub area responds to the improve connectivity. A rapid transit link between Bletchley rail station and Milton Keynes, distributing passengers to and from the gateway East West Rail station at Bletchley responds to increased interaction between the sub areas and supports employment and housing growth in the sub area.

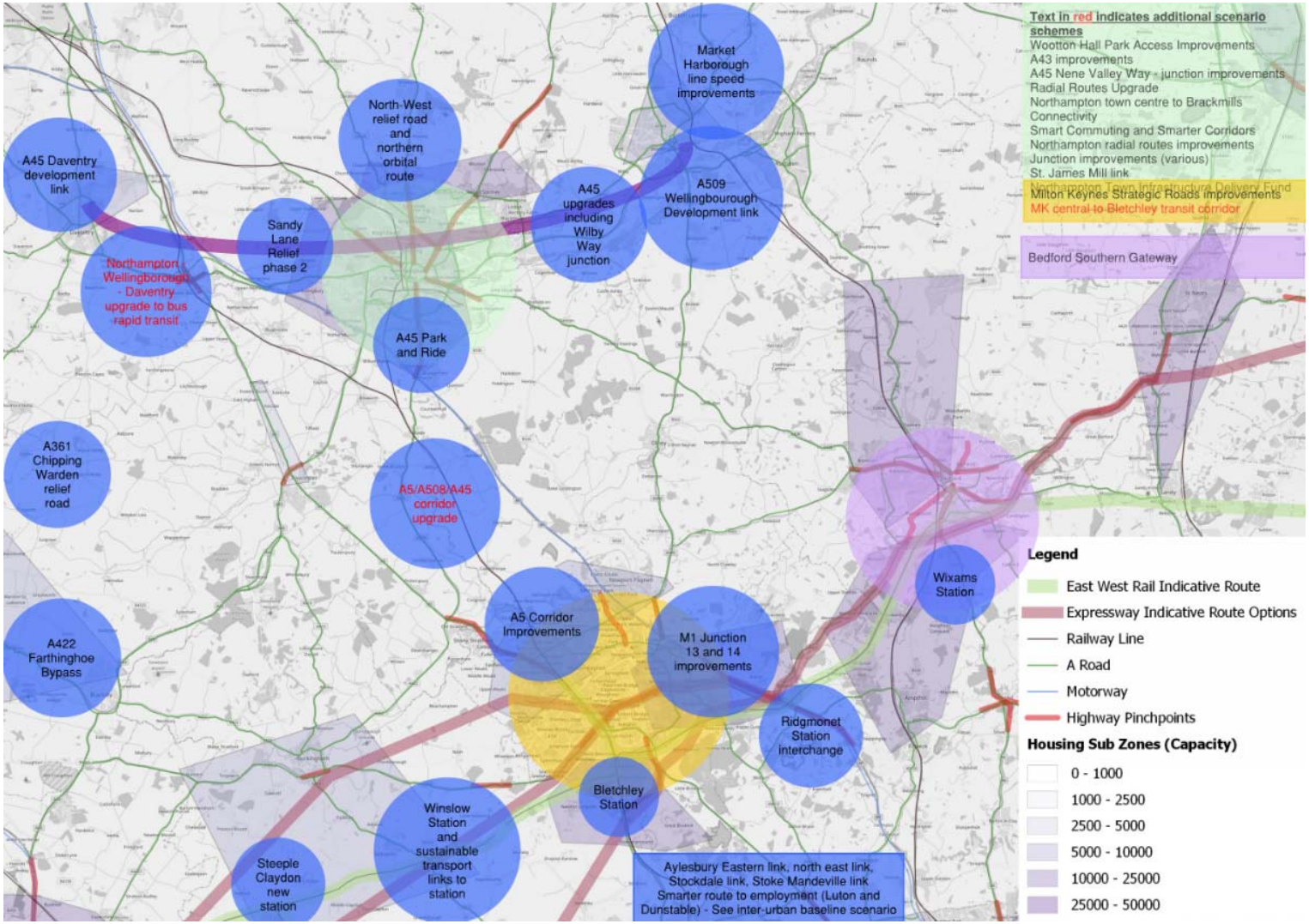
It is therefore proposed that a high frequency rapid transit service is provided, which can serve a wider range of destinations across Milton Keynes town. Given Milton Keynes's involvement in the development of autonomous vehicles, this proposal could provide an opportunity to deploy a driverless taxi-type trial project. This could support potential housing growth of around 17,000 homes in the Milton Keynes area.

The additional investment would support a full bus rapid transit system between Northampton-Wellingborough-Daventry to improve journey time reliability and

respond to increasing ridership from the faster build out of 24,000 homes in the area.

The transformational scenario for Milton Keynes-Northampton is shown below, with the transformational schemes listed in red to differentiate them from the baseline and incremental schemes. The package of schemes in summarised in Table 15.

Figure 21: Transformational scenario – Milton Keynes-Northampton



Source: Open street map, Savills, Arup

Table 15: Transformational scenario – Milton Keynes – Greater Northampton Area

TRANSFORMATIONAL SCENARIO – transport investment package – Milton Keynes – Greater Northampton	Cost (£m)
Baseline and incremental schemes Milton Keynes - Northampton	622.7
A5/A508/A45 improvements between Mk-N to provide alt route for local traffic off motorway network	20.0
MK Central – Bletchley Transit corridor (fast Bus/Tram link, potential to be suitable for AV/GRT in car as service world).	150.0
Upgrade Northampton-Wellingborough-Daventry busway to high quality bus rapid transit system	200.0
Subtotal Milton Keynes and Greater Northampton (inclusive of baseline and incremental)	**992.7**

Source: Arup

Oxford-Swindon Area

Baseline

The baseline scenario projects growth in the Oxford area of just over 134,000 in housing and some 70,000 jobs by 2050 (from 2016)[27]. Investment in committed transport infrastructure schemes of £1.8 billion enables the planned housing growth to meet the increase in population to 2050; responds to increased demand for access to employment areas and supports economic growth in the sub area.

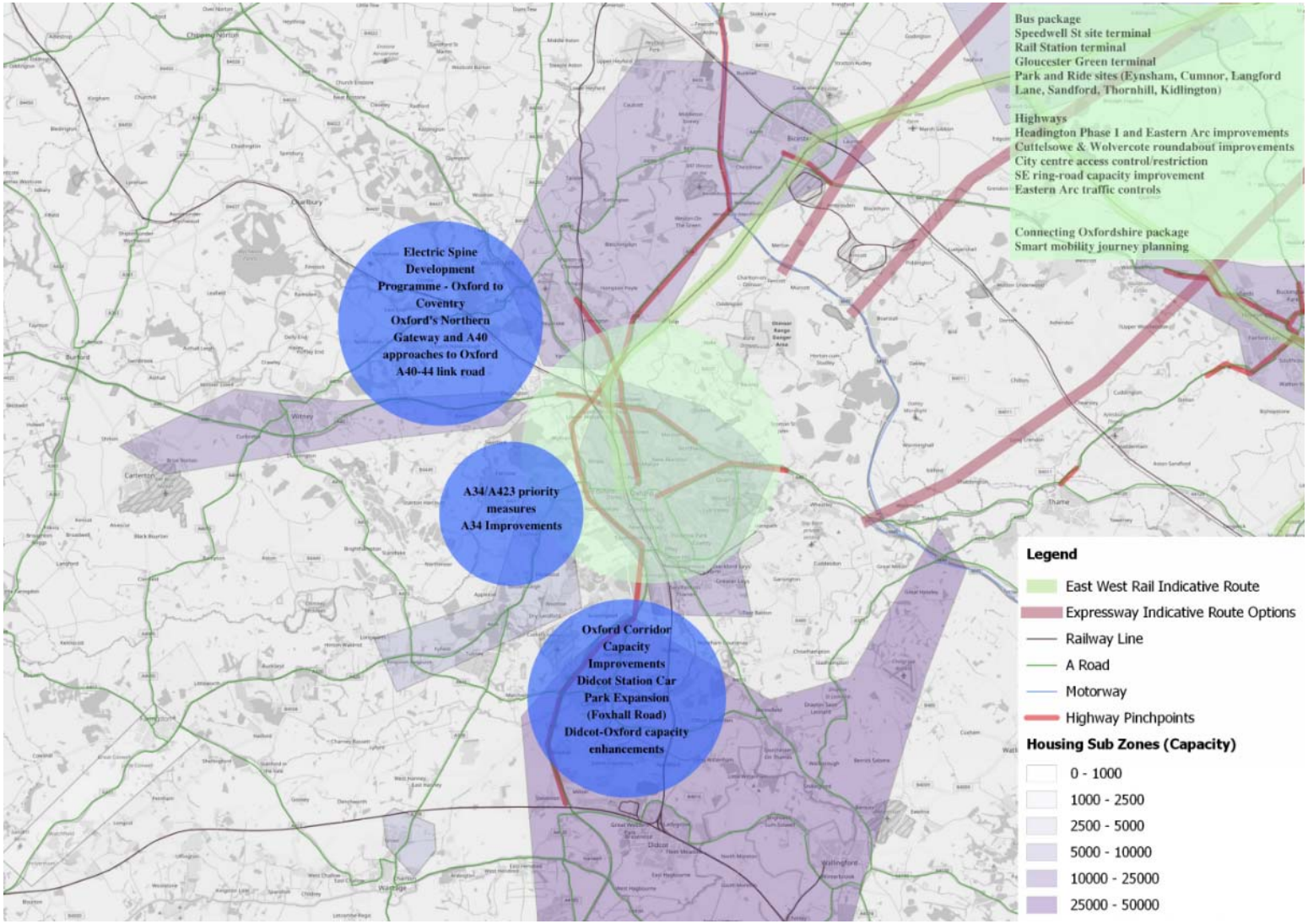
The investment includes a number of already committed schemes including £800m for Highways England's A34 improvements and £208m for the Oxford to Coventry electric spine which provides capacity benefits on this route.

It also includes £40m for the Oxford Science Transit Scheme, which expands the integrated public transport system along the Oxford Knowledge Spine, delivering major enhancements to the A40 strategic road between Oxford, Northern Gateway and Witney and connecting centres of innovation and economic growth with Oxfordshire's universities.

These schemes will significantly improve public transport services and address pinch points on the road network, particularly on the A34 through Oxfordshire. The baseline scenario for Oxford is illustrated in Figure 22 and the package of schemes is summarised in Table 16.

[27] Source: Savills

Figure 22: Baseline scenario – Oxford-Swindon Area



Source: Open street map, Savills, Arup

Table 16: Baseline scenario – Oxford-Swindon area

BASELINE SCENARIO – transport investment package – Oxford-Swindon	Cost (£m)
Electric Spine Development Programme - Oxford to Coventry	208.0
Headington Phase 1 & Eastern Arc Transport Improvements	12.5
Oxford Corridor Capacity Improvements	50.0
Oxford's Northern Gateway and A40 approaches to Oxford	11.8
Didcot Station Car Park Expansion (Foxhall Road)	13.5
Cowley Branch Line	450.0
Eynsham P&R	11.1
Cumnor P&R	11.3
Langford Lane P&R	11.0
Sandford P&R	11.4
Thornhill expansion	2.8
Kidlington P&R	11.0
A34/A423 priority measures	2.0
City centre access control/restriction	0.1
Rail station bus terminal	12.5
Gloucester green terminal	7.5
Speedwell St site terminal	7.5
Smart mobility journey planning	88.2
Cuttelsowe & Wolvercote roundabout improvements	10.0
A40-44 link road	11.8
HE A34 improvements	800.0
SE ring-road capacity improvement	12.0
Eastern Arc traffic controls	10.4
Subtotal Oxford-Swindon	**1,766.4**

Incremental

The need for investment

Oxford suffers from many of the same challenges and constraints as Cambridge. It has chronic congestion at road access points to the city and poor local public transport connectivity.

The green belt arguably restricts the city's ability to increase the supply of housing within its boundaries and it would benefit from a similar approach to that suggested in the section for Cambridge. As previously noted many of the call for evidence responses highlighted the need to target investment at resolving pinch

points and the England's Economic Heartland's position statement identified the importance of interchange and first mile/last mile connectivity.

Delivery of the baseline scenario schemes will address existing pinch points on the road network, particularly on the A34 corridor, it will improve the rail service through Oxford and provide additional road and public transport capacity on the southern spine through the Science Vale area. However, with an incremental growth scenario Oxford will require further infrastructure investment to mitigate impacts of the additional population and maximise opportunities for growing knowledge based jobs in the city.

Incremental scenario transport package

The incremental scenario projects growth in the Oxford area of nearly 220,000 in housing and some 195,000 jobs by 2050 (from 2016)[28]. Transport infrastructure investment amounting to an additional £1.1 billion supports the projected growth in housing and jobs within the sub area.

With limited space in the city, environmental constraints and a sensitive historic centre there is little scope to provide additional road capacity into the city's employment centres to connect more people to knowledge based jobs. It is therefore important for the incremental scenario to provide additional public transport capacity into the city to remove this constraint. This involves further upgrades to the rail service and delivery of sustainable and integrated transport infrastructure across the city to support the additional growth.

The planned Oxford station and Oxford-Leamington electrification scheme will increase capacity for rail users travelling to and from Oxford, particularly important for rail commuters accessing knowledge based jobs in the city centre.

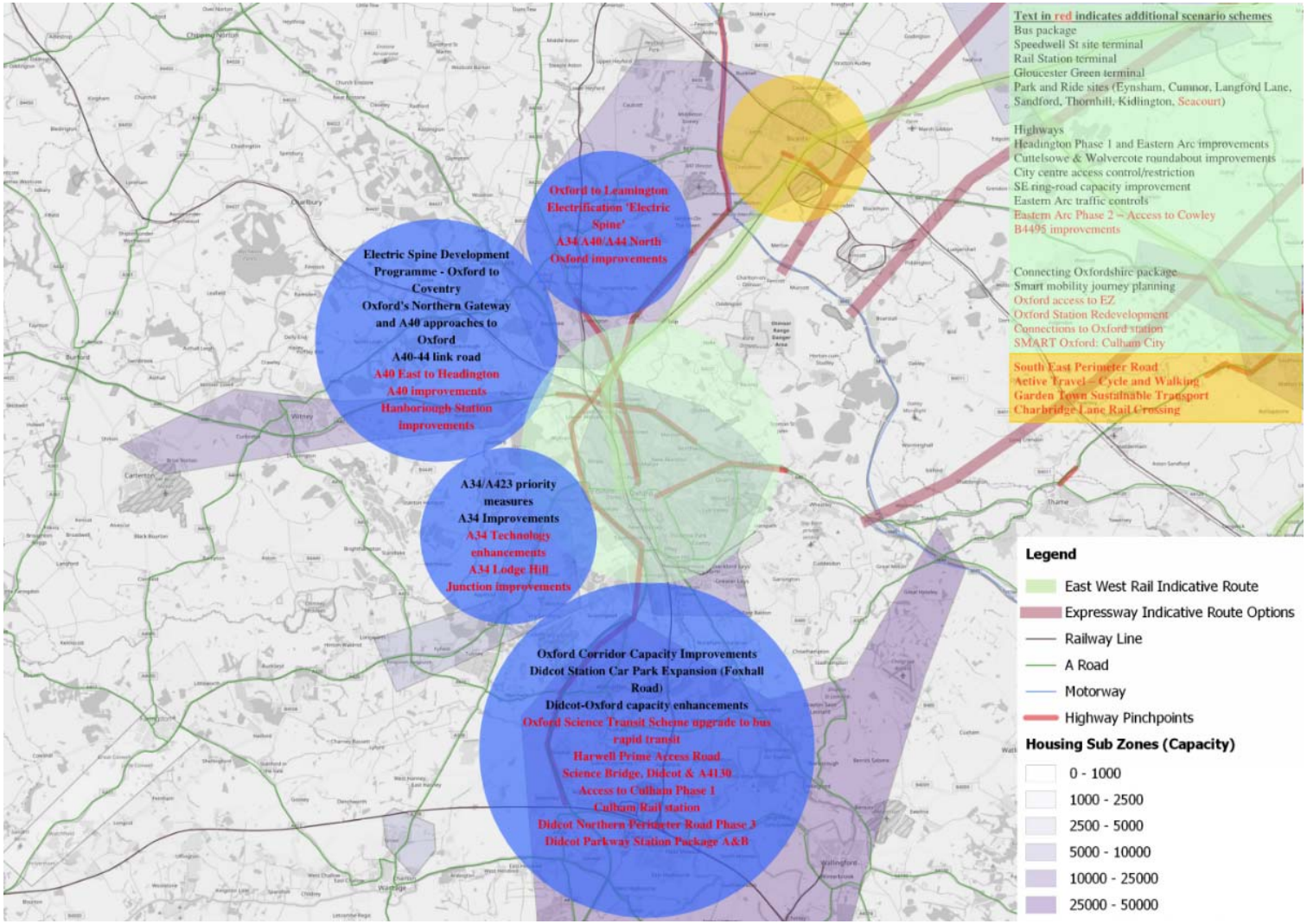
The planned Oxford Transport Strategy includes a range of schemes to provide better access to jobs in the city centre for more people. This includes improved bus services (with increased segregation), walking and cycling infrastructure and managing traffic and travel demand. This has the potential to support delivery of 18,000 new homes across the wider city, and improve access to nearly 49,000 jobs in the city centre.

The proposed upgrade of the Science Transit scheme will support the Oxford Transport Strategy by further improving the public transport spine connecting employment areas in south Oxfordshire to the city centre and beyond to housing growth in Bicester.

The incremental scenario for Oxford is shown below, with the incremental schemes listed in red to differentiate them from the baseline schemes. The package of schemes in summarised in Table 17.

[28] Source: Savills

Figure 23: Incremental scenario – Oxford-Swindon Area



Source: Open street map, Savills, Arup

Table 17: Incremental scenario – Oxford-Swindon area

INCREMENTAL SCENARIO – transport investment package – Oxford	Cost (£m)
Baseline schemes Oxford	1,766.4
Oxford Science Transit Scheme	40.0
A34 Technology Enhancements	25.0
Oxford access to EZ	28.8
Oxford Station Redevelopment	75.0
Oxford to Leamington Electrification 'Electric Spine'	208.0
A34 North Oxford	2.1
A40 East to Headington	2.1
A40 into Oxford from West	54.0
A40 North Oxford	10.0
A44 North Oxford	3.5
B4495 improvements	2.0
Science Bridge, Didcot & A4130	53.4
Access to Culham Phase 1	15.8
SMART Oxford: Culham City	88.2
Seacourt Park & Ride	2.1
Bicester Charbridge Lane Rail Crossing	17.7
Culham Rail station	13.1
Didcot Northern Perimeter Road Phase 3	12.5
A34 Lodge Hill Junction	31.5
Bicester South East Perimeter Road	28.5
Hanborough station	8.0
Harwell Prime Access Road	29.0
Didcot Parkway Station Package A&B	175.0
Eastern Arc Phase 2 – Access to Cowley	10.4
Connections to Oxford station	13.9
Bicester Active Travel – Cycle and Walking Bicester Garden Town Sustainable Transport	7.7
Upgrade of Oxford Science Transit to high quality bus rapid transit system	175.0
Subtotal Oxford (inclusive of baseline)	**2,900.7**

Transformational

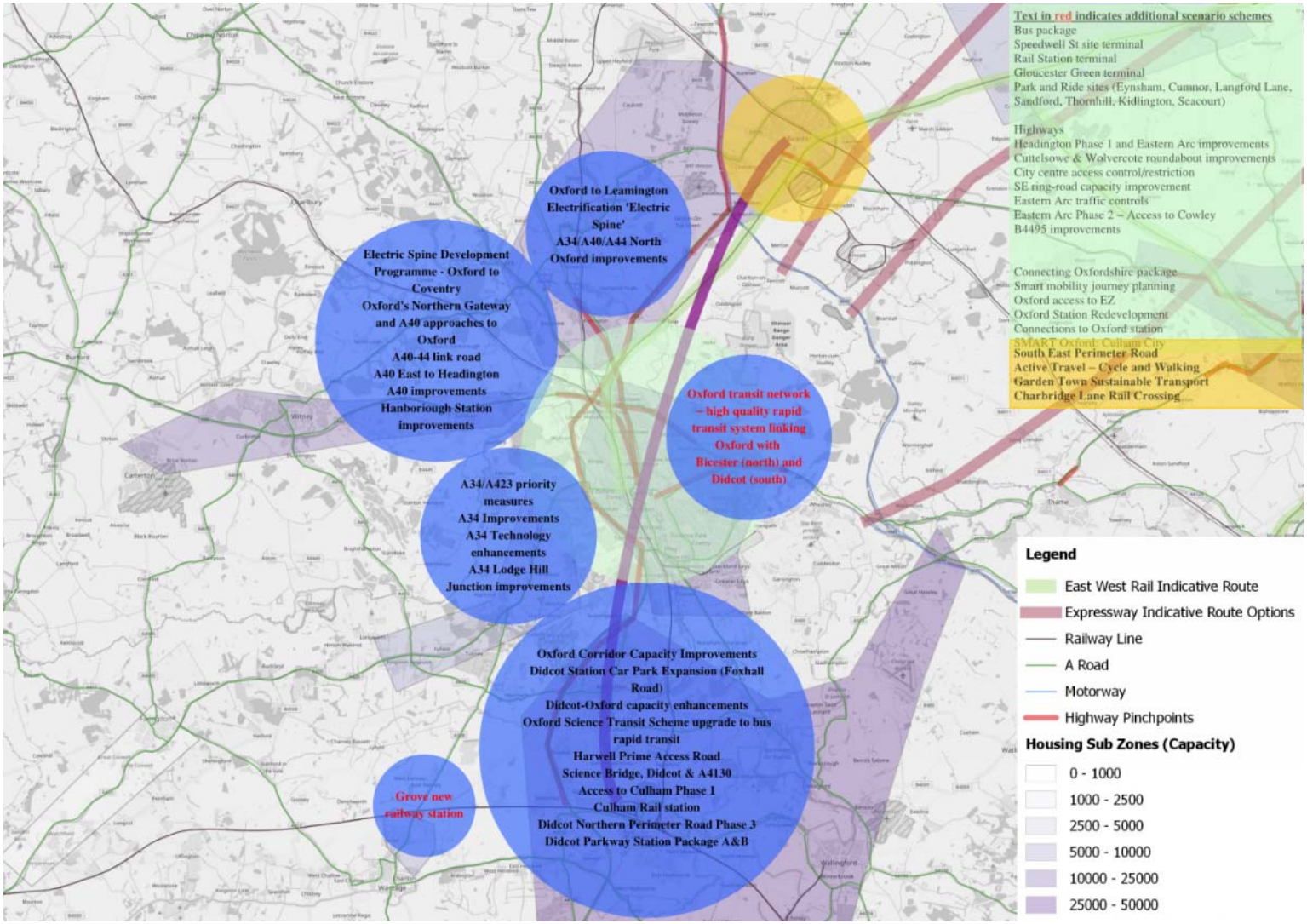
The transformational scenario projects growth in the Oxford area of nearly 233,000 households and 288,000 jobs by 2050 (from 2016)[29]. An additional £300 million investment in transport infrastructure responds to the faster house building rate and higher employment growth at the main employment zones in the sub area. The additional infrastructure builds upon the packages identified for the previous scenarios to unlock further housing sites and improve journey time reliability between housing sites and key employment zones.

The investment enhances the public transport offer to provide high levels of public transport accessibility across the city to unlock housing sites and to provide access to jobs growth in the Science Vale. The exact scheme will need to be defined depending on the exact location of housing and jobs growth in the city, but is expected to be on corridors from Bicester in the north and Didcot in the south. It may also include upgrade of some or all of the system to light rail if demands under the transformational scenario warrant that level of capacity.

The transformational scenario for Oxford is shown in Figure 24, with the transformational schemes listed in red to differentiate them from the baseline and incremental schemes. The package of schemes in summarised in Table 18

[29] Source: Savills

Figure 24: Transformational scenario – Oxford-Swindon area



Source: Open street map, Savills, Arup

Table 18: Transformational scenario – Oxford-Swindon area

TRANSFORMATIONAL SCENARIO – transport investment package – Oxford	Cost (£m)
Baseline and incremental schemes Oxford	2,900.7
Oxford transit network – high quality rapid transit system linking Oxford with Bicester (north) and Didcot (south)	250.0
Grove New Station	50.0
Subtotal Oxford (inclusive of baseline and incremental)	**3,200.7**

Example: A multi-pronged approach to dealing with congestion, with new light rail or bus based transit as its centrepiece

The study area towns suffer from increasing amounts of congestion. In dealing with this, it may be noted that small delays to a journey (below a five minute threshold, for example) may be perceived differently to the same delay above the threshold. Furthermore, certain journeys and certain driver types will be more or less sensitive to congestion. An approach to tackle congestion could include provision of additional infrastructure, changes to bottlenecks, pricing levers and driver information.

Additional infrastructure:

- Alternatives to the road system, such as improved cycle networks, light rail or bus rapid transit. This would also improve the capacity of the transport system to cope with growth, improve urban realm, offer faster journey times, improve air quality, provide city centre penetration, and potentially trigger land value uplift.
- Improved cycle lanes and bus provision.

Changes to bottlenecks:

- Debottleneck junctions, especially those around ring roads, through redesign.
- Automate traffic signals, including prediction, area-wide linked automation, and pedestrian flows, improvements to cyclists and buses.
- Consideration of road works charge for busy locations and overrunning works.

Pricing:

- Road pricing central zone congestion charge, workplace parking levy, which could be emissions-based.
- Growing number of freight vehicles or LGVs could face increased charges or be banned at peak times.
- Relative price of public transport alternatives will need to remain price competitive.
- Information:
- Accident prevention through educational campaigns, reduce clear-up time through working with blue light authorities.
- Real-time information from the customer so the operator can better manage congestion: mobile phone based satnavs, Bluetooth, Twitter.
- Real-time information to the customer so they can self-manage away from congestion: mobile phone based satnavs, radio.

Inter-Urban Corridors

The packages for the sub areas are supported by a package of investment for each scenario which is focused on inter-urban connections. The inter-urban connections support economic growth across the corridor and the investment responds to increases in movements across the corridor.

Baseline

The baseline scenario for the Inter-Urban Corridors involves investment in a number of already committed schemes adding up to £4.61bn including electrification of the Great Western Mainline (£2.8bn) which supports growth inside and outside the area.

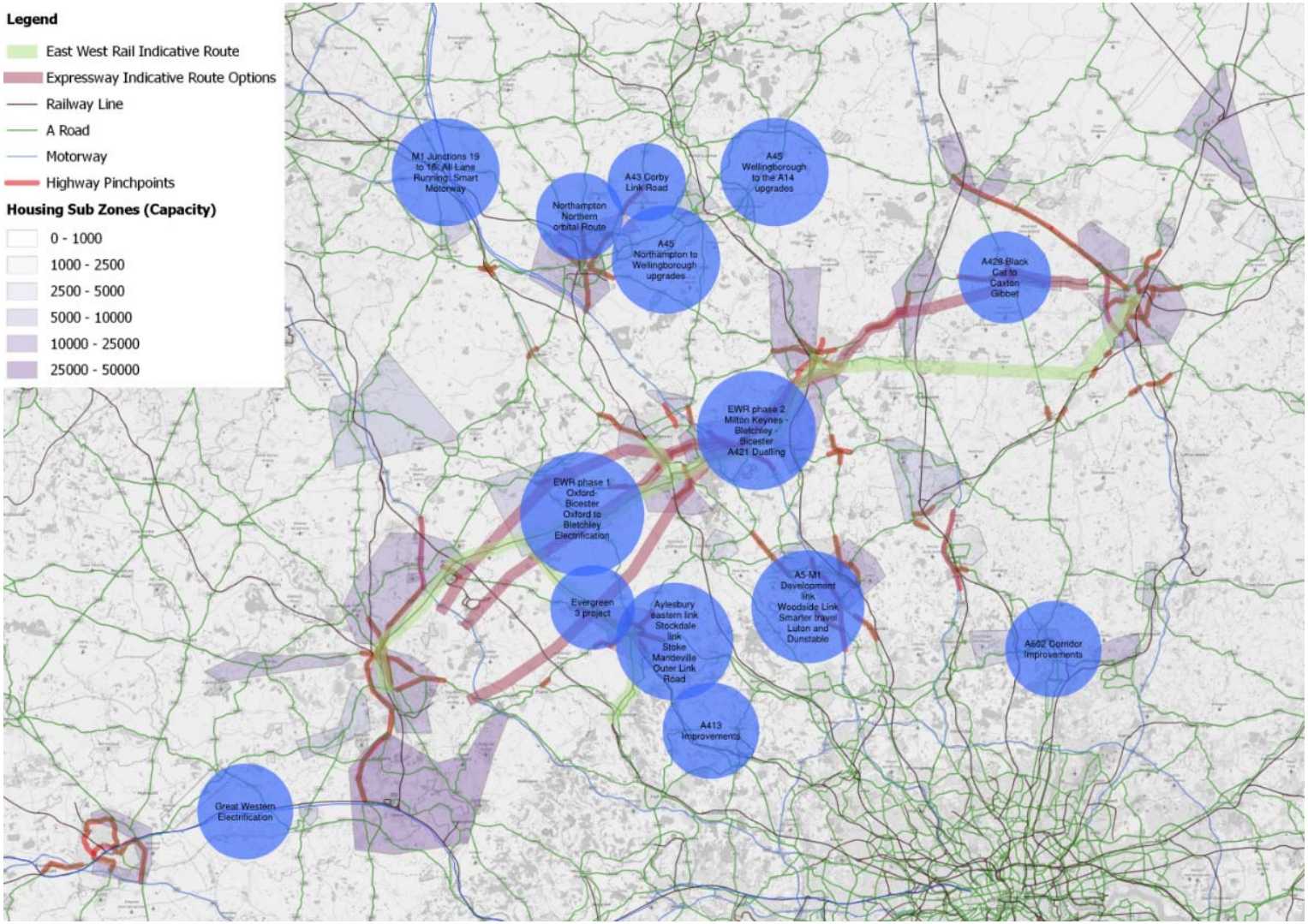
It includes delivery of the Western section of East West Rail to Milton Keynes/Bedford (Phase 2) enabling housing development along the route and supporting movements to and from the key urban centres.

It also includes delivery of the A428 Black Cat to Caxton Gibbet project near St Neots, which addresses a key pinch point on the existing highway network and creates a high standard link between the Milton Keynes and Cambridge via Bedford. This is a precursor to the Expressway project.

These schemes address existing pinch points and public transport services on some of the key corridors between the main centres in the study area.

The baseline scenario for Inter Urban Corridors is illustrated below, and the package of schemes is summarised in Table 19.

Figure 25: Baseline scenario – Inter Urban



Source: Open street map, Savills, Arup

Table 19: Baseline scenario – Inter-urban corridors

BASELINE SCENARIO – transport investment package – Inter-Urban Corridors	Cost (£m)
A5 - M1 Link Road	162.1
East West Rail Link Western Section Phase 1 Oxford-Bicester	332.0
East West Rail Link Western Section Phase 2 Bicester-Milton Keynes/Bedford	402.0
Evergreen 3 Project on the Chiltern Line	200.0
Great Western Electrification	2,800.0
M1 Junctions 19 to 16: All Lane Running: Smart Motorway	91.4
M1 Old Park Charity Toddington Parapet	1.8
Oxford to Bletchley Electrification	190.0
Woodside Link	20.0
Improving the A413 to enhance connections within the County and to growth areas beyond	20.0
A428 Black Cat to Caxton Gibbet	375.0
A5 Trunk Corridor	3.5
A602 Corridor Strategy - Ware to Stevenage Improvements	15.7
Subtotal Inter-Urban Corridors	**4,613.5**

Incremental

The need for investment

The inter-urban links have two key roles:

- They address existing and forecast pinch points on the road network to reduce journey times and improve reliability, thus providing better connections between workers and jobs and between businesses in the study area;
- They improve public transport connectivity to provide access to jobs and to provide fast links between centres to allow businesses in similar sectors to collaborate.

The inter-urban infrastructure should provide a strategic link between Oxford, Milton Keynes/Bedford and Cambridge to encourage ‘knowledge spill overs’ (the availability and spreading of information that occurs when businesses locate close to one another) , as far as practicable, across the corridor. It is recognised that ‘knowledge spill over’ is reduced by distance and any such benefits are likely to be limited to the adjacent urban centre, i.e. between Oxford and Milton Keynes, and between Milton Keynes and Cambridge. It should also provide access to jobs from areas of high population growth in the Milton Keynes-Northampton area.

Inter urban transport infrastructure is vital to join the economic centres with fast public transport links to enable more interaction between them. East West Rail

has the best potential to achieve this, as it is relatively fast, reliable as it provides a segregated route to the city centres. The Expressway can also achieve this, although it is likely to generate additional traffic so will need additional roadspace in the cities to provide for access and parking, or some form of demand management tools (park and ride or pricing) to manage the traffic.

Table 20 shows planned East West Rail and Expressway journey times.

Table 20: EWR and Expressway JT impacts

Key Route	East West Rail			Expressway		
	JT without scheme (minutes)	JT with scheme (minutes)	% JT reduction	JT without scheme (minutes)	JT with scheme (minutes)	% JT reduction
Oxford – Milton Keynes	103	26	-75%	70	45	-36%
Milton Keynes – Cambridge	133	34	-74%	83	45	-46%
Oxford – Cambridge	167	60	-64%	140	90	-36%

Sources: East West Rail consortium, Oxford to Cambridge Expressway Strategic Study Interim Report, WSP et al, 2016

Whilst the East West Rail journey times are competitive with the car (even with the Expressway), the frequencies (at two trains per hour for most journey pairs) are lower than most commuter rail services, and are perhaps too low to be immediately appealing to a business traveller. If higher frequencies cannot be achieved immediately, passive provision could be built in through designing the line for higher speeds, or perhaps by the opening date, taking advantage of future digital railway potential. We recommend that East West Rail should be designed to be as fast and frequent as possible.

This meets the needs of many of the respondents to the Call for Evidence, who identified improvements to strategic road and rail links between the Oxford, Milton Keynes area and Cambridge as a priority. A fast and reliable road link is needed to reduce the journey time and reduce journey time variation due to congestion, and a fast rail link is needed as there is currently no alternative to the car in this corridor (other than a slow bus link).

Given the dispersed nature of much of the study area, outside the high volume transit corridors, accessibility will need to be improved. New technology may be able to play a role here, with smaller on-demand bus services and the associated control centre infrastructure. The physical infrastructure development should be accompanied by network management and data analytics to manage transport demand, e.g. if autonomous vehicles increase travel demand in the short term before they move to a sharing model and then reduce traffic.

Incremental scenario transport package

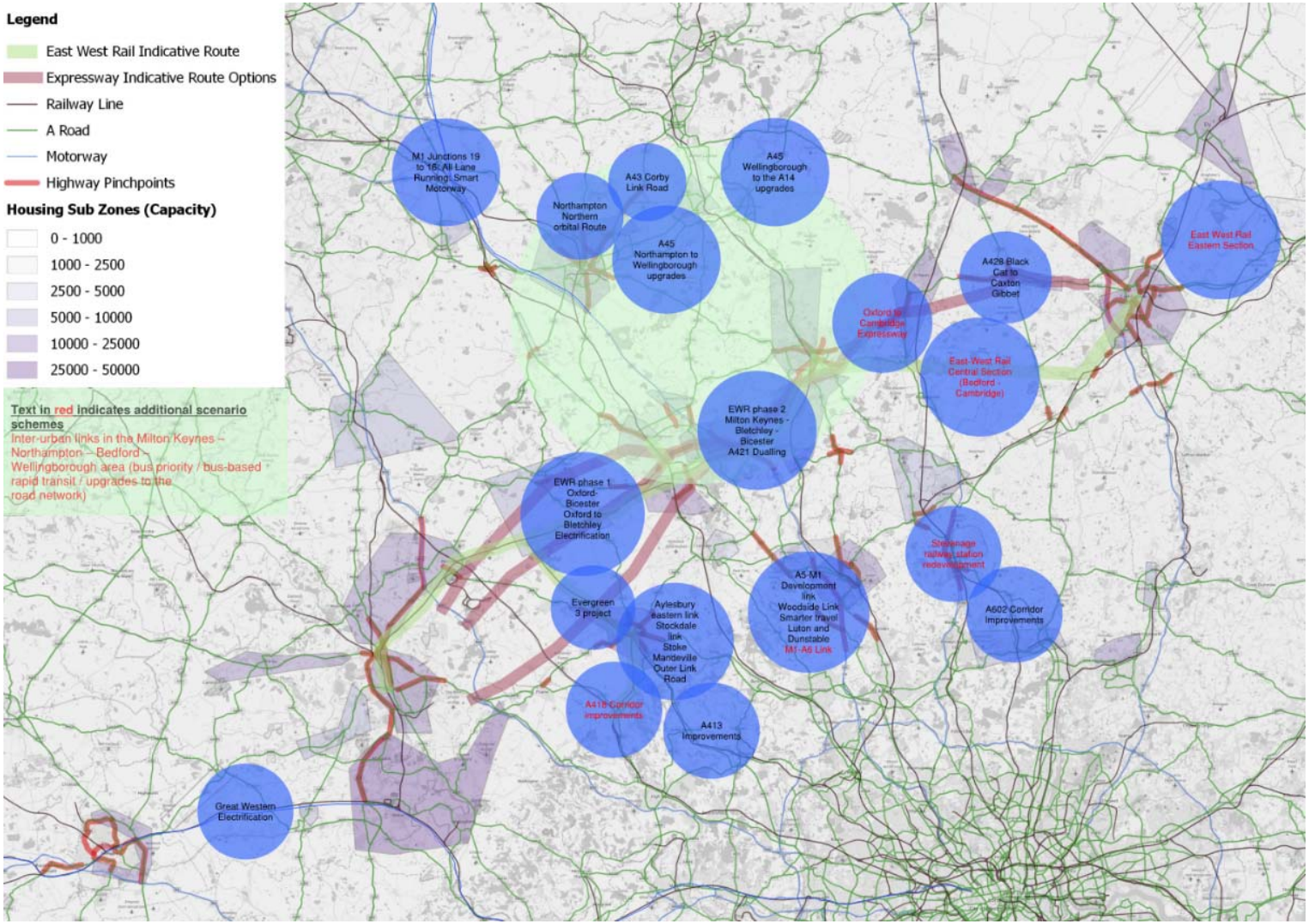
The incremental scenario delivers a number of planned schemes that connect the urban centres. The total cost is over £6.5bn, of which £5.6bn is allowances for East West Rail Central section and eastern section and the Oxford-Cambridge Expressway project.

The remaining £0.9bn includes further planned road and rail improvements to the south of Oxford and on the A5 to improve reliability and journey times between centres.

It also includes one new proposed scheme, which is to deliver general improvements to inter-urban bus links in the Milton Keynes – Northampton – Bedford – Wellingborough area, which may include bus priority, busway sections and upgrades to the road network to improve journey times and reliability and provide an alternative to the private car for these journeys, enabling more people to access jobs in the central area towns.

The incremental scenario for Inter Urban Corridors is below, with the incremental schemes listed in red to differentiate them from the baseline schemes. The package of schemes in summarised in Table 21.

Figure 26: Incremental scenario – Inter-Urban corridors



Source: Open street map, Savills, Arup

Table 21: Incremental scenario – Inter-urban corridors

INCREMENTAL SCENARIO – transport investment package – Inter-Urban Corridors	Cost (£m)
Baseline schemes Inter-Urban Corridors	**4,613.5**
East West Rail Link Eastern Section	734.0
East West Rail Link Central Section (Bedford – Cambridge)	1,361.0
M1 to A6 Link Road	50.0
Inter-urbanA418 corridor study	375.0
Stevenage First: Stevenage railway station redevelopment - transformational investment in a new railway station for Stevenage	452.0
Inter-urban links in the Milton Keynes – Northampton – Bedford – Wellingborough area (bus priority / bus-based rapid transit / upgrades to the road network)	50.0
Oxford to Cambridge Expressway	3,500.0
Subtotal Inter-Urban Corridors (inclusive of baseline)	**11,135.5**

Source: Arup

Transformational

With all of the schemes identified above, although road and rail capacity will have increased under a transformational scenario, interurban links are expected to be under strain as travel demand increases. The package of schemes to support the higher rate of growth across the corridor amounts to an additional £360 million of investment to support the higher rate of growth and support more reliable journeys across the corridor.

The transformational schemes are intended to support growth in the area by reducing road journey times and reliability to bring workers and businesses closer together to enhance the productivity of the study area, and to provide better accessibility to employment through the provision of enhanced public transport links and development of housing sites.

The transformational scenario includes a number of new schemes identified in this study as follows:

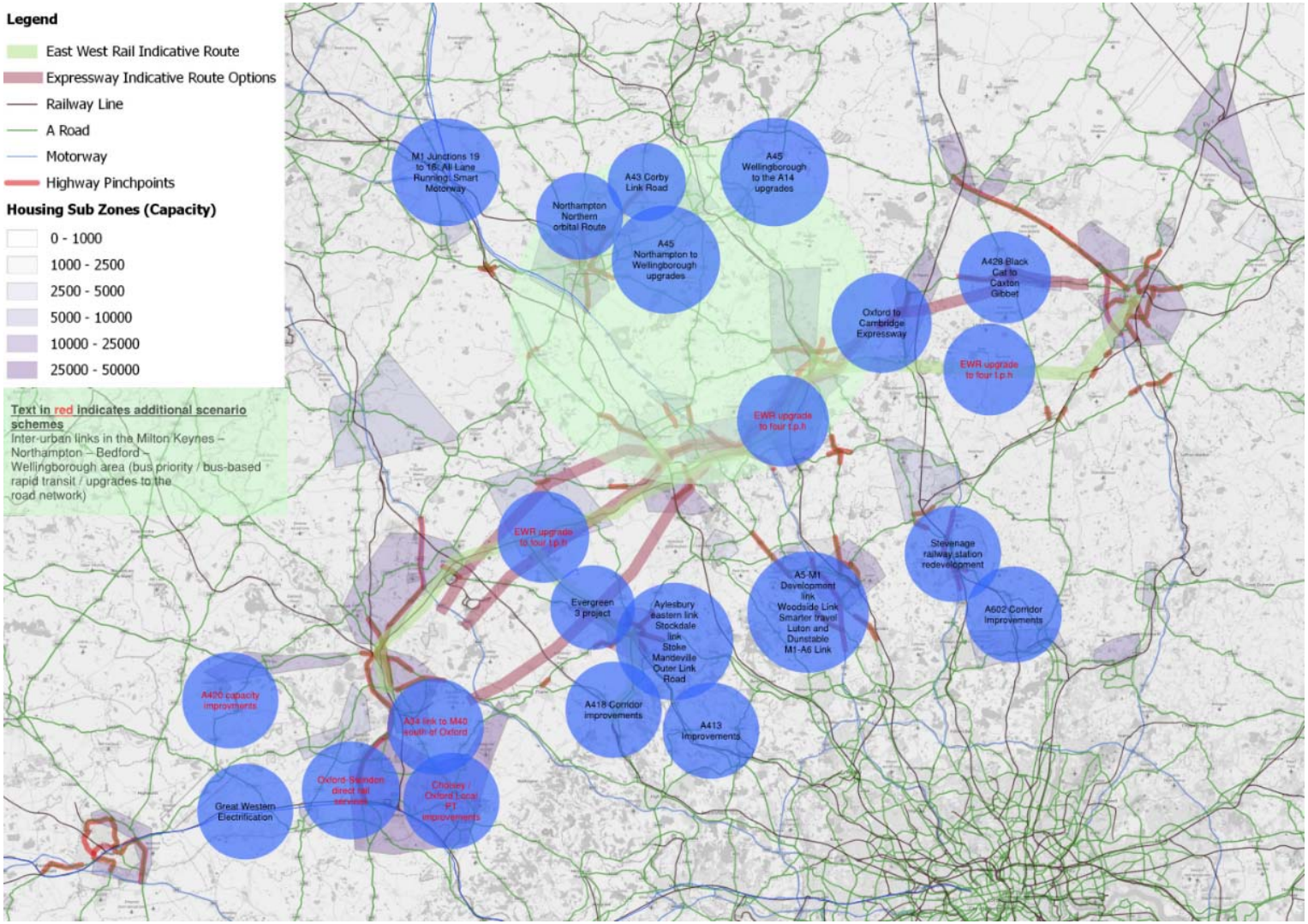
- Upgrade East West Rail to four trains per hour metro style service – to provide a high frequency rail service across the study area to support transformational housing and jobs growth;
- A420 improvements – improvements between Swindon and Oxford to reduce journey time between the two centres;
- Direct rail Swindon-Oxford via Didcot – currently passengers need to change at Didcot, so this proposal is to provide a direct rail service between the two centres thus reducing journey time and improving convenience to passengers;
- Cholsey / Oxford PT improvements (connect rail at Cholsey and into Oxford by bus) – this scheme is to support major housing development to the south

east of Oxford by connecting to Cholsey station on the Great Western Main Line for services to Oxford and Swindon; and

A34 link to M40 south of Oxford – this scheme enables strategic traffic that would currently travel around Oxford on the A34 to connect to the M40 south of Oxford thus avoiding the Oxford city area. This supports distribution of trips from the planned Expressway.

The transformational scenario for Inter Urban Corridors is shown below, with the transformational schemes listed in red to differentiate them from the baseline and incremental schemes.

Figure 27: Transformational scenario – Inter-urban



Source: Open street map, Savills, Arup

Table 22: Transformational scenario – Inter-urban corridors

TRANSFORMATIONAL SCENARIO – transport investment package – Inter-Urban Corridors	Cost (£m)
Baseline and incremental schemes Inter-Urban Corridors	**11,135.5**
A34 link to M40 south of Oxford	75.0
A420 improvements	20.0
Direct rail Swindon-Oxford via Didcot	50.0
Cholsey / Oxford Local PT improvements (connect to rail at Cholsey and into Oxford by bus)	15.0
Upgrade East West Rail to four trains per hour metro style service	200.0
Subtotal Inter-Urban Corridors (inclusive of baseline and incremental)	**11,495.5**

Radial Links with London

Whilst the focus of the transport packages above has been on movement within cities and between cities in the study area, it is important to consider transport links with London and the infrastructure requirements that will support growth in travel demand between the study area and London.

The following sections present the schemes identified for investment for radial links with London under the three scenarios: Baseline, Incremental, and Transformational.

Baseline

The baseline scenario includes a number of committed strategic road and rail projects totalling just over £4bn. This includes expenditure on major road projects such as improvements on the M40 and A1M, which will improve road access into Greater London for travellers from the study area. The package of schemes is summarised in Table 23.

It also includes significant rail improvements such as the Thameslink Programme. The Thameslink Programme will improve journey times and increase capacity through train lengthening on services from Bedford to London.

Table 23: Baseline scenario – Radial routes to London

BASELINE SCENARIO – transport investment package	Cost (£m)
Committed schemes	
M40 major Maintenance Junction 6 to 8	200.0
A1(M) HCC transport package A1(M) Growth Area	18.0
London Luton Airport Surface Access	20.0
Thameslink Programme	3,550.0
Hitchin Flyover	47.0
Proposed improvement to Luton Station	10.0

BASELINE SCENARIO – transport investment package	Cost (£m)
Luton Airport Mass Passenger Transit Scheme	200.0
Total	**4,050.0**

Incremental

The need for investment

As the study area is expected to grow, London is also experiencing significant growth[30] and the population is expected to increase from 8.2m in 2011 to 9.5m in 2026 and 10.1m by 2036 (23% increase on 2011 prices). Employment is expected to increase from 4.9m jobs in 2011 to 5.8m jobs in 2036 (+18%). This is expected to increase the demand for travel for commuting and for business. With the housing shortage in London, there is potential for the expansion of existing settlements with good transport connections to London and for enhanced capacity on these routes.

The Call for Evidence responses highlight the importance of connectivity to London. Responses state that connections are important between the universities in the study area with other world-leading universities and institutes in London. Proximity to London is also important because it provides access to world city functions that the city has to offer including finance, legal and advertising activities.

There are significant volumes of people already commuting between the two areas. Our analysis presented earlier in the report shows over 50,000 people living in the study area and commuting into London, of which some 22,000 (42%) use rail. There are also around 24,000 people living in London and commuting into the study area, with 5,000 of these (21%) using rail. Given the strategic nature of the trip it is likely that most other travellers will use the strategic road network (i.e. M40, M1, A1M, M11) to get into London.

Whilst the radial road and rail links between the study area and London are relatively good, there are challenges in connecting to its labour and business markets. Capacity on many lines is constrained and they are subject to delays and journey time uncertainty.

Incremental scenario transport package

The incremental scenario includes two major planned schemes: Crossrail 2 and the West Anglia Mainline Improvements. Crossrail 2 could provide direct journeys for the very southern edge of the study area (Hertfordshire) but it also relieves capacity on the West Anglia Main Line (for services from Cambridge).

[30] Data from The London Plan (March 2016).

Table 24: Incremental scenario – Radial routes to London

INCREMENTAL SCENARIO – transport investment package	Cost (£m)
BASELINE SCHEMES PLUS:	**4,050.0**
Planned Schemes	
West Anglia Mainline Improvement	3,550.0
A10 Buntingford - Improvements to the capacity of a roundabout on the A10	1.5
Crossrail 2	32,000.0
Subtotal	**35,551.5**
Cumulative Total	**39,601.5**

Transformational

The transformational scenario includes one planned and one new scheme. The planned scheme is HS2, which provides additional long distance capacity in the West Coast Main Line (WCML) corridor through the study area with the potential to unlock capacity elsewhere on the WCML, which could open up growth capacity for Milton Keynes to absorb housing growth. In particular, HS2 could reduce crowding on the WCML and offer potential benefits for current and future passengers from the study area (particularly Milton Keynes), with opportunities for more commuting capacity, more regional journeys and more rail freight. This could allow more local stopping services to serve locations in the study area, such as Milton Keynes to provide connections to London.

The new scheme recognises the importance of Heathrow Airport, particularly to promote the study area's status as a global business destination, and proposes to run direct trains from the study area via Oxford and Reading using the planned Western Rail Access to Heathrow link (from the Great Western Main Line west of Heathrow into Terminal 5 station). This could transform connectivity from the study area if East West Rail trains could provide a direct connection to the airport.

Table 25: Transformational scenario – Radial routes to London

TRANSFORMATIONAL SCENARIO – transport investment package	Cost (£m)
BASELINE AND INCREMENTAL SCHEMES PLUS:	**39,601.5**
Planned Schemes	
High Speed 2 (HS2) released capacity on West Coast Main Line	55,000.0
Total	**94,601.5**

Source: Arup

The investment would support growth in travel between the study area and London, which could amount to nearly 23,000 additional trips (43% increase from 2011) by 2050, if commuting grows in line with population under the transformational scenario. This is for commuting only, and business and leisure travel would significantly increase these figures.

Case study: San Francisco Bay area

The transformational scenario could bring further economic benefits, along the lines of the San Francisco Bay Area, which is a global success story for agglomeration, despite having relatively slow urban rail, and is a model for what could be achieved by the CaMkOx corridor in a transformational scenario by 2050. This is demonstrated in the case study below.

Example: Agglomeration of separate clusters through transportation, densification and policy intervention – San Francisco Bay Area

The Bay Area is larger than the CaMkOx corridor and more densely populated. It spreads over 6,700 square miles, and is home to more than seven million people. The population is projected to increase to 9.3 million by 2040, putting further pressure on a transport network that already experiences overcrowding and congestion[31]. Knowledge-based sectors in the Bay Area accounted for 42% of total employment in 2010[32], and the Bay Area's longstanding innovation and technology advantage comes from having the highest percentage of college graduates in the workforce of all major regional economies in the United States (44% compared to 28% for national average)[33]. High-skill and high-tech services are expected to continue to drive employment growth in other business support and service sectors, with most of that growth up to 2040 set to occur in the cities of San Francisco (34%), San Jose and Santa Rosa (39%), and along the US-101S highway[34] – assuming an appropriate provision of infrastructure, transit and access to affordable housing. Although the knowledge-based sectors define the overall pace of growth for the region, their success is supported by and advanced by a very diverse regional economy.

Generally, the places with the highest concentration of jobs – which we would expect to benefit from agglomeration economies – experienced the highest level of growth in knowledge-based sectors[35]. In particular, regional centres, mixed-used corridors, transit-town centres, urban neighbourhoods, and city centres accounted for most of the growth in knowledge-based jobs[36]. This is partly the result of the Bay Area's 'Jobs-Housing Connection Strategy', serving as the land-use element of the Bay's first Sustainable Communities Strategy (SCS) mandated by Senate Bill 375[37], which requires that California's regions align land use planning and transportation investments[38].

Based upon the emerging demographic changes and employment growth forecasts, and in alignment with the 'Jobs-Housing Connection Strategy', an annual average of approximately 22,000 units, or 660,000 homes are forecasted to be constructed by 2040[39]. Demand for smaller flats and apartments is projected to increase as seniors downsize and seek the greater access to shops and services that urban locations provide. Market demand for new homes will tilt toward town-homes, condominiums and

[31] Plan Bay Area – *Chapter 2 The Bay Area in 2040*
[32] Historic and projected trends in the bay area, *CTOD, 2012*
[33] Bay Area Job Growth to 2040, *CCSCE, 2012*
[34] Jobs-Housing connection strategy, *Metropolitan Transportation Commission, 2012*
[35] Transit and Regional Economic Development, *CTOD, 2011*
[36] Historic and projected trends in the bay area, *CTOD, 2012*
[37] MTC Planning Committee, ABAG Administrative Committee – Plan Bay Area Preferred Land Use Scenario / Transportation Investment Strategy
[38] Jobs-housing connection: the sustainable communities strategy, *ABAG, 2012*
[39] Final forecast of jobs, population and housing, *Metropolitan Transportation Commission, 2013*

apartments in developed areas. These homes are typically closer to transit than single-family residential development pattern of earlier decades[40].

Figure 28: San Francisco Bay Area BART Map (excludes commuter rail)

Source: Bay City Guide

Transport

Unlike the corridor, the major centres of the Bay Area are well served by metro and commuter rail. Ridership on the Bay Area Rapid Transit (BART) and CalTrain – the main rail systems operating across the Bay Area - is increasing due to growth in jobs and housing, increasing traffic on highways and new and improved ways to get to and from rail stations[41]. The daily cost of disruption to the BART of $73 million[42] shows how important the transit system is to the Bay's regional infrastructure and commuter needs.

Due to in part to large interactions between the economies, and relatively good road and rail links between San Francisco and Palo Alto, the Bay Area has demonstrated strong

[40] Making the most of transit: density, employment growth, and ridership around new stations, *Public Policy Institute of California, 2011*
[41] BART 2016 Factsheet: connecting people to opportunity, *BART, 2016*
[42] Bay Area council economic institute puts economic cost of BART strike at $73 million a day, *Bay Area Council, 2016*

agglomeration effects and growth in knowledge-based jobs. The current journey times are around 42 minutes, similar to the journey times between Oxford and Milton Keynes once East West Rail is built (based on broadly similar distances). With the arrival of East West Rail, Oxford and Milton Keynes could be connected in 40 minutes. The two study area centres have similar numbers of knowledge-based jobs and fairly big employment bases to draw from. Quicker rail connections could see agglomeration processes become more prevalent between the two but the lesson from San Francisco is that there are obviously other drivers of agglomeration. Figure 29 below compares socio-economic indicators, including job and knowledge-based jobs, as well as information about road and rail journeys. Housing affordability ratios also help draw comparisons; Oxford's is very high relative to the rest of the UK, and perhaps East West Rail may see people opt to live in Milton Keynes and commute to Oxford.

Figure 29: Socioeconomic comparisons, San Francisco/Palo Alto & Oxford/Milton Keynes

	San Francisco County	Palo Alto	Oxford	Milton Keynes
Population	837,000	66,000	160,000	262,000
In employment	569,000	32,000	130,000	181,000
% Knowledge-based jobs	63%	53%	82,300	81,300
Ratio of median house price to median earnings	14.66	7.87	11.56	7.98
Distance	34 miles		40 miles	
Rail journey	Around 40 min		80 min (today) 40 min (with East West Rail)	
Quality rail journey	4 direct trains per hour		1 change journey through Coventry or London. Quickest route from Oxford to Milton Keynes is via Coventry and takes 80 minutes with one train per hour	
Road journey	33 min		67 min	
Quality road journey	Dedicated highway US-101S		A34 – A41 – A421 going through Bicester and Buckingham's ring road, and through Bletchley's high-street.	

Source: ONS, Annual Population Survey; Cambridge Econometrics baseline data, California Economic Forecast, Plan Bay Area Statistics, Open Listings San Francisco, Data USA – Palo Alto

5 Housing, and the wider economic impacts of transport investment

5.1 Introduction

Two important areas that the NIC has asked us to consider in this study include the extent to which well-targeted transport investments can unlock housing sites and the extent to which investing in new strategic intercity links is likely to produce greater economic benefits than investing in constrained transport intra-urban transport networks.

Savills' report on housing[43] identified that the supply of new homes and employment space needs to increase significantly and in optimum locations relative to new and existing infrastructure. As such, the rationale for the NIC's review of transport investments in this area is partly predicated on the potential for infrastructure investment to unlock housing sites to avoid constraining population growth in one of the fastest growing parts of the country.

The CaMKOx area is home to some of the most advanced scientific research in the country and three of the fastest growing employment centres in the south east of England. Milton Keynes has the highest rate of private sector job creation of anywhere outside London[44] and Cambridge has by far the highest rate of patents granted per head of population in the country (more than ten times the next most innovative area). Oxford and Milton Keynes both have patent rates that outstrip London[45]. Some of the literature[46] suggests that urban extensions, densification, and expansion or consolidation of existing functional urban areas may be more likely to lead to higher agglomeration benefits than dispersed development. There is also the potential to boost productivity by linking centres with separately strong and high value economies to allow them to benefit from the opportunities, particularly for knowledge spill over – that those links might offer.

This section considers the potential impacts of the transport packages in the study area on its economic geography and economic growth.

5.2 Unlocking housing as a rationale for investment

The housing workstream analysis for this assignment, suggests that current housing plans do not meet future housing need. The report identified that recent housing delivery is some 25% less than SHMA (Strategic Housing Market Assessment) need, with large gaps in Oxfordshire, Swindon, Hertfordshire and Northamptonshire.

[43] The Property Market Within The Cambridge – Milton Keynes – Oxford Study Area, *Savills, 2016*
[44] 2010-2014 private sector jobs, percentage change, *BRES.*
[45] Patents granted per 100,000 population (2014): Cambridge – 102; Oxford – 8.7; Milton Keynes – 8.5; London – 3.8. *Centre for Cities data tool; data drawn from Intellectual Property Office FOI release.*
[46] See literature review in **Appendix E**

The case for bringing about transformational changes within the housing and employment offer requires sufficient investment to deal with transport capacity constraints which may be practical planning obstacles to development. There is evidence for this from previous Arup work in relation to HS2, Crossrail, the Royal Docks and new highways developments, such as the A14 realignment and capacity upgrade from Cambridge to Huntingdon opening up residential development opportunities (such as the phased development at Northstowe). Transport investment can lead to housing developments and economic growth. The Savills report backs this up by suggesting that "aligning transport and sites is crucial to both outcomes. As evidence of this, high rates of sale of new homes can be observed on large sites that have easy access to large employment markets (e.g. Cambridge southern fringe, Milton Keynes) or where there is good direct rail access to London (e.g. Aylesbury)."

The dynamics of the housing market and in particular unmet demand are creating practical obstacles for new household formation in areas where the greatest job creation potential exists. This in turn drives travel to work distances further which in the absence of new infrastructure such as segregated and guided bus ways or better East West Rail connectivity, compounds congestion and provides further constraints on economic activity that could weaken growth forecasts.

Arup and Savills carried out joint analysis that identified housing sites that have the potential to be brought forward through investment in transport infrastructure. We undertook work to sift the transport schemes within each scenario to determine those that have an impact on unlocking land for housing use. The two following tables list the transport schemes identified in the incremental and the transformational scenarios, by sub area, and the number of houses they are collectively and individually thought to unlock.

This joint work with Savills suggests that the long term housing strategy for the corridor is partially dependent on options for east-west connectivity. There are locations along the East West Rail line and the Expressway where housing sites are unlocked. In addition, other methods of connectivity, within the urban areas, and on a north-south axis, also open up additional housing. The latter could be particularly important in accommodating some of London's growth.

On the 301 large housing sites identified, there is the potential capacity for around 400,000 units. There are 207 transport schemes that could have an impact on bringing forward these housing sites (of which 59 could have a "high" impact). Table 26 shows there are 255 housing sites which have an impact on housing delivery; this is because some of the transport schemes interact with more than one zone.

The areas that would benefits most from transport investment are Cambs-Herts, MK-Beds-Bucks and Oxford-Swindon, with around 100,000 houses per area. The higher number of houses that can be brought forward in these areas, relative to Northampton, is due to availability of sites, and the strength of the local market (Northampton only has a single transport scheme that could be said to have a high impact on housing, whereas Cambs-Herts has 22).

For the baseline schemes, the total cost of those that would have a "high" impact on housing is some £5.4 billion. The additional cost of the "high" housing impact

schemes in the incremental scenario is some £6.5 billion (without Crossrail 2) across the corridor. The additional cost of the "high" housing impact schemes in the transformational scenario is £0.6bn, making the total of the schemes that have a "high" impact on housing across the corridor some £12.5 billion (without Crossrail 2).

Whilst investment in transport infrastructure is often necessary to support housing developments, unlocking land for development is an important, but one of many measures of success of well-targeted investment, alongside others that we have listed in the previous section of this report. Nevertheless, the mapping of residential development needs and transport infrastructure opportunities in the Cambridge, Milton Keynes / Northampton and Oxford Swindon areas, following the tables on subsequent pages, begins to build the strategic case for investment to deliver achievable growth across the corridor.

Figure 30, Figure 31 and Figure 32 below show the current house building plans alongside linked transport investment schemes.

Table 26: Site capacity for selected locations by development status, and transport schemes grouped by potential impact on housing delivery, on the 300 largest housing sites

		Large Site Capacity (Homes)						Transport Schemes by Impact on Housing Delivery					
		Under Construction	Permission	Application	Allocation	Promotion	Total	High	Mid-High	Mid	Low-Mid	Low	Total
Cambs-Herts	B Stortford	0	2,531	685	3,500	1,500	8,216	2	0	0	0	0	2
	Buntingford	318	0	509	0	0	827	0	0	0	1	0	1
	C Beds and N Herts	0	0	0	4,700	1,780	6,480	0	0	0	0	1	1
	Cambridge & S Fringe	6,427	381	3,023	3,303	1,300	14,434	6	22	13	1	4	46
	Harlow	0	0	0	0	10,500	10,500	2	0	0	0	0	2
	Hertford	0	0	0	6,000	0	6,000	0	1	0	0	0	1
	Huntingdon	5,015	438	2,826	0	3,750	12,029	3	0	0	0	0	3
	N Cambridge	6,106	0	5,504	0	0	11,610	2	0	2	0	1	5
	Newmarket	0	0	0	851	800	1,651	1	0	0	0	1	2
	Royston	0	0	961	0	0	961	0	0	0	1	3	4
	Soham-Ely	0	2,003	251	5,365	5,495	13,114	0	2	3	1	1	7
	Stevenage	0	0	886	360	950	2,196	0	2	0	0	0	2
	W of Cambridge	0	0	2,355	3,500	3,500	9,355	2	0	6	1	0	9
	Waterbeach	0	0	0	9,000	0	9,000	4	1	1	0	0	6
	Outside zones	0	0	0	-1,000	0	-1,000						
	Sub-Total	17,866	5,353	17,000	35,579	29,575	105,373	22	28	25	5	11	91
MK-Beds-Bucks	Aylesbury	5,450	0	3,404	0	11,981	20,835	1	2	2	0	1	6
	Dunstable	0	1,221	0	0	2,500	3,721	0	0	0	0	0	0
	Luton	688	736	3,107	2,507	5,327	12,365	1	2	0	0	2	5

		Large Site Capacity (Homes)						Transport Schemes by Impact on Housing Delivery					
		Under Construction	Permission	Application	Allocation	Promotion	Total	High	Mid-High	Mid	Low-Mid	Low	Total
	N & W MK	6,550	0	646	0	678	7,874	0	2	3	0	0	5
	N & W of Bedford	2,775	251	0	0	15,300	18,326	0	0	0	0	0	0
	N and E MK	0	0	0	0	6,082	6,082	0	0	0	0	0	0
	S of Bedford	4,771	1,226	1,986	3,470	651	12,104	3	1	0	0	1	5
	Sandy	0	2,803	1,250	0	6,040	10,093	2	0	1	0	0	3
	SE MK	3,155	2,304	0	978	5,604	12,041	2	0	2	0	0	4
	SW MK	1,653	0	3,659	0	6,699	12,011	1	1	4	0	0	6
	West of Luton	0	6,650	624	0	0	7,274	2	1	0	0	1	4
	Winslow and B'ham	600	0	0	0	5,525	6,125	3	1	1	0	1	6
	Outside zones	302	350	0	300	1,398	2,350						
	Sub-Total	25,944	15,541	14,676	7,255	67,785	131,201	15	10	13	0	6	44
Northampton	Daventry	1,000	452	304	4,000	0	5,756	1	0	1	1	1	4
	Northampton	1,053	3,012	0	9,407	2,470	15,942	0	6	3	12	12	33
	Towcester	2,750	0	0	0	0	2,750	0	0	0	0	1	1
	Wellingborough	0	6,200	600	0	0	6,800	0	2	1	2	0	5
	Outside zones	0	0	0	0	0	0						
	Sub-Total	4,803	9,664	904	13,407	2,470	31,248	1	8	5	15	14	43
Oxford-Swindon	A420 NE	0	280	0	0	5,032	5,312	1	1	0	0	0	2
	A420 SW	0	0	727	0	0	727	1	0	0	0	0	1
	Banbury	412	1,891	1,302	2,500	500	6,605	0	0	2	0	2	4
	Central Swindon	0	0	0	4,500	0	4,500	1	0	1	0	0	2
	N Oxford to Bicester	3,905	1,900	3,008	3,500	7,046	19,359	5	3	4	0	2	14

		Large Site Capacity (Homes)						Transport Schemes by Impact on Housing Delivery					
		Under Construction	Permission	Application	Allocation	Promotion	Total	High	Mid-High	Mid	Low-Mid	Low	Total
	Outer Swindon	454	0	3,353	16,900	250	20,957	1	0	0	0	0	1
	Oxford and fringe	894	0	0	0	15,132	16,026	7	13	6	1	2	29
	SE of Oxford	3,302	0	6,079	902	31,500	41,783	2	2	6	3	4	17
	Wantage	0	1,500	2,957	0	700	5,157	2	0	0	0	0	2
	West of Oxford	250	0	1,964	0	10,816	13,030	1	3	1	0	0	5
	Outside zones	0	0	0	500	878	1,378						
	Sub-Total	9,217	5,571	19,390	28,802	71,854	134,834	21	22	20	4	10	77
Total		57,830	36,129	51,970	85,043	171,684	402,656	59	68	63	24	41	255

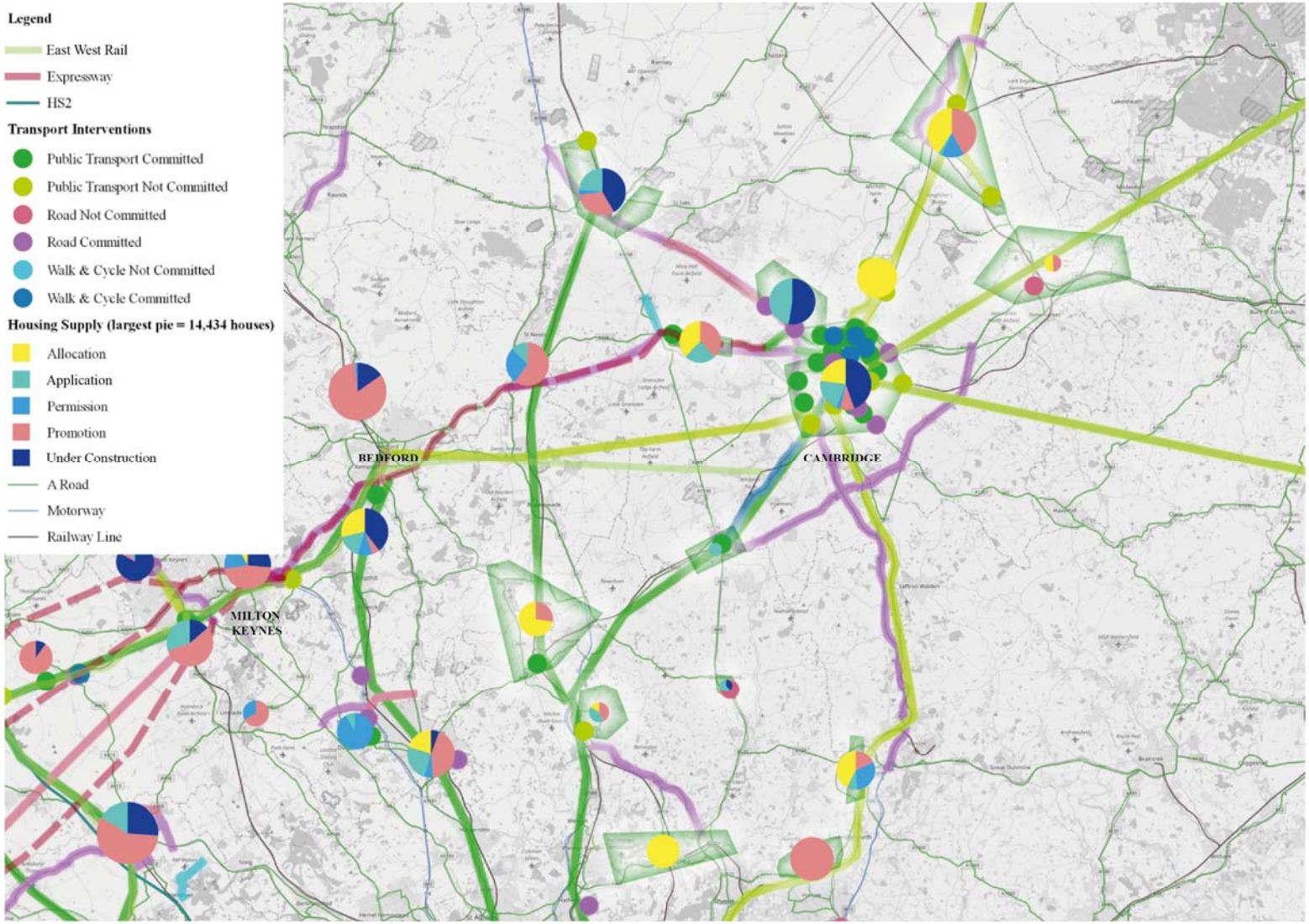
Source: Arup, Savills

Table 27: Cost and number of transport schemes by impact on housing

Scenario	Impact on housing	No. of transport schemes	Cost (£m)	
			Incl. HS2/Crossrail2	Net of HS2/Crossrail2
Baseline	Very Low	25	846	846
	Low	15	93	93
	Mid	25	4,223	4,223
	Medium-High	48	1,989	1,989
	High	9	5,382	5,382
	Total Baseline	122	12,534	12,534
Incremental	Very Low	13	358	358
	Low	6	276	276
	Mid	16	4,214	4,214
	Medium-High	10	803	803
	High	25	38,476	6,476
	Total Incremental	70	44,127	12,127
Transformational	Very Low	0	-	-
	Low	0	-	-
	Mid	6	55,565	565.0
	Medium-High	3	370	370
	High	6	645	645
	Total Transformational	15	56,580	1,580
Total	Very Low	38	1,204	1,204
	Low	21	369	369
	Mid	47	64,002	9,002
	Medium-High	61	3,163	3,163
	High	40	44,503	12,503
	Grand Total	207	113,240	26,240

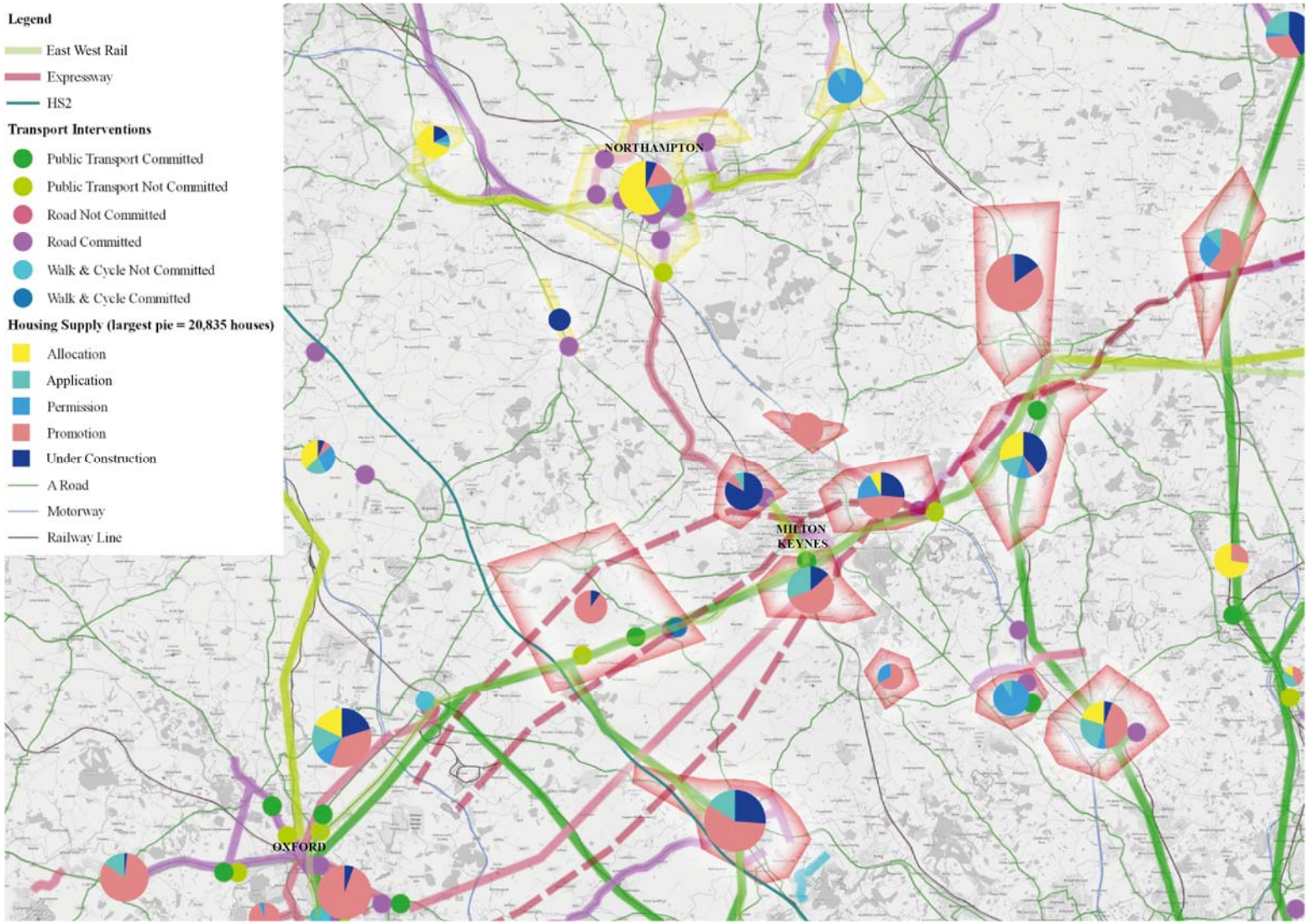
Source: Arup, Savills

Figure 30: Greater Cambridge area - current house building plans shown alongside linked transport investment schemes



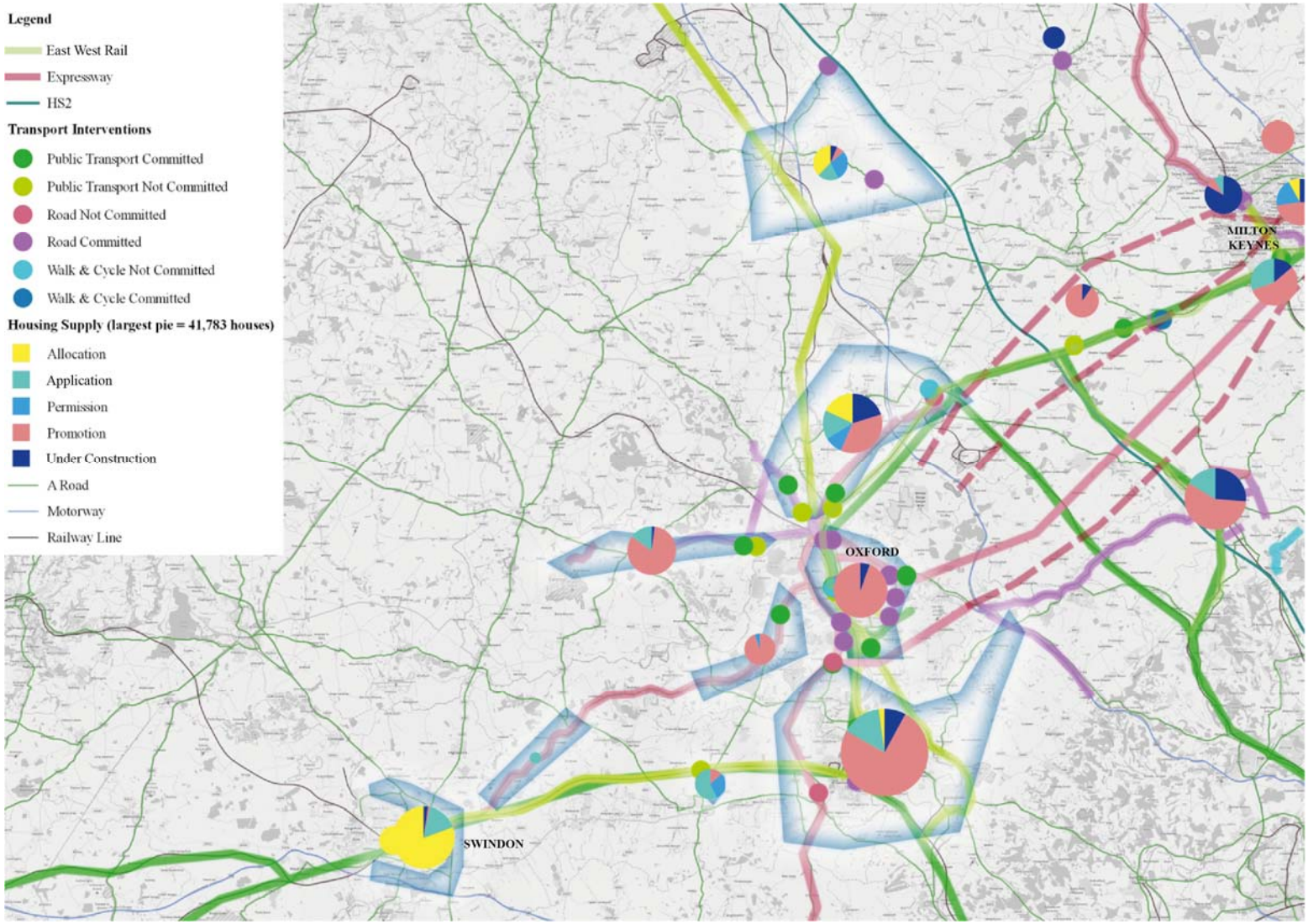
Source: Open street map, Savills, Arup

Figure 31: Milton Keynes –Northampton area – current house building plans shown alongside linked transport investment schemes



Source: Open street map, Savills, Arup

Figure 32: Oxford – Swindon area: current house building plans shown alongside linked transport investment schemes



Source: Open street map, Savills, Arup

5.3 Wider economic impacts from transport investment

The case for bringing about transformational changes in productivity is predicated on a number of different mechanisms for growth. The literature suggests that regions that do function as a single economic entity tend to enhance their economic performance[47] although agglomeration benefits appear to erode over distance. Medium-sized urban areas that are more than 40 minutes apart (like those in our study area) experiencing an eighth of agglomeration benefits than those which are five minutes apart. The full productivity literature review is set out in Appendix E.

It broadly suggests a number of channels through which transport investment has the potential to drive productivity benefits[48]. These channels are not mutually exclusive and in some cases overlap slightly. A transport scheme may have the potential to increase productivity through a combination of the channels. These channels are:

- **User benefits**: lower operating costs for businesses through time savings, lower vehicle operating costs, improved safety and through the cheaper and more reliable transport of freight;
- **Increased market access** may allow firms to increase output and potentially benefit from economies of scale. It may also increase competition between firms reducing monopoly and monopsony power and increasing average efficiency;
- **Improved access to intermediate inputs** allowing firms to source inputs at a lower price and/or higher quality;
- **Increased size and effectiveness of labour markets** allowing firms to access a wider pool of labour leading to better matching of skills and jobs, particular with higher skilled jobs in both Oxford and Cambridge; reduced labour market stickiness and, ultimately, productivity increases;
- **Support for agglomeration through knowledge spill overs**: where proximity supports innovation which increases the stock of human capital. This is particularly relevant in knowledge intensive sectors;
- **Support for specialisation (clusters)** through facilitating trade and allowing cities and regions to specialise in sectors in which they have a comparative advantage;
- **Reduced coordination failure between industries** for example where firms gain benefits from relocating but only if other relocate with them; and
- **Increased technology diffusion between regions** allowing peripheral places to more quickly benefit from the dissemination of new technologies and process innovation.

[47] *Hall and Marshall, 2000, Walmsley and Perrett, 1991*
[48] Transport Investment and Economic performance, *Venables et al, 2014*

The evaluation evidence base for the productivity impacts of transport investment is relatively small (this is thought to reflect the lack of quality ex-post evaluation rather than necessarily the absence of such impacts[49]) and, as such, it is difficult to be categorical about their potential scale, or the relative importance of these channels.

The following section presents findings of an illustrative qualitative and quantitative assessment of the potential for productivity and agglomeration benefits that are likely to arise in this corridor as a result of investment in improved transport links. The full assessment is included in Appendix F.

5.3.1 Assessing the potential productivity impacts of transport infrastructure investment

The response from LEPs to the Call for Evidence suggests that growth in the knowledge economy along the corridor will need to be support by sustained investment in public transport to provide the necessary options for commuters: "in the corridor, high-knowledge employment is polycentric, often in areas with limited public transport connectivity. This points to a need for high quality, fast, frequent, and reliable public transport to better integrate knowledge employment across the region and to expand labour markets and to improve business-to-business connectivity"[50].

This question has been assessed through both qualitative and quantitative methods, based on four typologies of transport investment (four illustrative schemes). The principle of defining these four illustrative schemes is to take the analysis beyond a purely abstract exercise and ground it in an understanding of what might be the relative scale of productivity impacts in the CaMKOx area specifically, with the economic, travel and demographic patterns that currently exist, and illustrative of the types of schemes that are being proposed around the study area. They are not intended to be directly comparable in terms of cost and the assessment does not comment on value for money at this stage.

The example schemes are:

- A: Intra-urban investment to reduce travel times within an economically successful, perhaps even overheating, area (Cambridge);
- B: Extra-urban investment to improve links between two centres which do not have a strong commuting relationship already (Bedford and Cambridge);
- C: Intra-urban investment to reduce travel times between a relatively deprived area and the city centre (Bletchley and Milton Keynes Central);
- D: Extra-urban investment to improve links between two centres which already have a commuting relationship (Milton Keynes and Northampton); and

[49] See Evidence Review: Transport by the What Works Centre for Local Economic Growth for a fuller explanation of the size and quality of the evaluation evidence base.
[50] LEPs response to the Call for Evidence, *2016, p.17*

- E: Extra-urban investment to improve links between knowledge-intensive employment sectors (Oxford and Cambridge).

For each illustrative scheme, a qualitative and quantitative assessment has been undertaken to identify the likely scale of different types of potential benefit that might arise through the various benefit channels set out above and ranked on a 'low – high' scale. The quantitative assessment takes the form of a high level modelling exercise to quantify agglomeration benefits to rapidly identify the relatively likely scale of productivity impacts that may arise through agglomeration when different types of connectivity improvements are targeted, in different economic contexts. More detailed analysis is set out in Appendix F.

5.3.2 Wider economic impacts findings

Findings by scenario are shown summarised in Table 28 overleaf. The qualitative assessment of the four schemes has shown the following:

- The largest form of benefits from improving connectivity within and between our sample projects is from user benefits (this is a typical characteristic of transport evaluations). The benefits are relatively straightforward to predict through modelling work, and will normally be highest where schemes mitigate high levels of congestion and where population and employment growth are forecast to be strongest. Schemes which support new housing and employment developments will lead to even higher benefits.
- Schemes that improve connectivity within and between places in the study area are likely to lead to some benefits from agglomeration. These benefits are likely to be positively correlated with the size of the towns, their proximity to each other and the level of sectoral synergies between them. The distances between many places in the Cambridge-Milton Keynes-Oxford Corridor is over 50 kilometres, which could limit the potential level of agglomeration benefits (which decay with distance). However, places in the centre of the Corridor such as Milton Keynes, Northampton, Bedford and Wellingborough are closer together and there is evidence that the labour markets in these areas already overlap. Transport schemes which reduce travel times between the latter places would be likely to lead to high agglomeration benefits through further enhancing existing mutual relationships and widening labour market catchments.
- The study area currently supports several successful clusters with high levels of productivity (including the Science Parks located in Cambridge and Oxford and Motorsport Valley based in and around Oxfordshire). In Scheme A journey times would be reduced within Cambridge which would increase interactions between firms within the city which could allow specialised firms to expand their output. The transport schemes for Scheme B and D would increase connectivity between places within and outside the study area which could lead to increased trade flows. This could allow firms and clusters to specialise further leading to enhanced productivity.
- There could also be benefits from improved access to markets and intermediate inputs. This is most likely where there are sectoral synergies but

these are likely to be relatively small compared to the benefits from other channels.

The quantitative assessment results for scheme A show that the benefits from improving journey times within Cambridge lead to significant agglomeration benefits at £26m per annum, with the majority of the benefits are achieved within Cambridge. There are also significant benefits in South Cambridgeshire and small benefits in other locations in the study area due to the increased accessibility of Cambridge. Plots of the absolute and percentage change in productivity for all schemes are included in Appendix F.

The scheme B results show that the benefits from improving journey times between Bedford and Cambridge are higher than in the within Cambridge scheme only as the schemes are specified. The benefits for Cambridge are 37 per cent of the those in scheme A but there are significant benefits in other places including Huntingdonshire (£11m), South Cambridgeshire (£7.6m), Bedford (£4.9m) and Milton Keynes (£2.7m). In addition, there are small benefits from other places which will see journey time savings to Cambridge but there will be zero benefits for O-D pairs which do not use the A421/A428 to traverse the corridor.

The benefits from scheme C are much lower than in the other schemes which is because there are only benefits within Milton Keynes and the other parts of the study area are unaffected by the scheme. However, the cost of this scheme is likely to be significantly less than the other schemes and these results show that targeted local schemes which improve accessibility can lead to benefits to the local economy.

The scheme D results are lower than the scheme A scheme. This is because the majority of the benefits result in Milton Keynes and Northampton and the scheme does not improve significantly connectivity with other areas. However, if similar schemes to reduce journey times to other nearby places such as Bedford and Wellingborough were added into this scheme it is likely that the agglomeration benefits would be greater than in scheme A.

The results for scheme E show the highest benefits. This is due to the greater time saving compared to other schemes and also because there are significant benefits across many parts of the study area. It should be noted, however, that the cost of the scheme is likely to be high compared to the other schemes which may limit the overall impact. In addition, the scheme is transformational and the analysis of current trip patterns showed a limited number of trips between the east and the west of the corridor which could limit the extent to which the benefits of the scheme would be realised.

The implications of these findings are:

- Schemes which improve journey times within urban areas can lead to significant benefits from agglomeration. These benefits derive from increasing the economic mass of the urban area through improving interactions between firms, knowledge spill overs and expanding the labour market which leads to improved matching between skills and jobs, particularly in the higher skilled and more specialist jobs;

- There are likely to be benefits from targeted schemes which enhance accessibility within urban areas. The benefits from individual schemes may be small but the benefits would be greater if several similar schemes were introduced in other parts of the study area; and
- There are potentially significant benefits from improving links across the Corridor, albeit with substantially higher costs. These benefits are as a result of the reduced journey times which lead to improved market access and expanding the size of the labour markets. The benefits are likely to be higher for schemes which improve connectivity between places which are closer together. To fully realise potential benefits would require significant changes to the current trip patterns in the study area (i.e. dynamic land use effects). This highlights the importance of ensuring that transformational investments have a twin focus on unlocking new housing and access to jobs and on delivering new transport linkages between knowledge intensive jobs in Oxford and Cambridge.

Findings by scenario are shown summarised in Table 28 overleaf, and are elaborated in Appendix F.

Table 28: Illustrative scheme assessment findings

Illustrative scheme		Example city / town	Example scheme specification	Qualitative assessment of potential productivity benefits								Quantified agglomeration benefits (annual, 2015 prices)
				1 User benefits	2 Increase market access	3 Access to intermediate outputs	4 Size and effectiveness of labour markets (agglomeration)	5 Knowledge spill overs (agglomeration)	6 - Specialisation	7 Reduced coordination failure	8 Technology diffusion	
A	Intra-urban investment to reduce travel times within an economically successful, perhaps even overheating, area	Cambridge	5 minute reduction in average journey time within Cambridge; 2 minute reduction for trips to and from Cambridge.	High	Low – medium	None	High	Medium	Low	None	None	£25.7m
B	Extra-urban investment to improve links between two centres which do not have a strong commuting relationship already	Bedford and Cambridge	10 minute reduction in average journey time for traffic using A421/A428).	High	Low – medium	Low	Medium - high	Low	Medium	None	None	£41.4m
C	Intra-urban investment to reduce travel times between a relatively deprived area and the city centre	Bletchley and Milton Keynes Central	5 minute reduction in average journey time.	High	None	None	Medium - high	Low	Low	None	None	£4.0m
D	Extra-urban investment to improve links between two centres which already have a commuting relationship	Milton Keynes and Northampton	10 minute reduction in average journey time.	High	Low	Low	High	Low	Medium - high	None	None	£29.3m
E	Extra-urban investment to improve links between knowledge-intensive employment sectors.	Oxford and Cambridge	30 minute reduction in average journey time.	High	Low-medium	Low		High	High	Medium-high	None	£70.7m

Source: Arup

6 Conclusions

6.1 Key study findings

The study area has three of the highest performing economies in the south-east in it. The Cambridge Econometrics work has identified that two of the three economies (Oxford and Cambridge) are facing constraints to growth, for a number of reasons including greenbelt constraints. These factors, together with the growth in population of Milton Keynes and Northampton, and the pressure of London overspill is putting pressure on the transport network. To this we would add that their radial and inner orbital transport networks are correspondingly struggling. Across the corridor, further economic growth and quality of life in the area is threatened by the increasing demand placed on transport links, and the need for good quality housing provision that is affordable, in the right places and connected to job opportunities and sustainable communities.

In addition, the four relatively self-contained labour market areas within the study area (Swindon, Oxford, the central area of Milton Keynes – Northampton – Bedford – Wellingborough, and Cambridge), and the degree of interaction with the London labour market, suggests that more could be done to enable the area to function as a corridor. The degree of interaction in the central Milton Keynes – Northampton – Bedford – Wellingborough constellation, reflects the better transport links between those towns.

Previous evidence also suggests that transport is most likely to deliver catalytic change when it assists in unlocking identified constraints to growth, and the current transport situation suggests that the worst pinch points are on urban networks, with less evidence of problems on inter-urban routes (although journey times remain long, and so the lack of problems may be partially reflective of a lack of use). As such, it is challenging to determine what the economic interactions might look like if new transport links were provided.

Nevertheless, our strategies suggest focussing on lifting the major constraints to the extent possible – this means targeting existing urban transport pinch points first, to create better access to the future employment opportunities in the major town centres, together with transport investments that open up housing and employment land opportunities (the most obvious constraints, and the building blocks for growth). The prioritisation of the unlocking of existing constraints (links to employment opportunities and deliver housing at scale) would be expected to deliver the fastest benefits. This is backed up by our quantitative assessment which suggests that intra-urban investments within economically successful areas, and extra-urban investments between centres that are more close together have the potential to generate significant agglomeration benefits.

The corridor is already a net contributor to the Exchequer, and plays an important role in the national transport story through hosting several of the main road and rail links, and well as the forthcoming HS2. Whilst local in nature, the investment packages that we have identified have significant national benefits. And in return, many national schemes are creating a good opportunity to yield local benefits. We have also identified investments that would potentially free up sites for housing development, which in addition to fulfilling other policy needs would potentially generate a source of additional funding for the infrastructure plan.

Our joint work with Savills suggests that the long term housing strategy for the corridor is partially dependent on options for east-west connectivity. There are locations along the East West Rail line and the Expressway where housing sites are unlocked. In addition, other methods of connectivity, within the urban areas, and on a north-south axis, also open up additional housing. The latter could be particularly important in accommodating some of London's growth.

A number of these short term enhancements to transport could help bring forward current plans for housing. There is "low hanging fruit" in other areas as well - whilst the long term strategy for growth should not focus exclusively on east-west connectivity across the whole corridor, there are segments of it, particularly in between Milton Keynes and Cambridge that could support growth in specific locations.

Areas of the corridor have enjoyed economic success, particularly in the knowledge based industries, which is coupled with a perceived high quality of life. In its response to the NIC's call for evidence, the joint response from the Local Enterprise Partnerships highlighted that whilst some of these strengths build on a history of success, future success should not be taken for granted, and similarly, the corridor has huge potential for further growth.

6.2 Delivering the transport strategy

The long term vision up to 2050 is to achieve a single, knowledge based cluster, a growth in economic performance within the corridor and to support growth outside of London. Ambition is needed to deliver this. The transport schemes identified, coupled with the building programme to meet the housing need, represent a step-change in the level of investment in the region that has perhaps not been seen since the building of the motorway network and subsequent establishment of the new towns of Milton Keynes and Northampton.

Recognising that we are facing an increased level of uncertainty, the infrastructure investment strategy in this document is intended to be updated frequently, and more detailed work is recommended. Further thoughts on the flexibility that might be needed are provided in Appendix G.

Furthermore, our identification of the key influences that transport can have on housing, and the key economic benefits that transport can bring, illustrates the level of interaction between the three sectors. In order to reap benefits from a unified approach, and to deliver the ambitious investment programme (which would include other utilities as well), a change in procedures may be needed, whereby local governance arrangements are built upon and enhanced. We suggest that this would include even greater coordination between the many organisations involved, including local authorities, LEPs, national transport bodies such as Highways England and Network Rail, other infrastructure providers, and housing providers.

This may come through merging some areas of sub-national planning, and the bid by the England's Economic Heartland alliance to become a statutory transport body is, potentially, a welcome step towards this. We note that England's Economic heartland is already seeking to simplify planning processes and to take a role in bringing forward housing developments through coordinating infrastructure investment, and alongside this, we note the importance of in-depth local knowledge in successful delivery of these schemes, and the success of the local authorities to date, whilst suggesting that there is scope for the Alliance to take on more responsibility, in the right circumstances.

This greater coordination is important for three other reasons that are in addition to improving deliverability. Firstly, it would increase the quality of the end-product – that is, infrastructure that better reflects the needs of the local residents, and housing that is better served by infrastructure. Secondly, an authority overseeing housing and transport may play a coordinating role in delivering supplementary funding mechanisms (such as revenue streams from housing). And thirdly, because the construction phases of the investment plans in particular will have to take careful account of one another. The recent Farmer review[51] into the labour market within the construction sector highlighted low investment in innovation and an ageing workforce as limitations on the industry to deliver the national infrastructure needs. At the margins, coordination is a means of addressing this, for example through coordinating work (to "dig once") and to ensure that the supply chain retains liquidity.

This will require a step up in the leadership and coordination role of the public sector. It will also require a step-up in levels of spending. In the housing report, Savills identified the need for greater public sector involvement if the transformational targets are to be met. Nevertheless, private sector funding (through land value capture, CIL, s106 or other means) is likely to have an increased role to play, will have an increased supplementary role in funding future schemes. For example, the Metro Dynamics work suggests that a Business Rate Supplement (BRS), which they suggest is the most effective way to capture land value, would yield between £2-3m per annum in each of the major cities. The public sector role for funding the remainder of the costs of transport schemes, through traditional means is likely to continue for the foreseeable future.

We have identified in this report that transport schemes such as those within our proposals can yield significant economic benefits. Delivering the investment plans will be subject to a satisfactory investment case, which will be reliant on an increased evidence base. We suggest that a more locally detailed and nuanced approach is required, based upon robust project appraisal at a scheme as well as programme level, and over the short, medium and long term. This may be iterative, as like this piece of work, transport need will respond to housing developments, and vice versa. Given the strategic value of the investments, and the uncertainties involved, the method of appraisal of transport schemes should have the strategic case at its heart, and a greater acknowledgement of wider economic benefits than might be expected for a more standard transport investment. We therefore suggest the case for East West Rail and the Expressway should continue to focus on the potential to unlock housing, link new and existing housing to employment opportunities, and increasing service frequencies against what is currently proposed in order to make their case[52].

[51] Modernise or Die: The Farmer Review of the UK Construction Labour Model, *Farmer, 2016*

[52] This is broadly in line with the NIC's recommended approach to Crossrail 2

To an extent, this would rely upon the level of detail that local partners have developed in their specific project proposals and planned growth schemes. Our packages of proposed enhancements on a local level provide a starting point for this, and we suggest that these might be taken down to the corridor level when being developed.

Finally, we acknowledge that the schemes involved, especially when coupled with the housing need and the funding mechanisms, are perhaps appropriately labelled as transformational in one scenario. There are likely to be challenges to delivery, including the environmental constraints identified in this report, and the funding needs identified in the Metro Dynamics report. Overcoming these will require national and local politicians to be ambitious, and to work closely with the public, businesses and other stakeholders in order to collaborate, to encourage buy-in, to minimise adverse impact and to realise the significant opportunities that we have identified.

Appendix A

Full sift results and scheme details

A1 Full sift results

The sift results are presented in Appendix A1 which accompanies this report as a separate document.

A2 Full package details

The full package details are presented in Appendix A2 which accompanies this report as a separate document.

Appendix B

Congestion

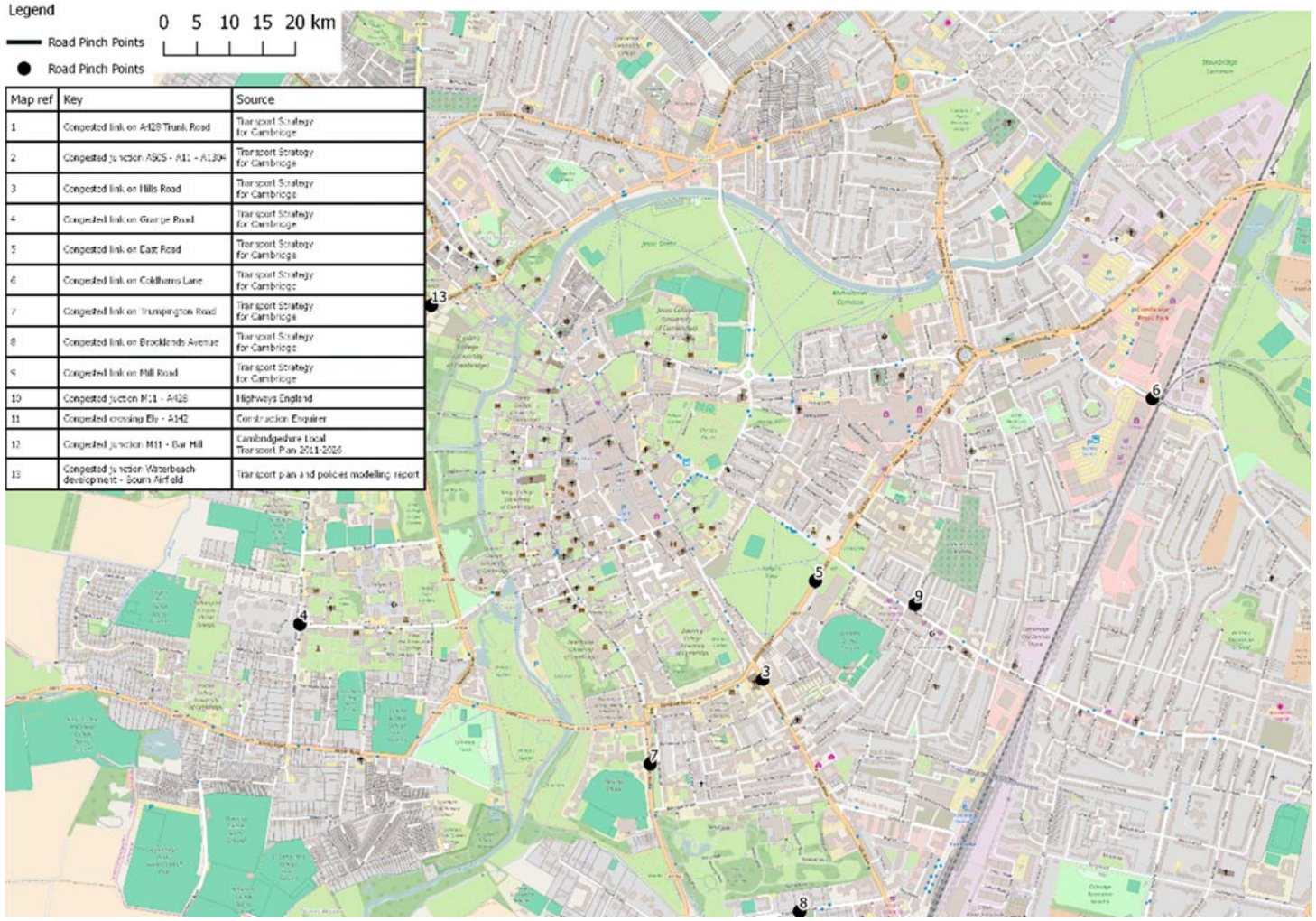
B1 Town Centre Congestion

Figure 33 to Figure 36 summarise the key congestion points in Cambridge, Milton Keynes, Northampton and Oxford. With the exception of Milton Keynes the congestion is, in part, typical of urban areas where the pattern of streets and the built environment became ingrained before the advent of the car:

- Radial routes into the centre of the urban areas are congested during the peak periods as a result of the tidal flow of movements into and out of the urban areas;
- Ring roads which also form part of the inter-urban network experience peak period congestion as movements to and from the urban centres compete with inter-urban traffic for space; and
- Specific junctions, where capacity is limited and opportunities to increase capacity is constrained by the built environment, exacerbate radial congestion.

Milton Keynes benefits from a street network designed for the car and radial route congestion is less pronounced. However junctions 13 and 14 of the M1 experience significant peak period congestion and the A5, where it forms part of the both the inter-urban network and Milton Keynes's urban network, is congested.

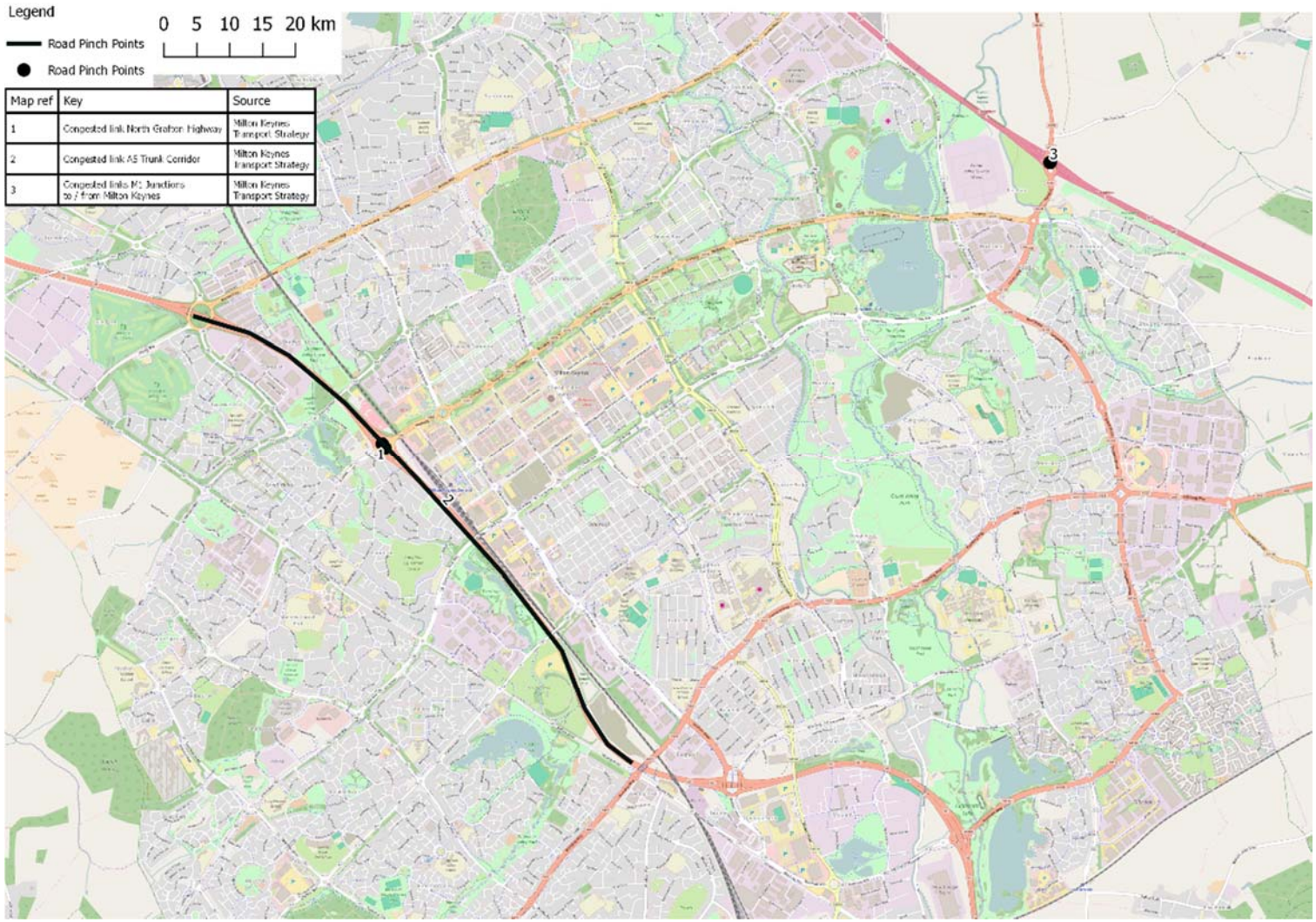
Figure 33: Congestion pinch points: Cambridge



Map ref	Key	Source
1	Congested link on A428 Trunk Road	Transport Strategy for Cambridge
2	Congested junction A505 - A11 - A1304	Transport Strategy for Cambridge
3	Congested link on Hills Road	Transport Strategy for Cambridge
4	Congested link on Grange Road	Transport Strategy for Cambridge
5	Congested link on East Road	Transport Strategy for Cambridge
6	Congested link on Coldhams Lane	Transport Strategy for Cambridge
7	Congested link on Trumpington Road	Transport Strategy for Cambridge
8	Congested link on Brooklands Avenue	Transport Strategy for Cambridge
9	Congested link on Mill Road	Transport Strategy for Cambridge
10	Congested junction M11 - A428	Highways England
11	Congested crossing Ely - A142	Construction Enquirer
12	Congested junction M11 - Bar Hill	Cambridgeshire Local Transport Plan 2011-2026
13	Congested junction Waterbeach development - Bourn Airfield	Transport plan and policies modelling report

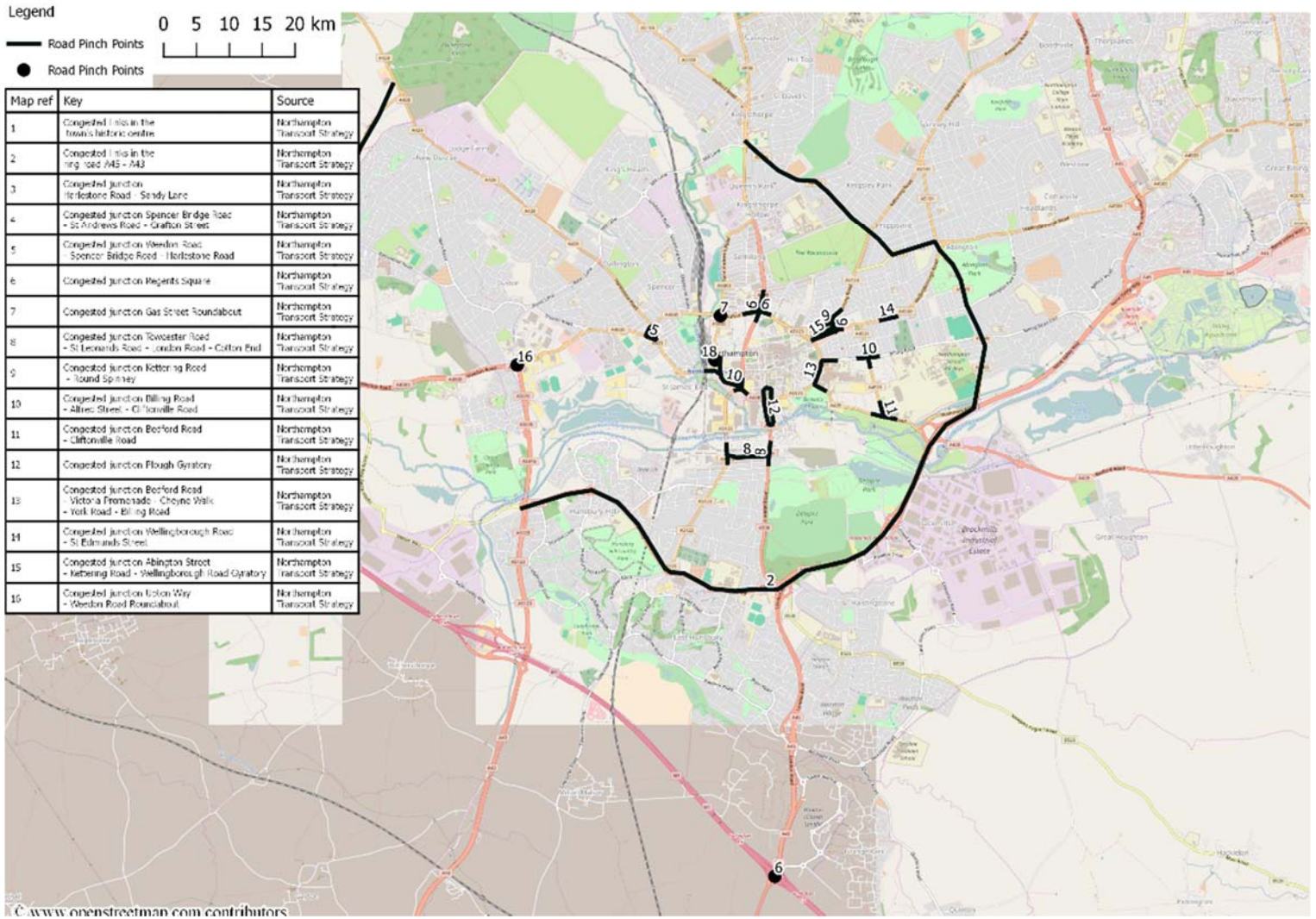
Source: Open street map, Arup, Local Transport Plans

Figure 34: Congestion pinch points: Milton Keynes



Source: Open street map, Arup, Local Transport Plans

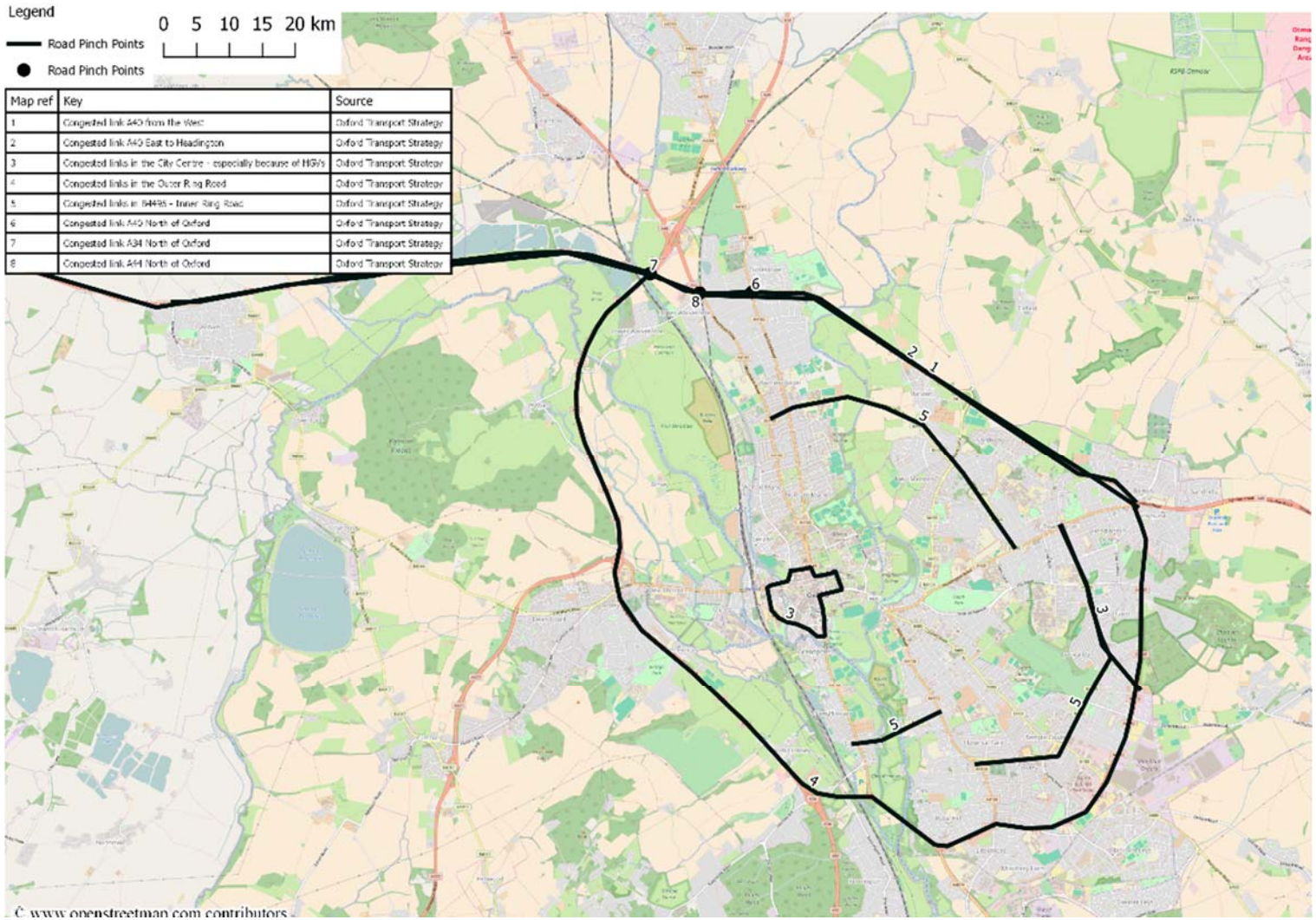
Figure 35: Congestion pinch points: Northampton



Map ref	Key	Source
1	Congested links in the town's historic centre	Northampton Transport Strategy
2	Congested links in the ring road A45 - A43	Northampton Transport Strategy
3	Congested junction Harlestone Road - Sandy Lane	Northampton Transport Strategy
4	Congested junction Spencer Bridge Road - St Andrews Road - Grafton Street	Northampton Transport Strategy
5	Congested junction Weedon Road - Spencer Bridge Road - Harlestone Road	Northampton Transport Strategy
6	Congested junction Regents Square	Northampton Transport Strategy
7	Congested junction Gas Street Roundabout	Northampton Transport Strategy
8	Congested junction Towcester Road - St Leonards Road - London Road - Colton End	Northampton Transport Strategy
9	Congested junction Kettering Road - Round Spinney	Northampton Transport Strategy
10	Congested junction Billing Road - Albert Street - Cliftonville Road	Northampton Transport Strategy
11	Congested junction Bedford Road - Cliftonville Road	Northampton Transport Strategy
12	Congested junction Plough Gyratory	Northampton Transport Strategy
13	Congested junction Bedford Road - Victoria Promenade - Cheyne Walk - York Road - Billing Road	Northampton Transport Strategy
14	Congested junction Wellingborough Road - St Edmunds Street	Northampton Transport Strategy
15	Congested junction Abington Street - Kettering Road - Wellingborough Road Gyratory	Northampton Transport Strategy
16	Congested junction Upton Way - Weedon Road Roundabout	Northampton Transport Strategy

Source: Open street map, Arup, Local Transport Plans

Figure 36: Congestion pinch points: Oxford



Source: Open street map, Arup, Local Transport Plan

B2 Inter Urban Routes

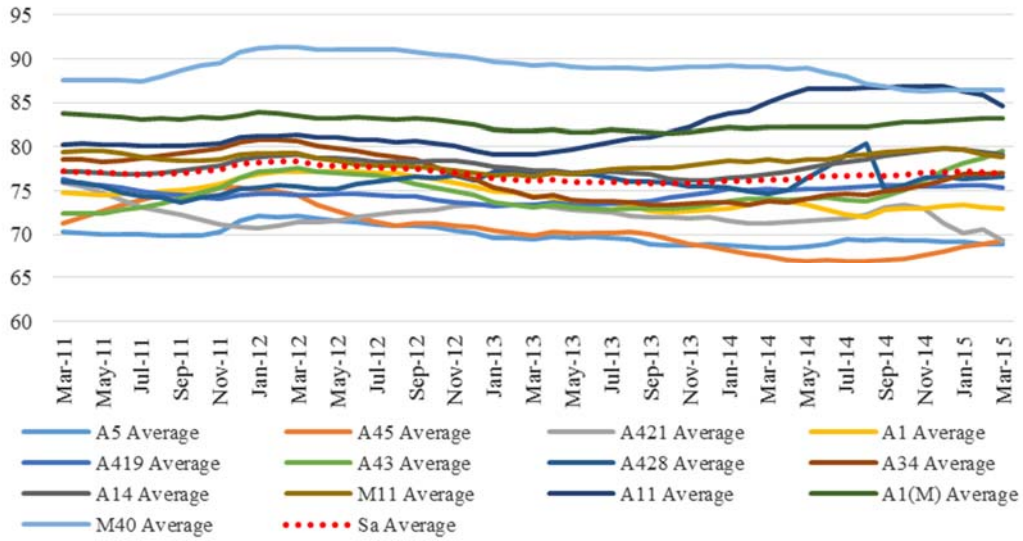
Figure 37 summarises the percentage of journeys ‘on time’ on the strategic network links in the study area and Figure 38 translates this information on the strategic highway network in the study area. Journey time reliability on the strategic road network is measured by Highways England and expressed in terms of the percentage of journeys which are ‘on time’. Journeys are defined as travel between adjacent junctions on the network and an ‘on time’ journey is one which is completed within a set reference time drawn from historic data on that section of road. A lower proportion of journeys which are ‘on time’ reflects greater variability in traffic conditions.

Sudden changes in the proportion of journeys ‘on time’ which are not sustained over a long period most likely reflect highway works, either on the route or on adjacent routes which resulted in reduced capacity or people choosing to alter their journey. Sustained changes most likely reflect permanent changes to the highway network although it should also be noted that updated reference times would also have an impact on the proportion of journey’s ‘on time’.

The proportion of journeys which are ‘on time’ for the strategic network has stayed broadly the same over the period for which data are available. Those routes which interact most closely with the urban network (such as the A5 and the A45) have a lower proportion of journeys ‘on time’. A review of the changes over time shown on Figure 37 in the context of completed schemes and works on the strategic network did not identify specific correlations. The changes over time may therefore reflect changes to the nearby local highway network.

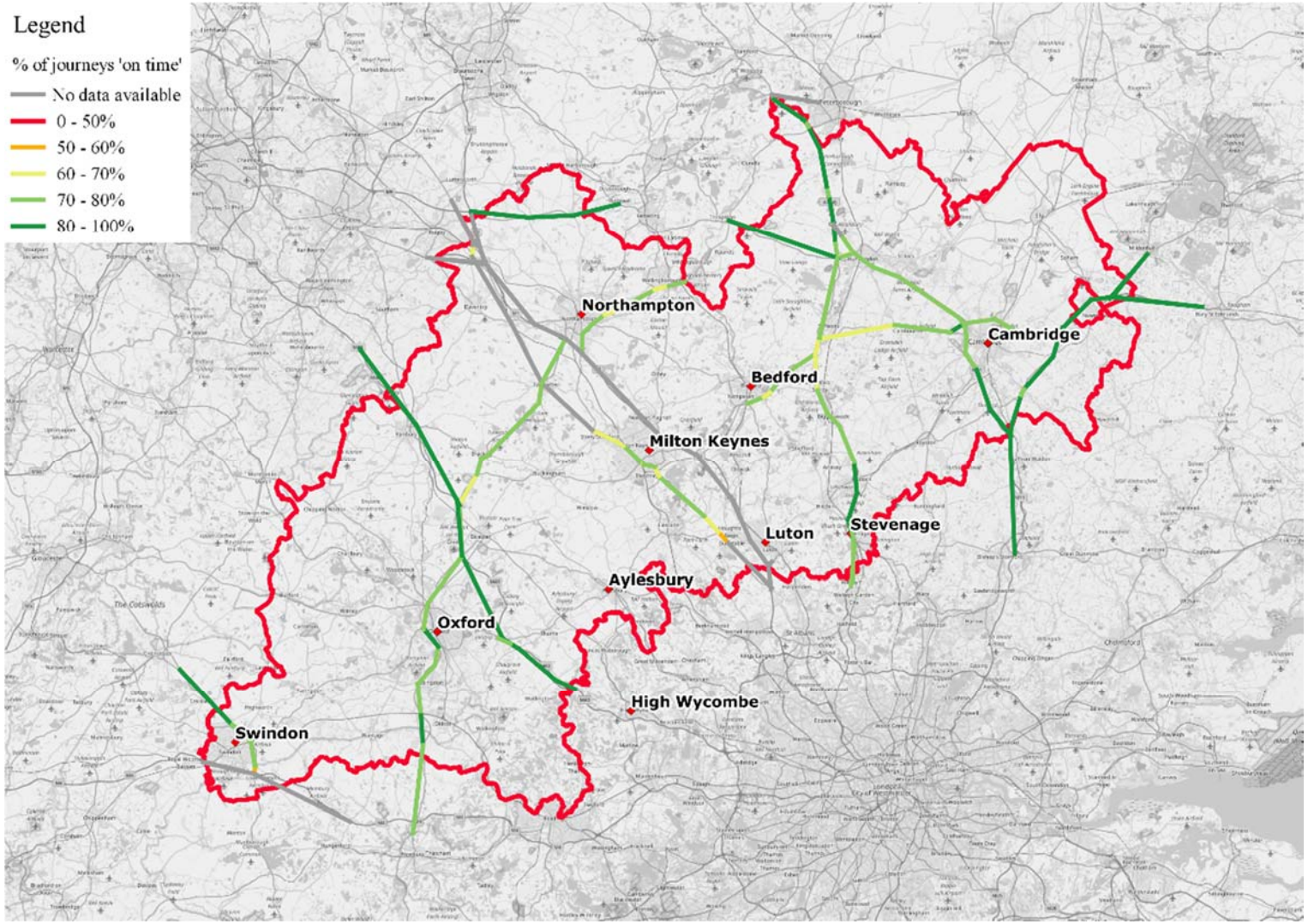
The overall performance of the strategic network within the study area: an average of 77% of journeys on time over the period for which data is available is marginally below the national average of 7% of journeys on time. The trend over time within the study area – a reduction in the proportion of journeys on time of less than 1% compares favourably to the national average where the proportion of journeys on time has fallen by 1.6%.

Figure 37: Percentage of journeys that are 'on time' – Strategic road network – Year Ending March 2011-March 2015



Source: DfT, Table CGN0106, Experimental Statistics: Percentage of journeys on Highways Agency roads that are 'on time

Figure 38: Percentage of journeys that are 'on time' – Strategic road network



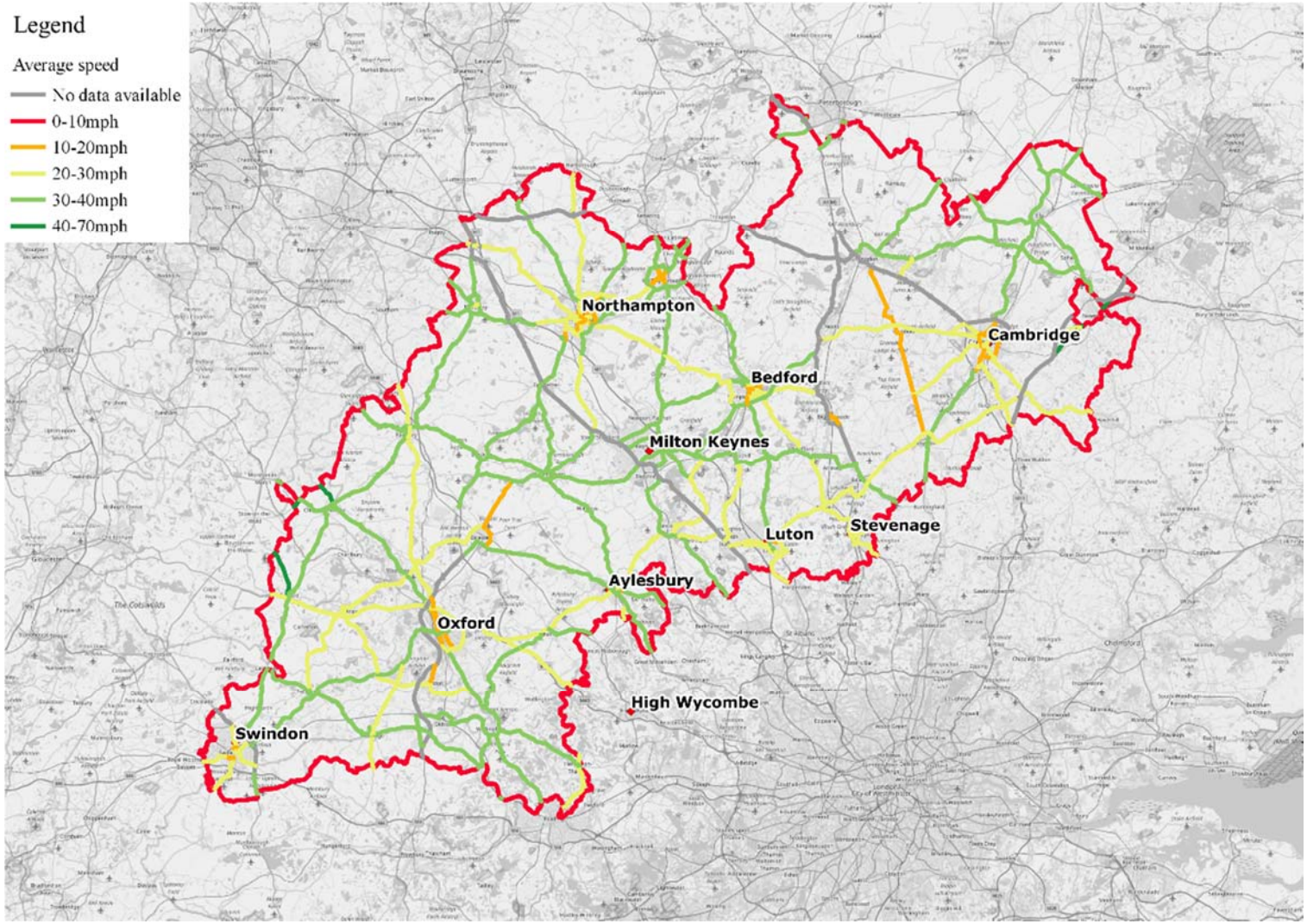
Source: DfT, Table CGN0106, Experimental Statistics: Percentage of journeys on Highways Agency roads that are 'on time', Open street map

Data for the ‘A’ roads managed by the local highway authorities within the study area is published by DfT. The data cover the weekday morning peak hour average speeds by direction of travel for each A road in the study area. Figure 39 shows the average speeds for the A roads in the study area and Figure 40 shows that these have remained broadly constant since 2007.

Luton’s average journey speeds are the lowest at around 20 miles per hour, and Central Bedfordshire’s are the highest at around 32 miles per hour.

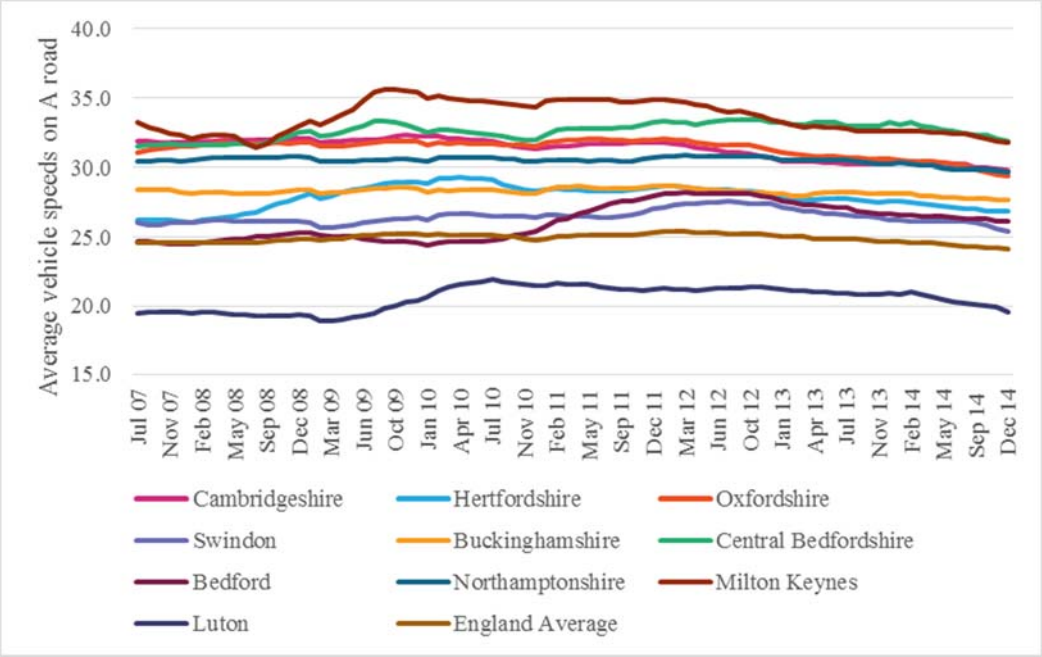
With the exception of Luton, all of the local authority networks have higher average speeds than the England average, although some of them have experienced sharper declines in recent years, perhaps reflecting the rate of economic growth in the study area relative to the country as a whole.

Figure 39: Average morning weekday peak hour speeds (average of directions)



Source: Dft, Table CGN0209, Experimental Statistics: Average vehicle speeds during weekday morning peak on locally managed 'A' roads

Figure 40: Average vehicle speeds on A Roads in the study area, 2007 – 2014



Source: Dft, Table CGN0209, Experimental Statistics: Average vehicle speeds during the weekday morning peak on locally managed 'A' roads`

B2.1 Top ten slowest A roads under local authority control

Table 29 below shows the average speeds for the 10 slowest roads in the study area, as of December 2014. All 10 roads have average speeds well below the England average of around 24 miles per hour, and the list features roads in Hertfordshire, Buckinghamshire, Oxfordshire, Bedford, and Northamptonshire.

There are two roads that feature twice in the list, with both directions of travel featuring amongst the slowest in the study area. These are the A5141 in Bedford, and the A4501 in Northamptonshire.

Table 29: Study area's 10 slowest A roads under local authority control, December 2014

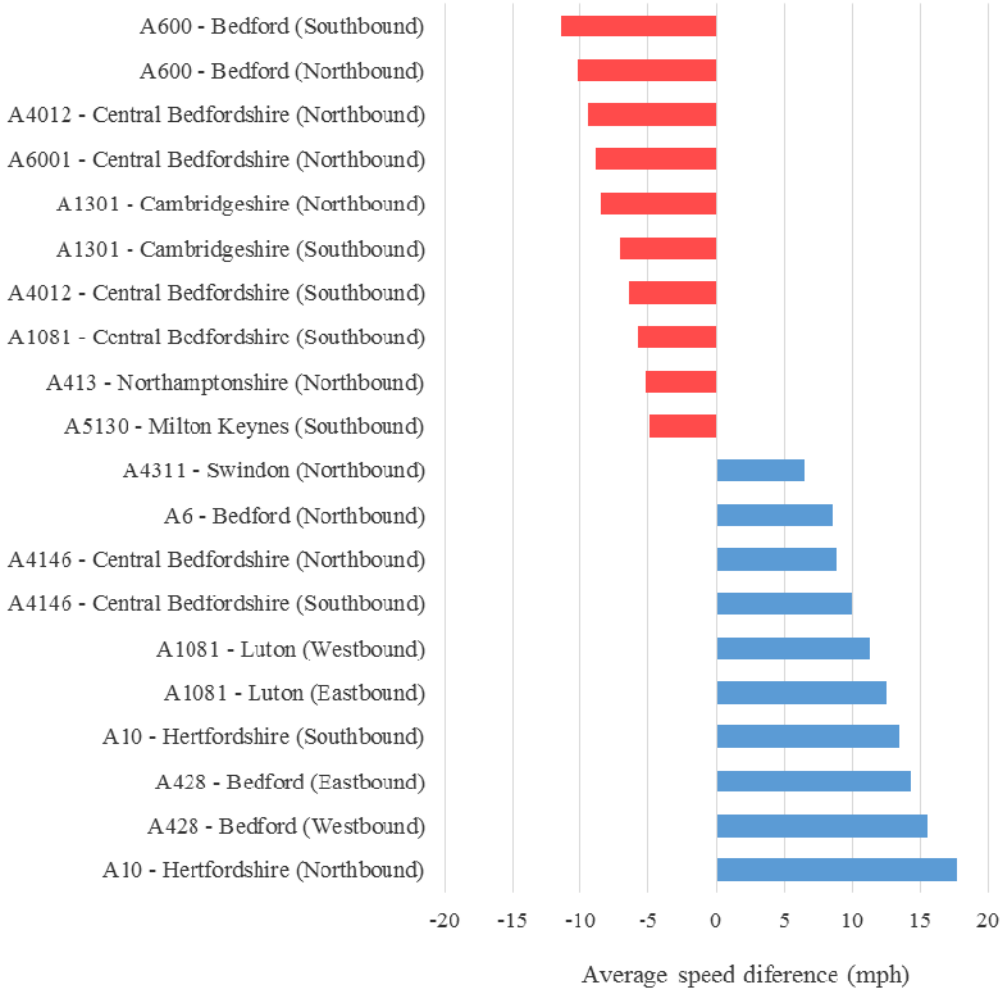
A Road	Average speed (mph)
A111 - Hertfordshire (Northbound)	8.2
A4178 - Hertfordshire (Southbound)	9.9
A4020 - Buckinghamshire (Southbound)	10.3
A4165 - Oxfordshire (Southbound)	11.3
A5141 - Bedford (Northbound)	12.1
A4140 - Hertfordshire (Eastbound)	12.6
A5141 - Bedford (Southbound)	12.9
A4501 - Northamptonshire (Northbound)	13.1
A4144 - Oxfordshire (Southbound)	13.2
A4501 - Northamptonshire (Southbound)	13.3
England Average	**24.1**

Source: Dft, Table CGN0209, Experimental Statistics: Average vehicle speeds during the weekday morning peak on locally managed 'A' roads`

B2.2 Top 10 average road speed increases and decreases, 2008 to 2014

Figure 41 below shows the top 10 increases and decreases in average speeds for 2008 to 2014. This indicates where specific pinch points may have worsened or where roads have become efficient parts of the network. An average was taken for the whole year for both 2008 and 2014 to avoid picking up what could be road works and short term schemes. In particular, many roads in Bedford and Cambridgeshire have seen increases in speeds of between 5 and 10 miles. The A600 in Bedford, which has seen reductions in speed in both directions, is likely to be a specific pinch point on the network, as is the A1301 in Cambridgeshire. In terms of improvements, the A428 seems to have become a more efficient part of the study area's road network.

Figure 41: Top 10 average A road speed increases and decreases in the study area, 2008 to 2014

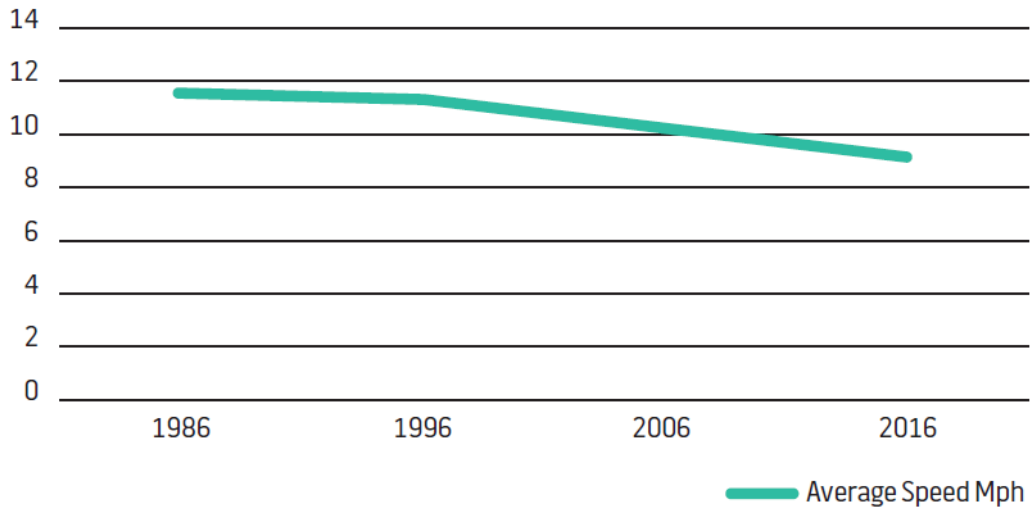


Source: Dft, Table CGN0209, Experimental Statistics: Average vehicle speeds during the weekday morning peak on locally managed 'A' roads`

B3 Public transport and congestion

Whilst the bus network in these towns is well used, the level of bus priority which can be accommodated within the available highway is limited. Bus priority measures on radial routes into the centres vary from the guided busways in Cambridge and Luton where buses are fully segregated from general traffic to limited sections of bus lane. The limited segregation from car means that buses are often susceptible to the same delays as the conventional road network. In Oxford, for example, bus average speeds have reduced by some 20% in the last 30 years.

Figure 42: Average bus speeds in Oxford, 1986 to 2016



Source: Greener Journeys (The Impact of Congestion on Bus Passengers) 2016.

Table 30 overleaf illustrates the impact that bus priority measures can have. Route C between Dunstable High Street and Luton Station runs along 4.8 miles of fully segregated busway allowing the buses to run unimpeded by general traffic. The impact of providing full segregation can be seen in the journey times for the bus compared to a car travelling between the same origin and destination. The remaining routes have varying degrees of bus priority: the city 2 route between Oxford Airport and Magdalen Street benefits from a continuous inbound bus lane along Oxford Road until it reaches the built up area of Oxford. From the edge of the built up area the bus lane is interrupted by pedestrian crossings, signal controlled junctions and roundabouts where buses are mixed into general traffic.

Bus priority measures can significantly improve journey times where the measures implemented are continuous for the length of the route as the Luton Dunstable Busway and Cambridge guided bus demonstrate.

Where the built environment constrains the ability to provide continuous bus priority, without significantly compromising highway capacity, the benefits of the limited priority that can be introduced are constrained as demonstrated by the performance of the bus on the radial routes identified in Table 30.

Table 30: Bus journey time comparison

City	Bus Route	Origin	Destination	Bus Departure	Bus Arrival	Bus Duration (minutes)	Car Trip Duration (minutes)	Distance (miles)	Time (hours) for bus	Bus Speed (mph)	Car Speed (mph)
Oxford	City 2	Oxford Airport	Oxford Magdalen Street	08:09	08:53	00:44	17.0	6.7	0.7	9.1	23.6
Cambridge	1Citi	Fulbourn	St Andrew's Street	08:00	09:03	01:03	24.0	5.1	1.1	4.9	12.8
Northampton	7	Grange Park, opp Lake	Northampton, North Gate Bus Station	08:22	08:52	00:30	18.0	5.1	0.5	10.2	17.0
Luton	C	Dunstable High Street North	Luton Station Interchange	08:04	08:23	00:19	21.0	5.4	0.3	17.1	15.4
Milton Keynes	14	Wolverton, Church Street	Milton Keynes Central Rail Station	08:29	08:58	00:29	12.0	3.5	0.5	7.2	17.5
Stevenage	SB8	Bragbury End	Stevenage bus and rail station	08:07	08:24	00:17	11.5	3.8	0.3	13.4	19.8
Swindon	16	Great Western Hospital	Fleming Way	08:07	08:21	00:14	13.0	3.6	0.2	15.4	16.6

Source: Online timetables

Appendix C

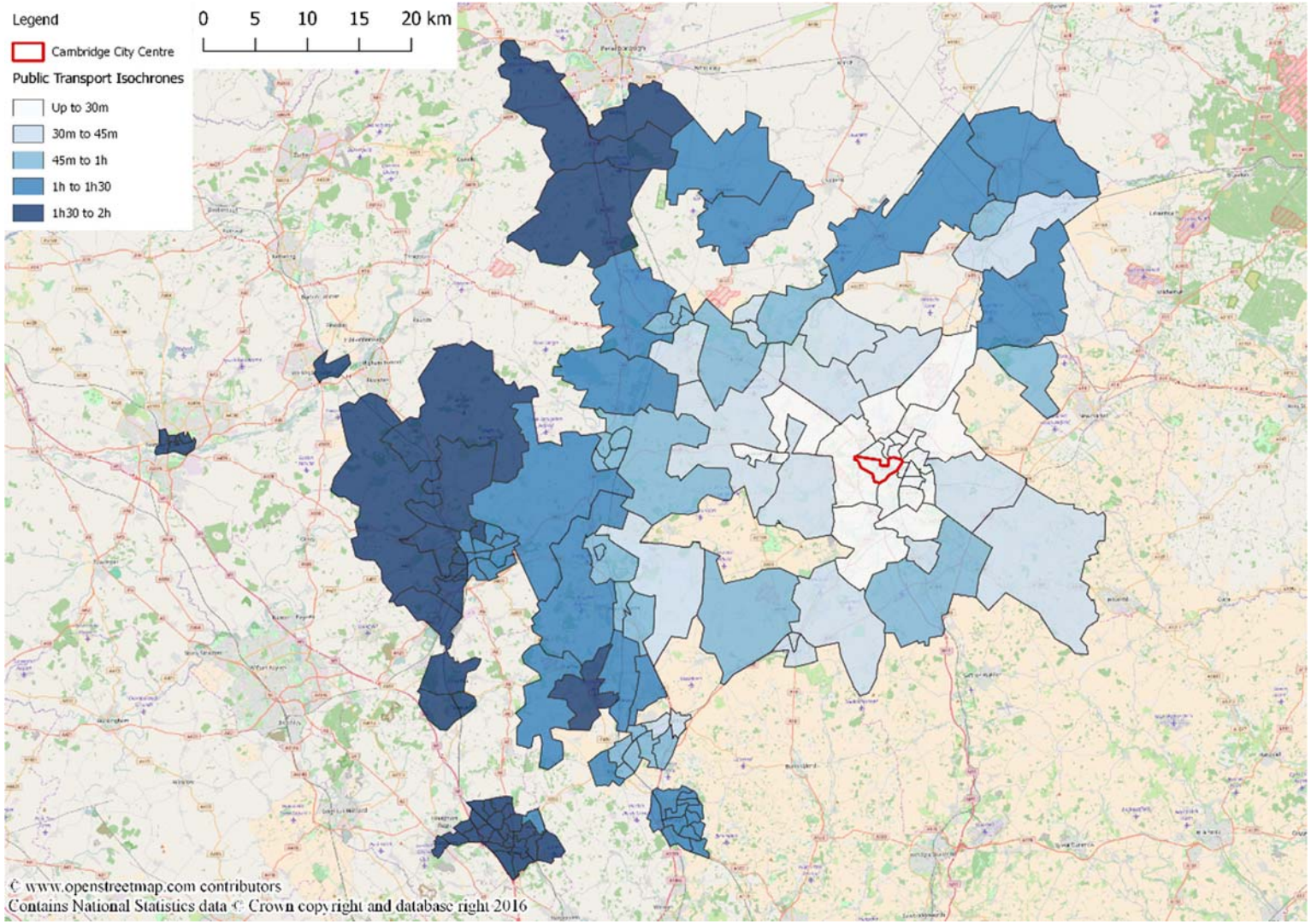
Bus journey isochrones

Bus journey isochrones - Overview

Public Transport isochrones plots for the urban centre show the paucity of high quality public transport connections beyond the built up areas. The plots show where a reasonable connection to public transport can be made: gaps indicate that those areas have no, or poor connectivity, to public transport. In many instances this is a reflection of the time it takes to reach a point on the local transport network from which a public transport trip can be made.

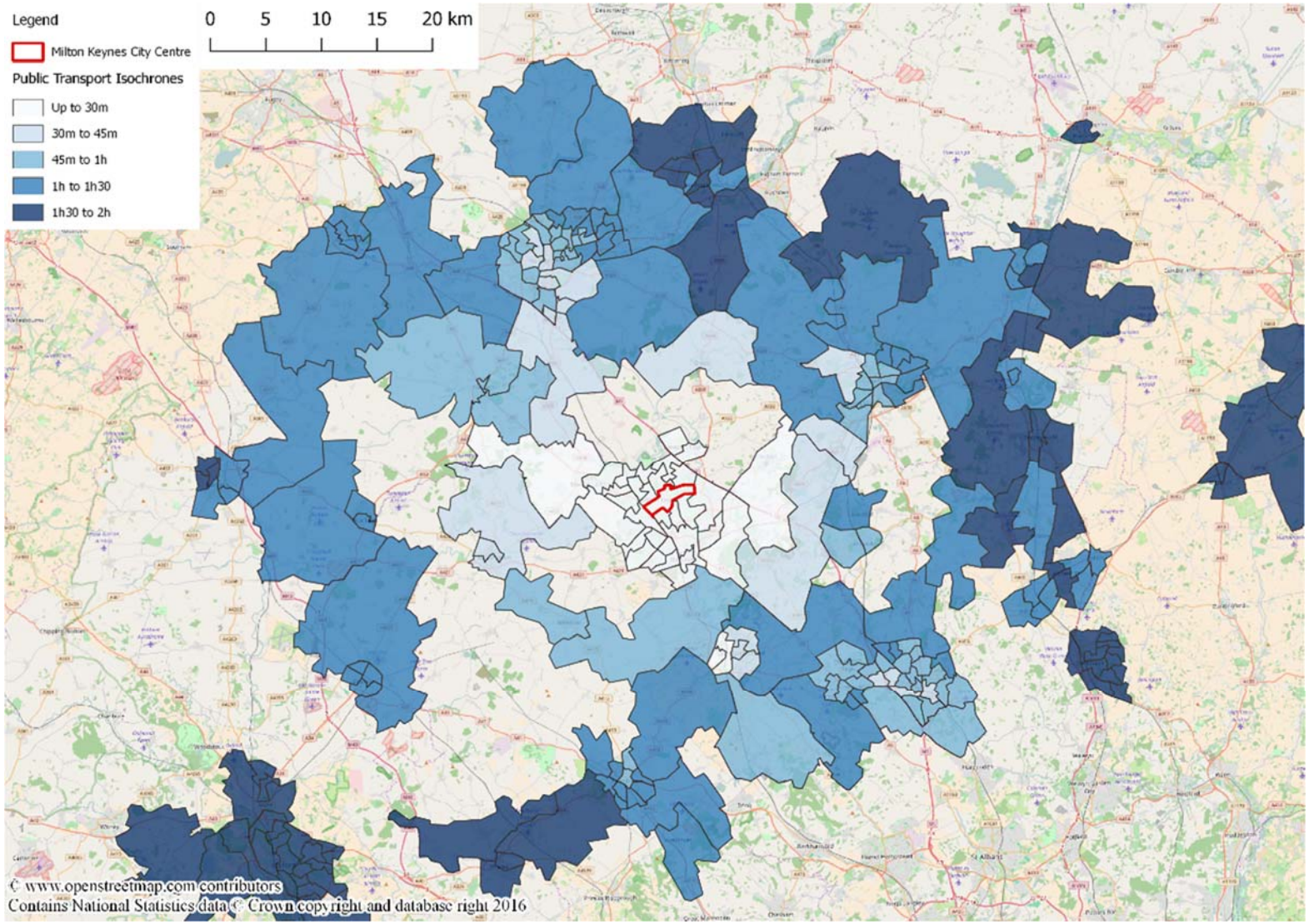
The implication is clear within and immediately surrounding urban centres bus routes offer a viable alternative to the car, into more rural areas and between urban centres outside of London the car is likely to remain the dominant mode of transport for reasons of journey time, convenience and comfort.

Figure 43: Public Transport Isochrones – Cambridge



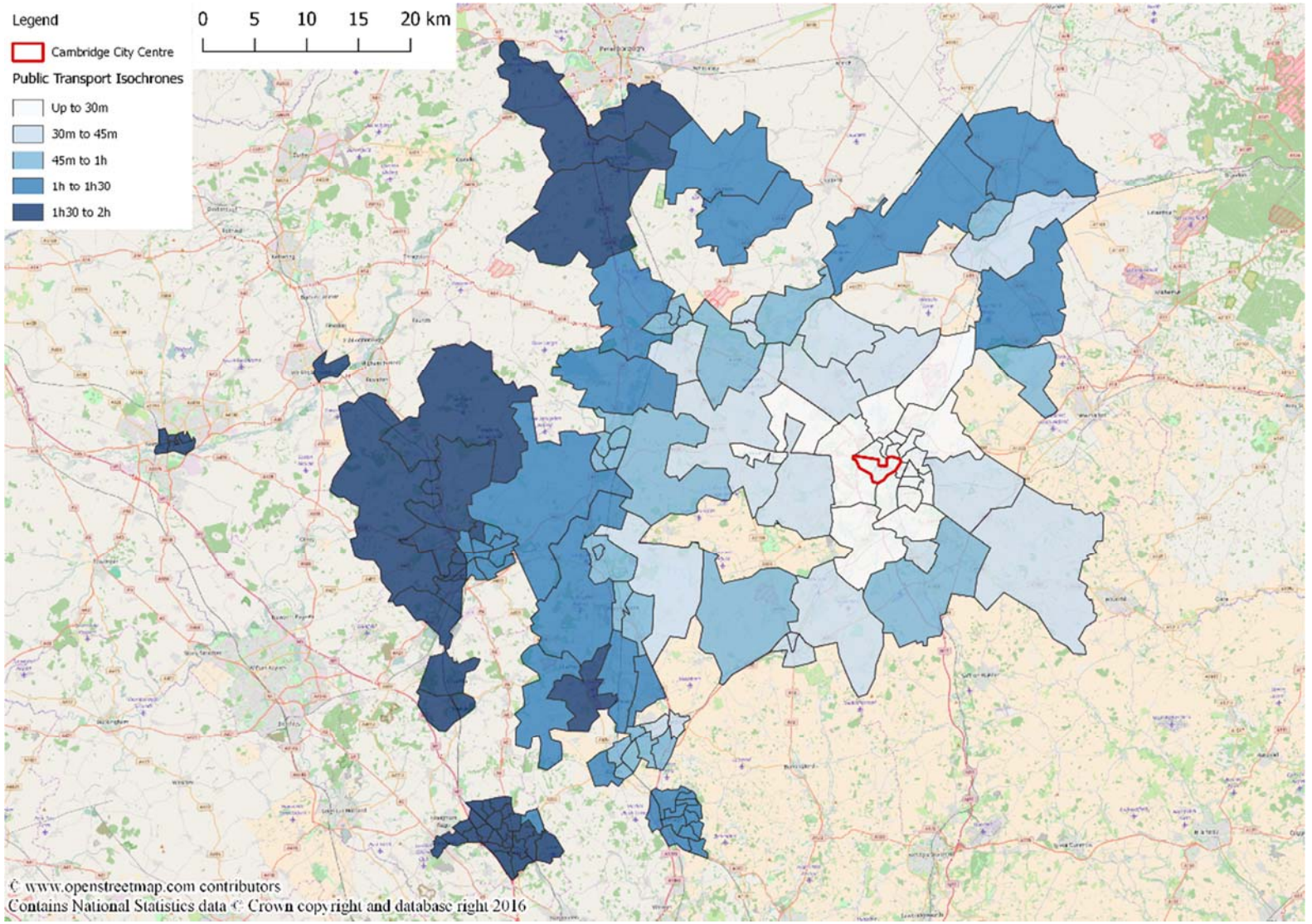
Source: TRACC

Figure 44: Public Transport Isochrones – Milton Keynes



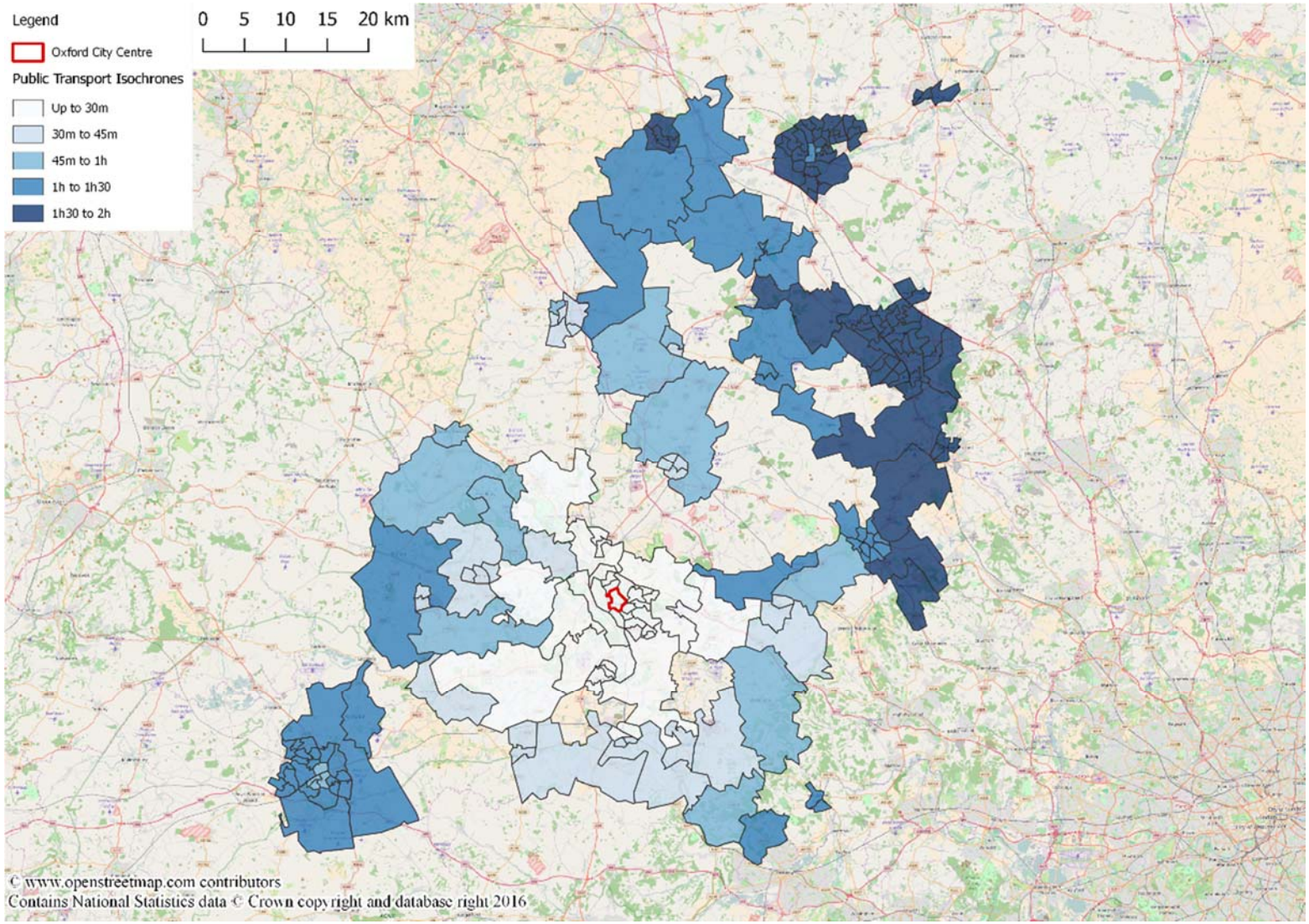
Source: TRACC

Figure 45: Public Transport Isochrones – Northampton



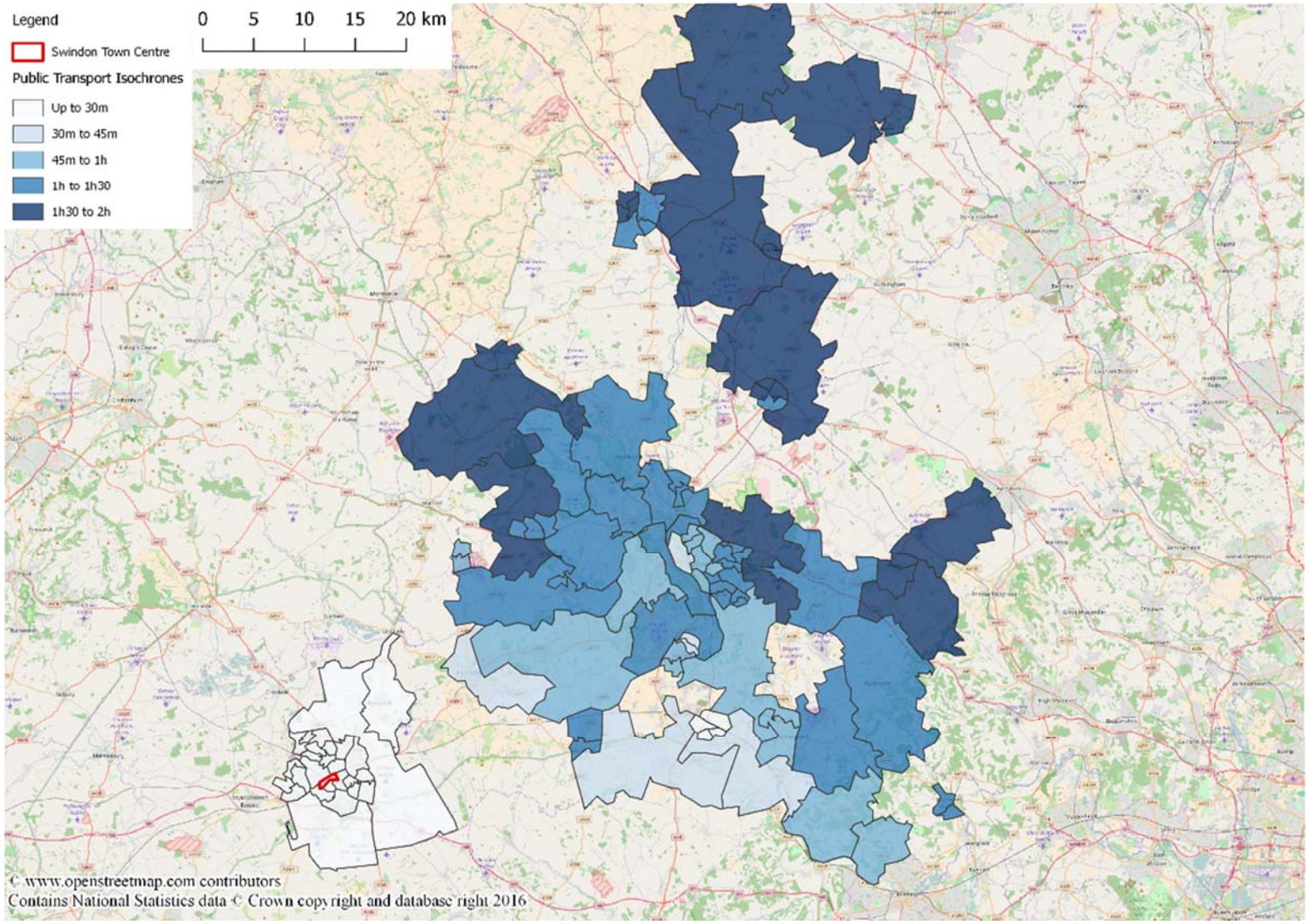
Source: TRACC

Figure 46: Public Transport Isochrones – Oxford



Source: TRACC

Figure 47: Public Transport Isochrones – Swindon



Source: TRACC

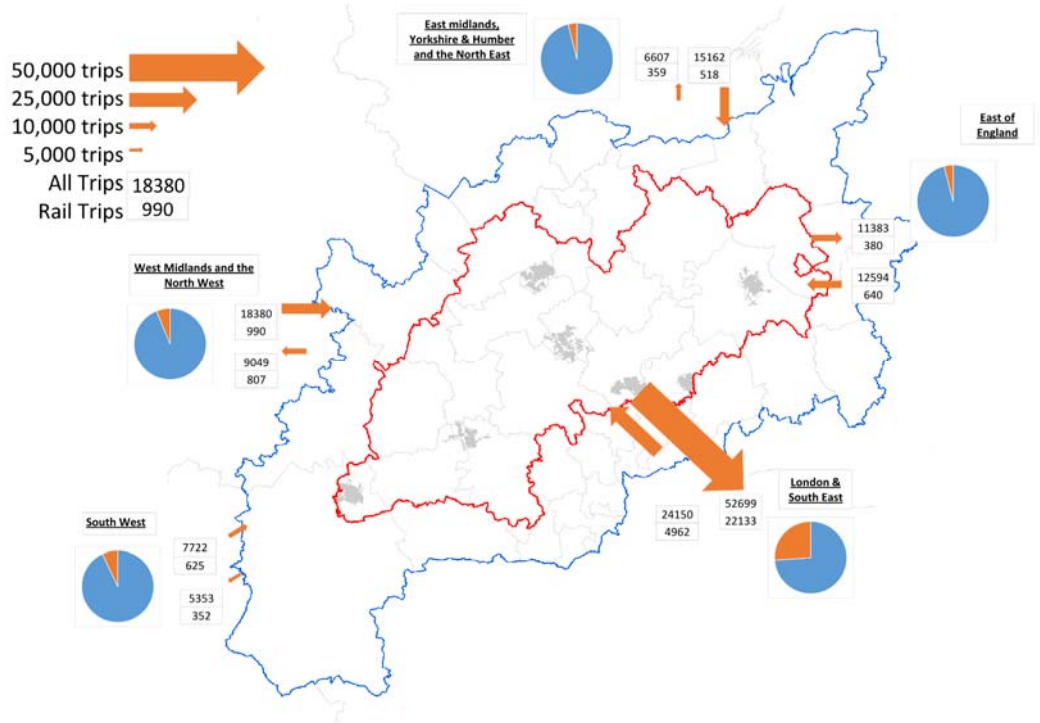
Appendix D

Commuting patterns

D1 Commuting patterns outside of the study area

Figure 48 shows the commuting patterns to and from the study area highlighting the strength of the relationship with London and the South East.

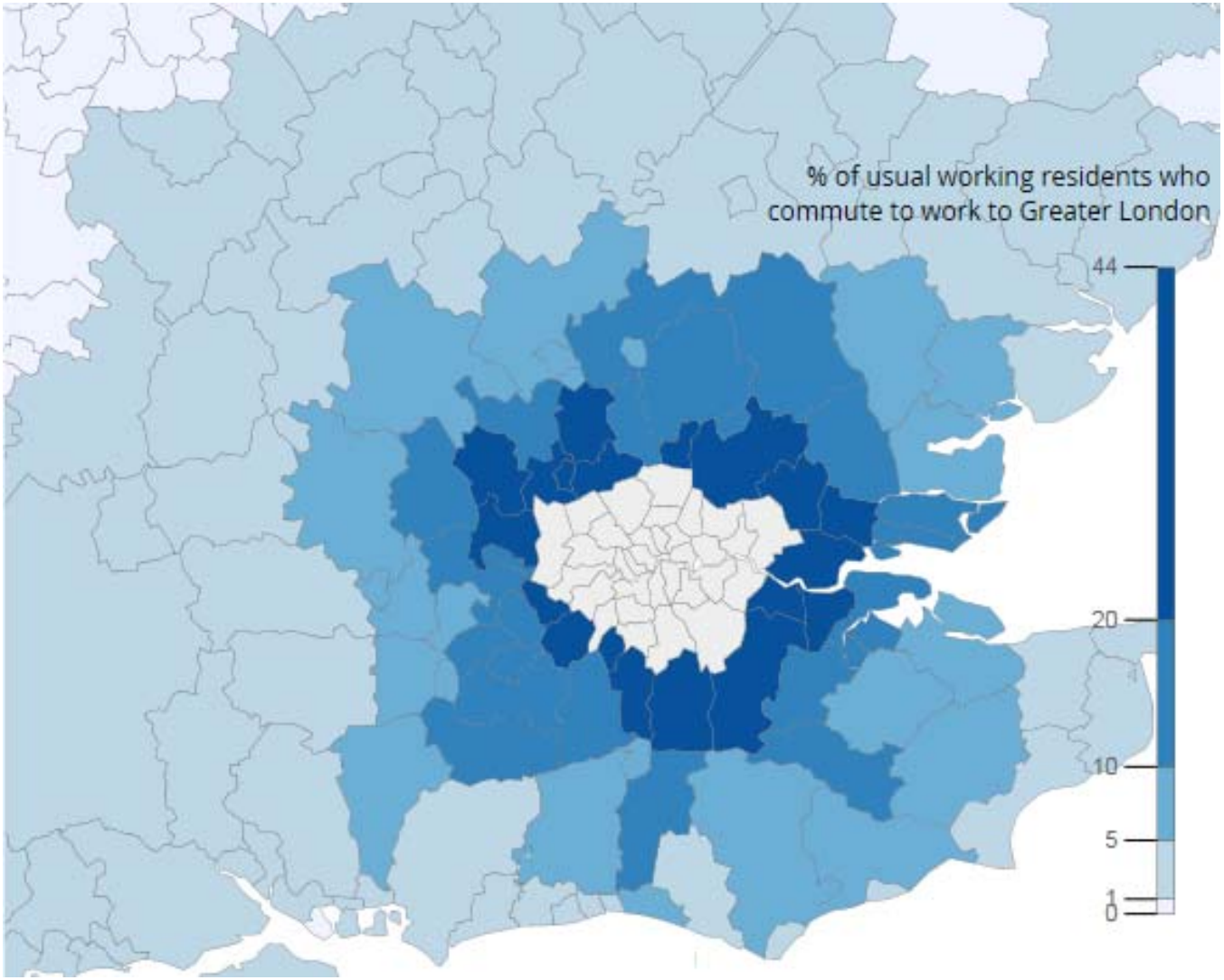
Figure 48: Commuting Patterns to and from the study area



Source: Open street map, Arup, ONS

Figure 49 further highlights the relationship of the study area to London. The southern portion of the study area (e.g. between London and Luton) has significant commuting interaction with London: for the more distant centres such as Northampton, Peterborough, Cambridge and Oxford the interaction is less pronounced.

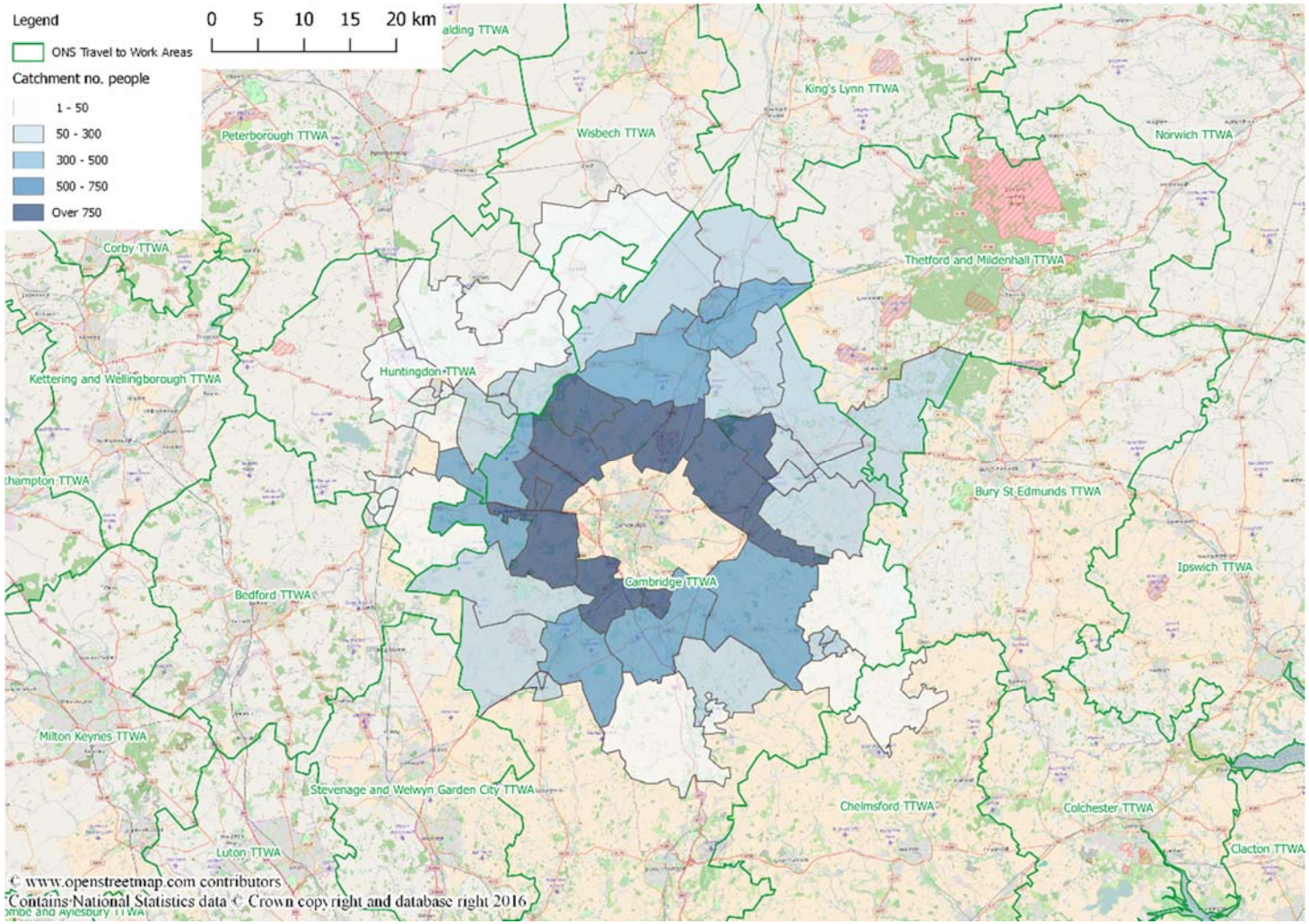
Figure 49: Percentage of local authority residents that commute to London



Source: ONS

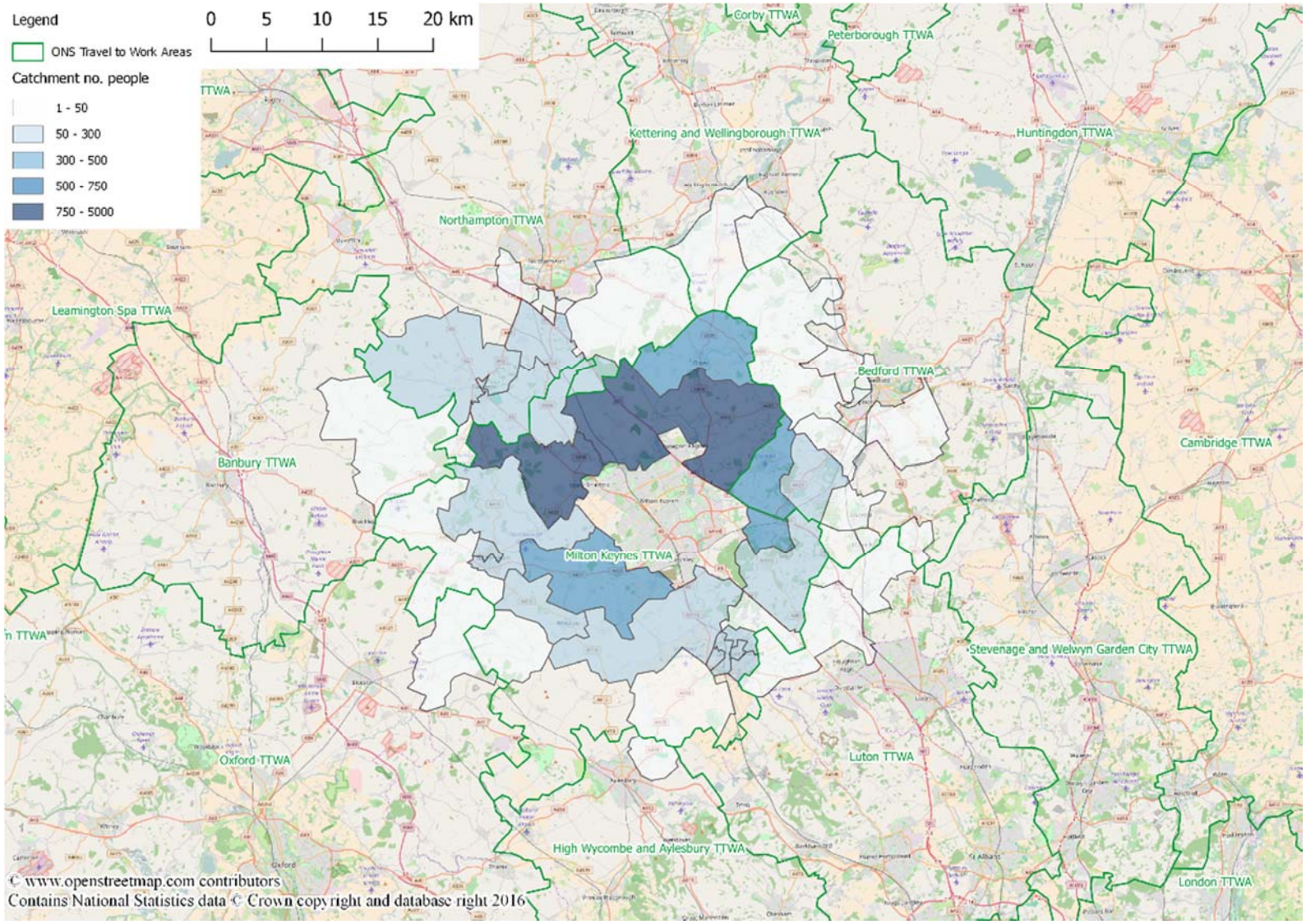
D2 Commuting catchments within the study area

Figure 50: Commuting catchments – Cambridge



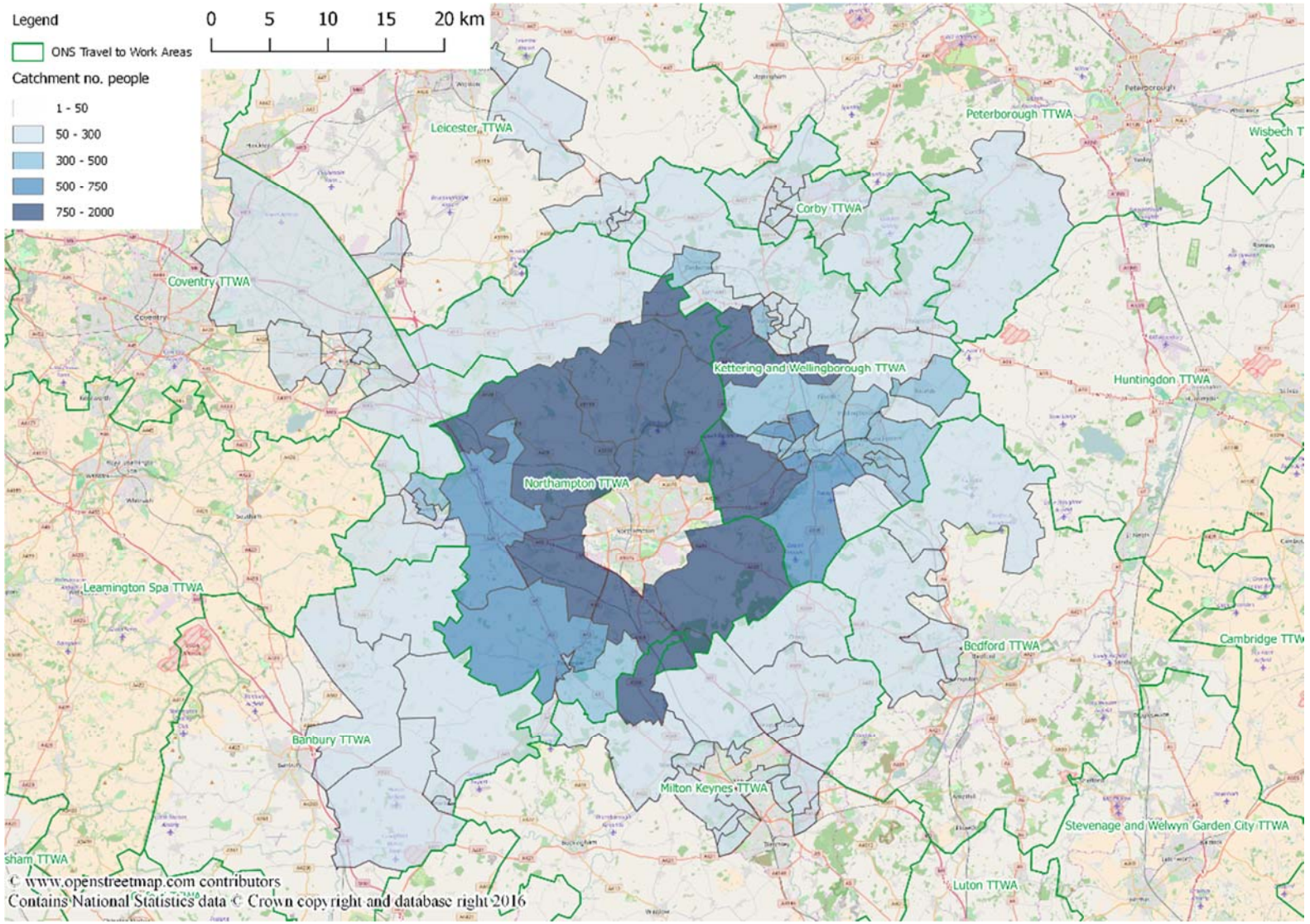
Source: Arup, ONS

Figure 51: Commuting catchments – Milton Keynes



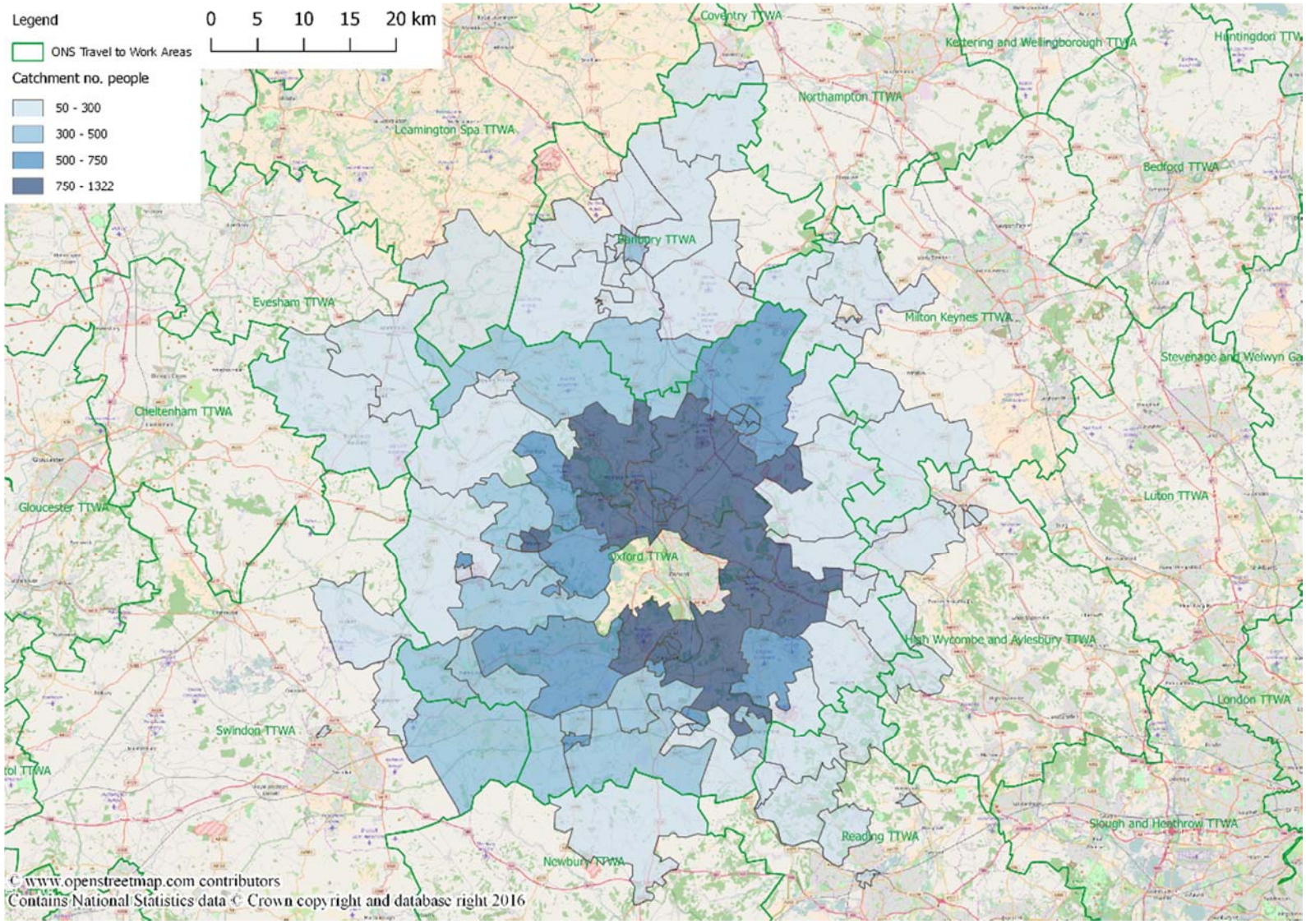
Source: Arup, ONS

Figure 52: Commuting catchments– Northampton



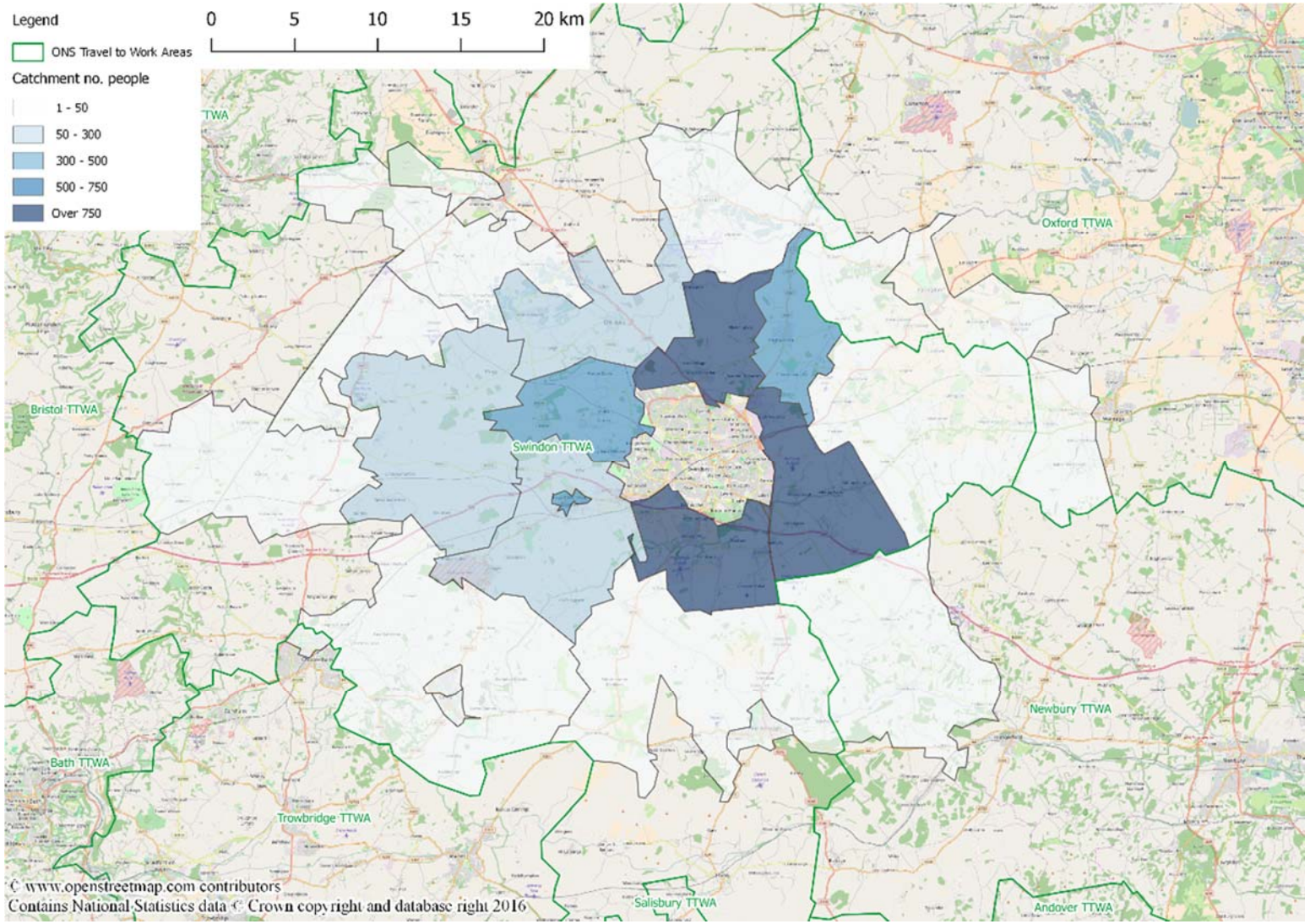
Source: Arup, ONS

Figure 53: Commuting catchments– Oxford



Source: Arup, ONS

Figure 54: Commuting catchments– Swindon



Source: Arup, ONS

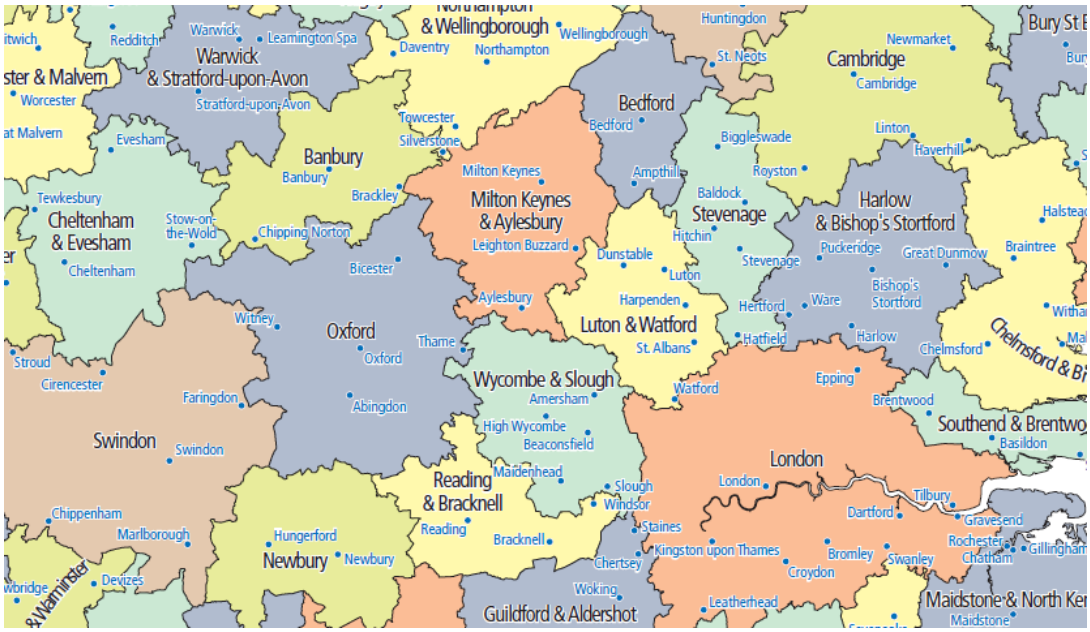
D3 Change in commuting over time

This section explores the change in commuting patterns over time, comparing 2001 and 2011 census data for the urban areas.

On balance the general pattern of commuting has not changed substantially between 2001 and 2011. Nonetheless, the data demonstrate a significant reduction in internalised commuting trips within the urban centres and a strengthening of the relationship between Milton Keynes and Northampton with over 1,200 additional trips between the two centres. Each of the urban centres draw more commuting trips from the remainder of the study area compared to 2001 although this growth is strongest for Milton Keynes and Northampton.

According to ONS travel to work areas (Figure 55), Cambridge's catchment has increased substantially to the south in recent years, taking in areas of Essex, and Oxford's has also increased. This may reflect the high house prices of the two cities, as well as the recent economic growth.

Figure 55: ONS travel to work areas in 2001 (top) and 2011 (bottom)



Source: ONS

Table 31: 2011 Urban Area to Urban Area commuting patterns

Destination / Origin	Cambridge	Luton	Milton Keynes	Northampton	Oxford	Stevenage	Swindon	Rest of Study Area	Outside Study Area
Cambridge	33,704	53	43	17	35	110	0	10,446	4,266
Luton	49	41,083	1,979	193	37	1,106	11	12,005	16,138
Milton Keynes	88	1,469	77,957	2,093	166	113	26	12,649	8,955
Northampton	35	276	4,221	63,048	104	52	14	13,334	8,354
Oxford	28	11	155	49	42,406	5	196	10,769	3,640
Stevenage	107	510	132	26	2	17,491	2	4,929	11,781
Swindon	3	35	42	17	658	6	68,153	11,486	11,081
Rest of Study Area	42,182	14,488	24,623	24,277	36,751	13,753	10,272		
Outside Study Area	8,122	17,158	12,952	12,540	7,648	5,450	11,912		

Source: ONS Census

Table 32: 2001 Urban Area to Urban Area commuting patterns

Destination / Origin	Cambridge	Luton	Milton Keynes	Northampton	Oxford	Stevenage	Swindon	Rest of Study Area	Outside Study Area
Cambridge	35,363	27	45	29	9	81	0	9,508	3,936
Luton	45	54,399	1,489	119	30	763	4	10,371	14,950
Milton Keynes	67	1,377	85,824	1,339	109	132	26	9,079	9,686
Northampton	31	320	3,749	74,884	102	33	23	9,663	7,310
Oxford	15	6	126	47	45,721	0	164	9,333	4,385
Stevenage	73	492	108	18	6	22,762	6	4,289	11,709
Swindon	3	12	25	7	305	8	79,769	2,520	10,928
Rest of Study Area	32,734	18,368	23,666	20,751	34,274	10,755	2,714		
Outside Study Area	10,325	8,933	9,096	13,913	5,016	7,189	24,919		

Source: ONS Census

Table 33: 2011-2001 Comparison (2011-2001) Change in Commuting Flows

Destination / Origin	Cambridge	Luton	Milton Keynes	Northampton	Oxford	Stevenage	Swindon	Rest of Study Area	Outside Study Area
Cambridge	-1,659	26	-2	-12	26	29	0	938	330
Luton	4	-13,316	490	74	7	343	7	1,634	1,188
Milton Keynes	21	92	-7,867	754	57	-19	0	3,570	-731
Northampton	4	-44	472	-11,836	2	19	-9	3,671	1,044
Oxford	13	5	29	2	-3,315	5	32	1,436	-745
Stevenage	34	18	24	8	-4	-5,271	-4	640	72
Swindon	0	23	17	10	353	-2	-11,616	8,966	153
Rest of Study Area	9,448	-3,880	957	3,526	2,477	2,998	7,558		
Outside Study Area	-2,203	8,225	3,856	-1,373	2,632	-1,739	-13,007		

Source: ONS, Census

Table 34: 2011-2001 Comparison (2011-2001) percentage change in Commuting Flows*

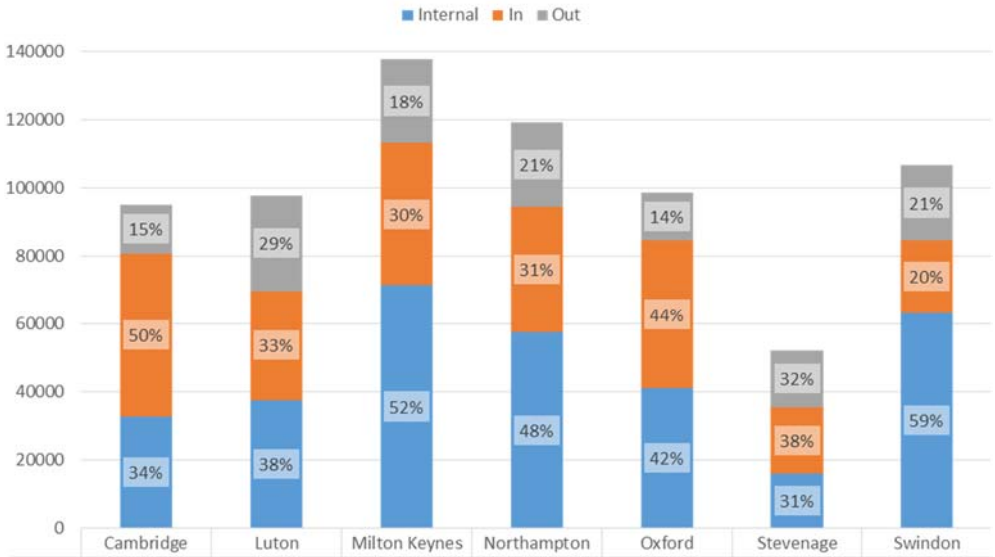
Destination / Origin	Cambridge	Luton	Milton Keynes	Northampton	Oxford	Stevenage	Swindon	Rest of Study Area	Outside Study Area
Cambridge	-4.9%		-					9.0%	7.7%
Luton		-32.4%	24.8%			31.0%		13.6%	7.4%
Milton Keynes			-10.1%	36.0%				28.2%	-8.2%
Northampton			11.2%	-18.8%				27.5%	12.5%
Oxford					-7.8%			13.3%	-20.5%
Stevenage						-30.1%		13.0%	
Swindon					53.6%		-17.0%	78.1%	1.4%
Rest of Study Area	22.4%	-26.8%	3.9%	14.5%	6.7%	21.8%	73.6%		
Outside Study Area	-27.1%	47.9%	29.8%	-10.9%	34.4%	-31.9%	-109.2%		

*Source: ONS, Census NB: *where the change in flow is greater than 100 trips*

Oxford and Cambridge have significantly lower levels of out-commuting than the other centres as shown in Figure 56 (around 15% of all commuting trips compared to around 25% on average for the others). They also have much higher levels of in-commuting (44% for Oxford and 50% for Cambridge compared to 30% on average for the other centres). Milton Keynes and Swindon have much higher levels of internal commuting trips (52% and 59% respectively compared to 40% on average for the other centres).

The figures below consider only those trips with origins and destinations within the study area and demonstrates that the pattern identified for all commuting trips holds true for those within the study area. On average 78% of all commuting trips to, from or within the urban centres have origins and destinations within the study area.

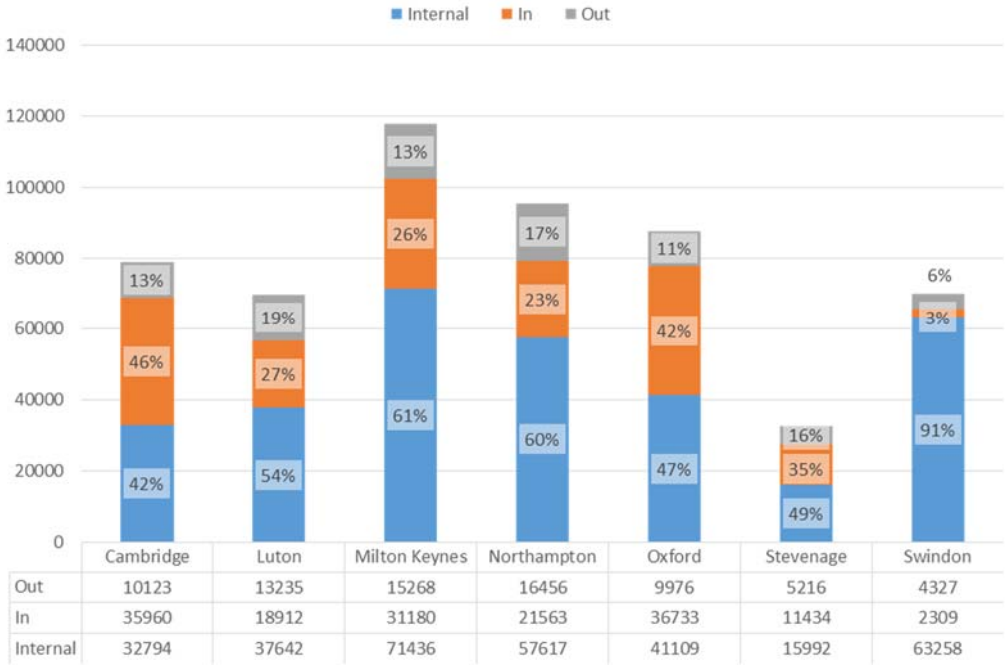
Figure 56: Commuting Patterns to, from and within the urban centres 2011



	Cambridge	Luton	Milton Keynes	Northampton	Oxford	Stevenage	Swindon
Out	14341	27966	24419	24617	14121	16611	22034
In	48065	32193	41930	37009	43541	19583	21458
Internal	32794	37642	71436	57617	41109	15992	63258

Source: ONS, Census

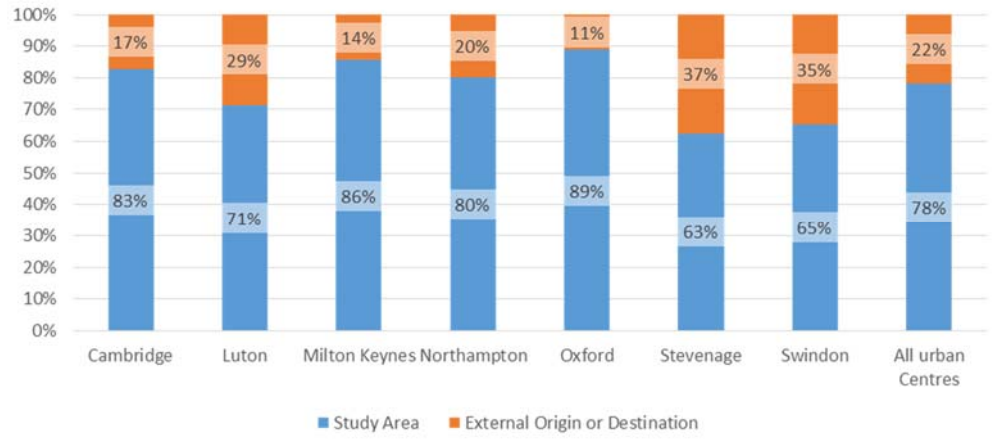
Figure 57: Study Area Commuting Patterns to, from and within the urban centres 2011



	Cambridge	Luton	Milton Keynes	Northampton	Oxford	Stevenage	Swindon
Out	10123	13235	15268	16456	9976	5216	4327
In	35960	18912	31180	21563	36733	11434	2309
Internal	32794	37642	71436	57617	41109	15992	63258

Source: ONS, Census

Figure 58: Study Area Commuting Internalisation 2011



Source: ONS, Census

These patterns likely reflect the housing constraints in Oxford and Cambridge that are less prevalent in Milton Keynes and Swindon. This is largely a result of the higher house prices and green belts around these cities which are not a constraint in the Milton Keynes area (forcing people to commute from further out).

D4 Mode share

D4.1 Rail mode share

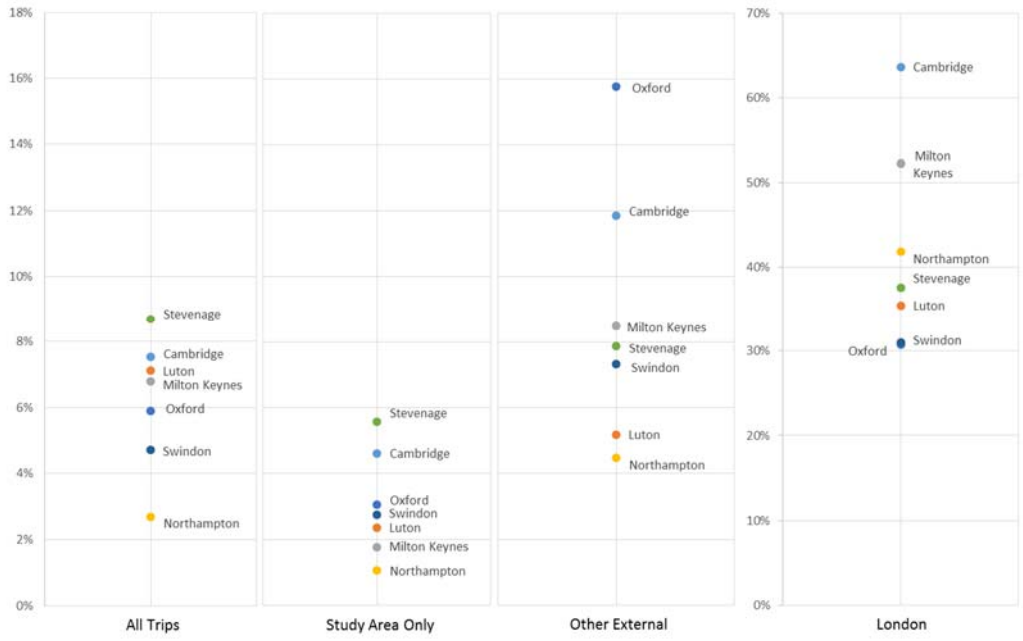
The rail mode share is 4% for all trips within, to and from the study area.

Stevenage (8.7%), Luton (7.1%) and Cambridge (7.5%) have the highest shares of the urban centres with Northampton having the lowest at 2.7%.

For trips to and from London, Cambridge (63.7%) and Milton Keynes (52.2%) have the highest rail shares, while Swindon (31%) and Oxford (30.8%) have the lowest. This is, in part, a reflection of the level of rail service available to destinations within London, the ease of driving to or from each location and, in Oxford's case, the Oxford Tube express bus service between Oxford and London. Oxford and Cambridge have the highest rail mode shares for trips with origins or destinations beyond the study area excluding London (15.8% and 11.9% respectively compared to an average of 6.7% for the other urban centres).

"Both East West Rail and an Oxford to Cambridge Expressway, unlike many other infrastructure projects, would result in transformational benefits. Providing significant enhancements to strategic connectivity benefits economies and communities well - beyond the immediate corridor. East West Rail, would provide linkages that simply do not exist currently between most urban areas. A lack of both East West Rail and the Expressway mean that much demand for travel is routed via London and its orbital road network. As such, funding for these two most strategic infrastructure investments would also provide for relocation of road and rail capacity to support the growth of London and the wider South East of England." (LEPs response to the Call for Evidence, 2016, p.17).

Figure 59: Rail mode share (trips in and out) for the urban centres



Source: ONS, Census

Whilst rail mode share is relatively low overall, rail use remains particularly important for travel to London, with around 22,000 people per day travelling to London by rail (42% mode share), highlighting the importance of connectivity to the capital city.

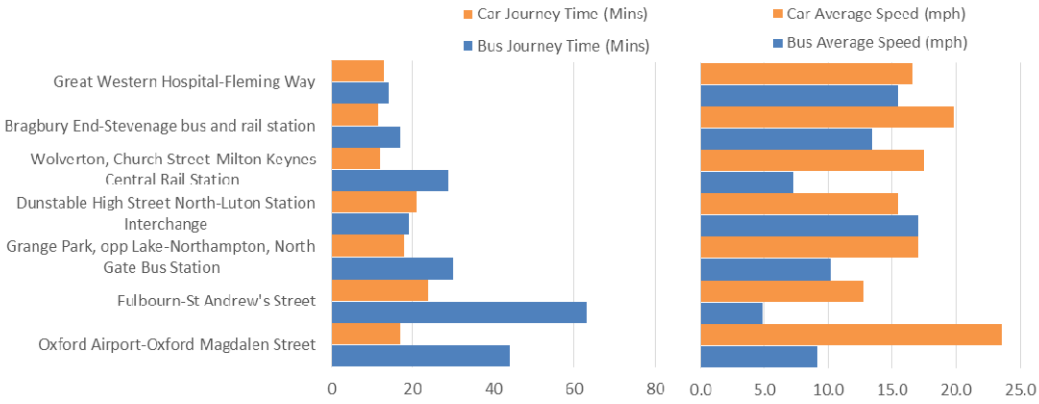
D4.2 Bus mode share

The bus mode share across the study area is 6%, reflecting the poor connectivity between urban centres by bus.

Bus's importance as a mode of travel for internalised trips within the urban areas is reflected in its mode share (21% of trips in Oxford and 11% on average across the urban centres).

Figure 60 compares bus journey times on a selection of radial routes into the urban centres with journey times by car along the same routes and demonstrates that car is on average 1.8 times faster than bus. The clear exception being the Dunstable to Luton Station route where the bus runs off road on bus way for approximately 80% of the route and benefits from bus priority measures for the majority of the remaining 20%.

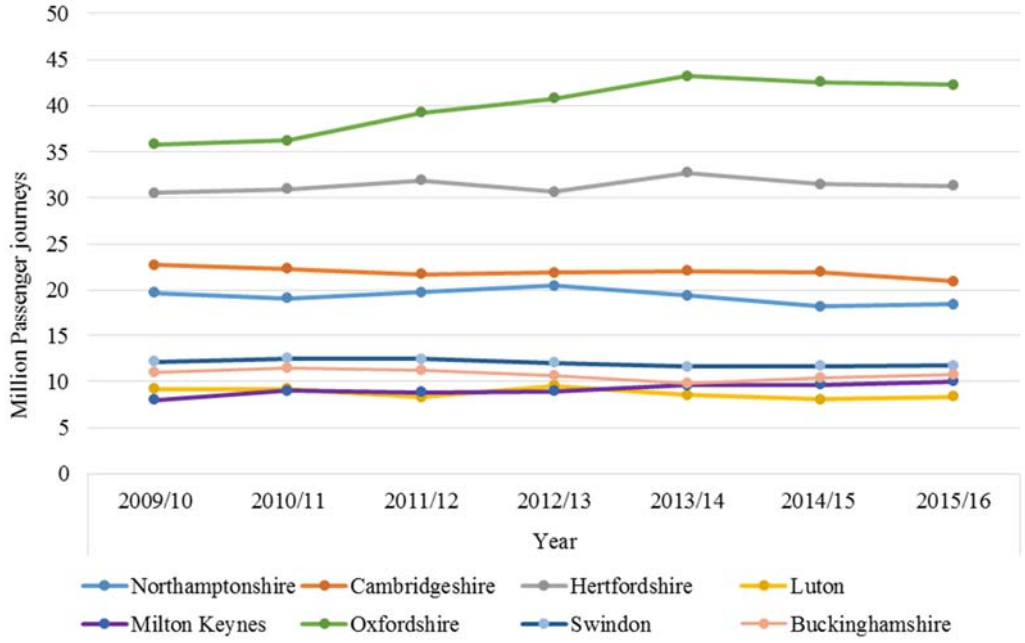
Figure 60: Bus journey time comparison – selected radial routes



Source: Arup

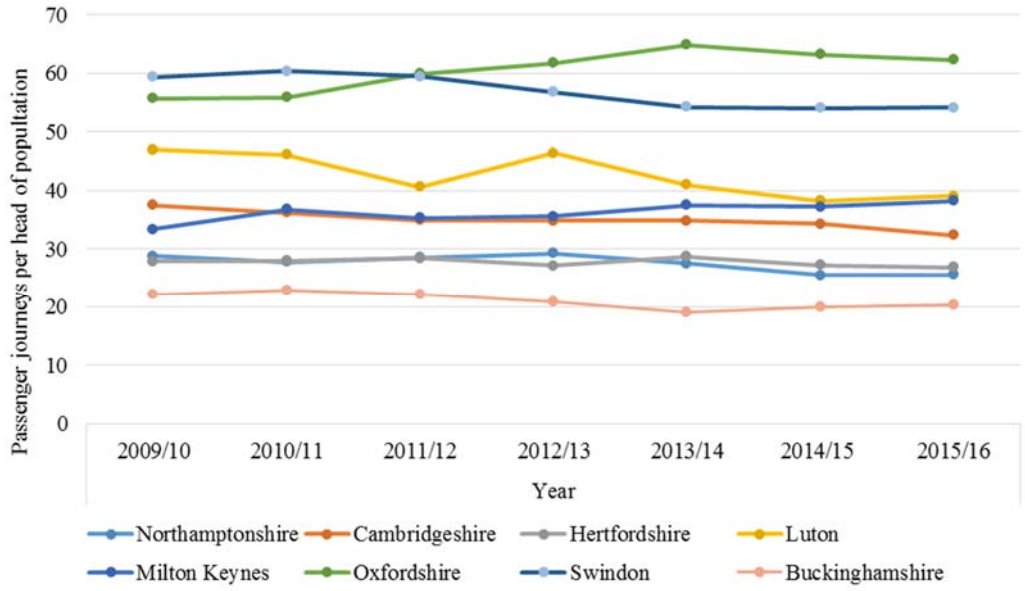
Bus passenger journeys within the study area have remained broadly the same over the last six year period as shown in Figure 61 and Figure 62 despite relatively poor performance of bus journey times within the urban areas compared to private motor vehicles trips.

Figure 61: Annual passenger journeys by local authority



Source: DfT, Table BUS0109a

Figure 62: Passenger journeys per head by local authority population



Source: DfT, Table BUS0110a

Appendix E

Wider economic impacts: literature review

E1 Literature review

The following sub-section discusses the different impacts that arise from transport interventions, and summarises a literature review about intra-urban as opposed to inter-urban interventions.

Impacts of Transport Interventions

The impacts of transport interventions on the economic performance of cities can be appraised through three broad categories; the direct user benefits; the productivity effects; and the investment and employment effects they generate. [53]

Direct user benefits

Direct user benefits include the cost and time savings created by new journeys and their impacts on congestion.

Productivity benefits

Transport interventions induce productivity gains arising from agglomeration benefits, allowing firms to cluster and consequently save on transport and communication costs, pool labour markets and share knowledge spill overs. Better transport links also foster economic interaction, enabling firms to compete in wider markets, benefit from economies of scale, and specialise in specific skills and industries[54].

Findings from the What Works Centre for Local Economic Growth, a partnership between the London School of Economics and Political Science (LSE), Centre for Cities and Arup, indicate that road projects may have a positive impact on productivity; the impacts of rail projects on productivity are not established due to a lack of high quality evaluation evidence in the area[55].

Investment and employment benefits

Locations which are the beneficiaries of transport interventions attract investment. Workers may find it easier to commute and firms may be able to draw on a larger labour market. The level and distribution of private sector investments then alter which in turn has an impact on the level of economic activity in the area affecting resulting spatial patterns of employment and GVA.

Measuring the social value of transport-induced private investments does require a robust assessment of whether or not they would have taken place elsewhere in the absence of improvements (additionality). While an investment may be additional

[53] Transport investment and economic performance: implications for project appraisal, *Venables et al, 2014*
[54]Principles of Economics, *Marshall, 1920*
[55] LSE; Centre for Cities; & Arup, What Works Centre for Local Economic Growth, Evidence Review 7: Transport

to the area in which it takes places, it may not be to a wider area or to the country as a whole. The investment is considered additional if it is drawn from outside of whatever spatial unit the policy maker is concerned with; perhaps taken from a place abroad. Moreover, even if the investment is additional, caution needs to be exercised when looking at whether or not the private investments simply displace resources, principally labour, coming from elsewhere (displacement). Workers may simply move between jobs of equal value, so other jobs are displaced with no net gain.

The What Works Centre transport study found evidence for road projects affecting local employment, with rail projects tending to affect property prices mainly, as opposed to investment.

Realising investment and employment benefits

One way of maximising the social impacts of transport interventions is to ensure they affect an area where market imperfections exist, such as structural unemployment or low labour force participation. If the investments are additional from a national perspective, and if they occur in an area where job creation is a policy priority, then they can remove barriers to private investment which delivers significant social value.

Intra-Urban vs Inter-Urban

There are a complexity of issues to be considered when looking at how transport interventions affect cities, especially when comparing the effects of inter-city and intra-city interventions. The former describes those which connect different cities together, while the latter describes those which improve transport connections within a city itself. Both types of interventions can drive economic growth, but it is important to understand which types may suit the context and nature of the Oxford to Cambridge Corridor.

Intra-Urban

The significance of cities and large urban areas cannot be downplayed; they are the highly productive economic drivers for the UK economy and centres of employment, knowledge, and innovation. With 55% of commuter journeys being to large urban areas, and 89% of these experiencing delays, there is a real need to meet the transport challenges facing cities.

The Eddington Review shows that, given their significance to the economy, strategic economic priorities for long-term transport policy should aim to be growing cities, and ensuring key inter-urban corridors are supporting them as efficiently as possible. Sustained investment should therefore be targeting these areas and their intra-city challenges.

A key part of the argument for intra-city focus, and a key part of this study's economic case, is the facilitation of agglomeration benefits. While connecting places better to each other can bring these types of benefits, the processes of agglomeration are more likely to flourish within urban areas themselves; they account for up to 50% of benefits of some transport schemes in London.

A focus on smaller schemes which tackle pinch-points' in particular is emphasised on numerous occasions in the Eddington Review; it describes how governments, reflecting on high returns, together with the private sector should focus investment on these types of projects. Clearly the world has changed in eleven years, however commuting patterns remain broadly similar and the findings still have traction.

Based on full appraisals of environmental and social benefits, tackling pinch points through focussed investment on existing networks can yield some of the highest returns for growth; without road pricing the economic case for additional road capacity at a strategic level is very strong, with a case for investing at a rate 50% higher than is assumed up to 2015, at a cost of £30 billion.

In particular, the highest returns are expected around major urban areas where there competing demands for a range of users. The best schemes, including inter-urban rail schemes and removal of bottlenecks can return in the region of £5 - £10 for each pound invested[56].

Inter-Urban

There is also evidence to suggest inter-city or inter-urban connections trigger rapid economic growth under certain circumstances. The role of mass transit railways connecting cities and the completion of motorways and highway networks has shown to increase productivity growth and permitted radical new production processes.

While transport demand in the UK specifically is predominantly local and concentrated within urban areas as opposed for inter-urban and inter-regional journeys, there is a growing need to focus on these routes too. Long-distance commuting is on the increase in the UK and there are approximately 60,000 long-distance (above 200 miles) domestic business trips. 72 per cent of HGV journeys are over 100km.

Unreliability on the UK's rail network is costing business over £400 million a year, with many inter-urban routes experiencing overcrowding.

Key inter-urban corridors between international gateways connect passengers with key cities and international airports, and freight transport to distribution hubs and their eventual markets. Inter-urban routes show an average return of just under £2 per £1 of expenditure, although this figure rises to just under £5 once large-scale and expensive rail infrastructure projects are removed from the average[57].

[56] Sir Rod Eddington, The Eddington Transport Study, December 2006
[57] Sir Rod Eddington, The Eddington Transport Study, December 2006

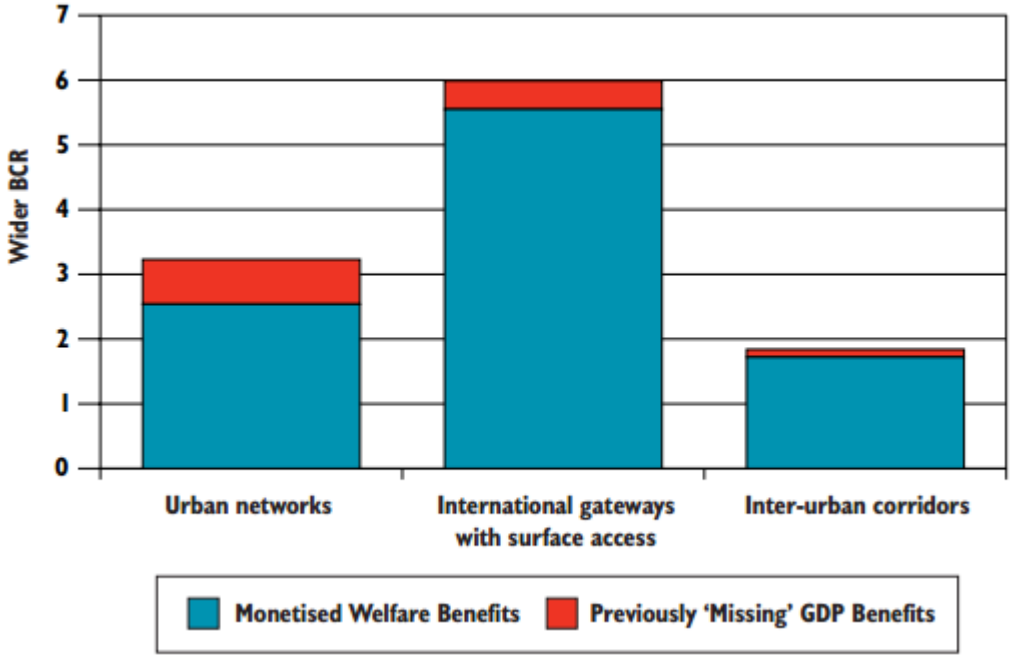
E2 Summary

The literature is clear in that intra-urban transport investments tend to yield higher economic returns.

Figure 63 below shows that intra-urban schemes capture more of the GDP benefits that have been missed previously by the transport appraisal processes, while yielding average BCRs above 3 compared to inter-urban schemes which average below 2. Transformational international gateway projects, including those at airports and ports yield BCRs of almost 6; these types of schemes are not directly relevant to the study area, but it must be noted that the other types of schemes facilitate connectivity to these gateways.

It is often that inter-urban and commuting journeys are competing to use the same networks; for example, on railways, overcrowding and congestion principally occurs on approaches to major urban areas, and this is also the case with the road network. Long-term transport problems in the UK will need to be overcome by a combination of schemes that relieve overcrowding and congestion on all parts of the network. The What Works Centre transport study actually found little evidence on whether large-scale projects have larger economic impacts than the spending of similar amounts on a collection of smaller local schemes.

Figure 63: Average BCRs for urban network, international gateway, and inter-urban schemes



Source: Source: Eddington Transport Study, 2006

Appendix F

Productivity assessment

F1 Approach

A central issue for this study is the extent to which investment in strategic intercity links where they do not currently exist is likely to produce greater economic benefits than investing in improving constrained transport intra-urban transport networks. A central rationale for investing in links along the Oxford – Milton Keynes – Cambridge arc is to drive productivity and growth by linking centres with separately strong and high value economies to allow them to benefit from the opportunities, particularly for knowledge spill overs – that those links might offer.

This question has been assessed through both qualitative and quantitative methods, based on four typologies of highways investment (illustrative schemes). The principle of defining these four schemes is to take the analysis beyond a purely abstract exercise and ground it in an understanding of what might be the relative scale of productivity impacts in the CaMKOx area specifically, with the economic, travel and demographic patterns that currently exist. These are chosen to be illustrative of the types of schemes that are being proposed around the study area, without attempting to specify actual schemes. The exception to this is Scheme E which is loosely based on the Oxford to Cambridge Expressway scheme. They are not intended to be directly comparable in terms of cost; the assessment does not comment on value for money at this stage, simply the potential scale of benefit for various types of highways investment, using standard agglomeration assumptions.

For each scheme, a qualitative assessment has been undertaken to identify the likely scale of different types of potential benefit that might arise through the various benefit channels set out below and ranked on a ‘low – high’ scale.

In addition to the qualitative assessment of the likelihood of different types of economic benefit, a high level modelling exercise to quantify agglomeration benefits is undertaken to rapidly identify the potential scale of productivity impacts that may arise through agglomeration when different types of connectivity improvements are targeted, in different economic contexts.

Table 35: Illustrative schemes

Scheme	Typology	Example chosen	Scheme specification
Scheme A	Intra-urban investment to reduce travel times within an economically successful, perhaps even overheating, area	Cambridge	5 minute reduction in average journey time within Cambridge; 2 minute reduction for trips to and from Cambridge.
Scheme B	Extra-urban investment to improve links between two centres which do not have a strong commuting relationship already	Bedford and Cambridge	10 minute reduction in average journey time for traffic using A421/A428).
Scheme C	Intra-urban investment to reduce travel times between a relatively deprived area and the city centre	Bletchley and Milton Keynes Central	5 minute reduction in average journey time.
Scheme D	Extra-urban investment to improve links between two centres which already have a commuting relationship	Milton Keyes and Northampton	10 minute reduction in average journey time.
Scheme E	Extra-urban investment to improve links between two centres which do not have a strong commuting relationship already but have high levels of knowledge intensive employment.	Oxford and Cambridge	30 minute reduction in average journey time.

Source: Arup

F2 Productivity impacts of transport investment

Transport can impact productivity through several channels. These mechanisms are not mutually exclusive and in some cases overlap slightly. A transport project may impact on productivity through a combination of the channels depending on the scheme. Nevertheless, the eight principal mechanisms through which transport might drive productivity are[58]:

- **User benefits**

  Improvements to transport provision may lead to benefits to users through time savings, lower vehicle operating costs and improved safety which leads to lower operating costs for businesses. There are also further productivity benefits to businesses through the cheaper and more reliable transport of freight.

- **Increased market access**

  Reducing transport costs can allow firms to access a larger number of markets. This allows firms to increase output and potentially benefit from economies of scale leading to increased productivity as the output is produced at lower average cost. Increasing accessibility to markets also leads to increased competition between firms. This will lead to a reduction in the monopoly and monopsony power of businesses and reductions in monopoly rents. The increase in competition will also lead to expansion and entry to the market of more efficient firms and reduced output and exit of less efficient firms.

- **Improved access to intermediate inputs**

  Improved transport connectivity may allow firms to source inputs at a lower price and/or higher quality. This is because firms may be able to access more suppliers leading to increased competition and efficiency in markets for intermediate goods and also because firms may be able to substitute their inputs for alternatives which were previously too expensive.

- **Increases size and effectiveness of labour markets**

  Reduced transport costs increase the efficiency of labour markets by allowing firms to access a larger and wider pool of labour leading to better matching of skills and jobs; reduced labour market stickiness and, ultimately, productivity increases. There may also be additional productivity benefits if a scheme improves access to education and training which will improve the stock of human capital. Lakshmanan (2011) highlights similar effects in other factors of production markets such as the development of the US Interstate Highway network which led to a change in land-use through increased suburbanisation, but the focus here is on labour market impacts.

[58] Venables et al, Transport Investment and Economic performance, 2014

- **Support for agglomeration through knowledge spill overs**

  It is widely accepted in the economic literature that there is a positive relationship between the size and density of an agglomeration and productivity. For example, Rosewell and Venables (2013) state that the empirical evidence suggests that doubling economic mass leads to a 3 to 8 per cent increase in productivity. Transport can support agglomerations through knowledge spill overs and innovation which increase the stock of human capital. This is particularly relevant in knowledge intensive sectors.

- **Support for specialisation (clusters)**

  Improving connectivity between locations can lead to increased trade and allow cities and regions to specialise in sectors in which they have a comparative advantage. David Riccardo first outlined this theory in the early 19th century and showed that trade can be beneficial between two places even if one of them is more efficient at producing all goods.

  Specialisation by cities and regions in particular sectors leads to gains in productivity as firms which have a comparative advantage in a particular task expand their output leading to the realisation of economies of scale. A historic example of this was 19th century England in which cities specialised in specific sectors with, for example, Sheffield specialising in steel and cutlery, Manchester in Cotton and Newcastle in ship-building. Rosewell and Venables (2013) note that specialisation increasingly now occurs not only at a sector-wide level but also at task-level such as the production of a specific component which is then used as an input to a final good.

- **Reduced coordination failure between industries**

  There may be efficiencies in the relationships between firms in different industries such as between a firm and one of its main suppliers. Venables, Laird and Overman (2014) outline two mechanisms for how transport can alleviate these inefficiencies. Firstly, two firms in inter-related industries may benefit from moving to the same location but only if both of the firms move and there may not be an incentive to do this without other policies such as investment in transport infrastructure. Secondly, low-level traps may exist, for example, in a deprived region where firms and households may find it difficult to improve their economic situation without policies to coordinate their activities such as improved transport provision which allows individuals to access jobs.

- **Increased technology diffusion between regions**

  Transport allows technologies to be transferred between regions leading to increases in productivity and economic growth. These benefits derive from external technology shocks. Examples of this include Japan and South Korea in the second half of the twentieth century which adopted technology from the West which contributed to their rapid industrialisation.

F3 Qualitative assessment of the illustrative schemes

A qualitative assessment of the potential scale of productivity impacts arising through each of the seven identified seven channels, for each of the four schemes defined above. A brief description of each of the channels is provided below along with an assessment of which channels are most likely to be relevant for each scheme and the potential magnitude of the benefits.

F3.1 User Benefits

Scheme A would involve reducing average journey times within Cambridge. This would lead to journey time benefits for trips both within Cambridge itself and also trips to and from the city. As the analysis of the transport situation has shown there is currently significant congestion within Cambridge particularly at junctions between the inter-urban and the intra-urban networks. Population and employment are forecast to continue to grow within the city and therefore journey times and reliability are likely to worsen without transport mitigation measures. This would reduce journey times within Cambridge which has high levels of congestion which is expected to worsen as a result of the forecast future growth in employment and population. The potential user benefits of this scheme are likely to be high.

Scheme B would reduce journey times for trips using the A421/A428 between Cambridge and Bedford by 10 minutes. These roads are currently congested at peak times with significant pinch points on the A421 between Bedford and St Neots and at the junction of the A428 with the A1198 between St Neots and Cambridge. There are also significant delays on the intra-urban networks in Cambridge and Bedford. The current highway journey time from Bedford to Cambridge is approximately 40 minutes so a 10 minute time saving would therefore represent a 25 per cent reduction in journey time. The scheme would also lead to journey time improvements for trips between Cambridge and many of the places to the west of the study area leading to further time saving benefits. The user benefits of this scheme are likely to be high.

Scheme C involves reducing journey times between Bletchley and Milton Keynes by 5 minutes. These places are adjacent and this scheme would improve traffic flows and reliability for trips within the area. Relatively few trips from and to other parts of the study area are likely to benefit from the scheme. This would lead to time saving benefits for trips between Bletchley and Milton Keynes.

Scheme D would reduce average journey times between Northampton and Milton Keynes by 10 minutes. This will lead to time saving benefits and improved connections would be expected to increase demand between these places leading to further benefits. Significant population and employment growth is expected in the future and, in particular, Milton Keynes which will further increase the scale of the benefits. In addition, the scheme will also improve connections between Northampton and areas in south of the study area leading to additional benefits. This would probably to lead to significant user benefits due to the size and close

proximity of Northampton and Milton Keynes. In addition, northbound and southbound trips using the link would also benefits from reduced journey times.

Scheme E would reduce the average journey time between Oxford and Cambridge by 30 minutes, which is a substantially larger time saving than the other schemes. The scheme would also lead to journey time improvements between several other O-D pairs across the corridor and as such user benefits are expected to be high.

F3.2 Increased market access

Scheme A would improve the economic mass of Cambridge and effectively bring firms and workers in Cambridge closer together. This will lead to increased market access for firms within Cambridge which could lead to increased competition. The scheme will also improve journey times to and from Cambridge city centre by 2 minutes, leading to additional benefits from market access with firms located outside the city but these benefits are likely to be minor given the scale of the time saving. There are likely to be low to medium benefits to firms in Cambridge of increased market access and marginal benefits of increased connectivity in and out of Cambridge.

Scheme B would allow increased interaction between Cambridge and places in the west of the study area. This will bring firms across the study area closer together and will increase market access for firms leading to increased competition and higher productivity. The extent of the benefits may be limited by the existing accessibility to London from many places in the corridor where firms can access many customers and markets. There are likely to be low to medium benefits to firms in the study area as firms in Cambridge and to the west of the corridor can access markets more easily.

Scheme C would primarily increase the size of the Milton Keynes labour market and it is not thought that there will be significant benefits to firms from improved market access. There are unlikely to be any benefits from improved market access from this scheme.

Scheme D would potentially allow firms in Milton Keynes and Northampton improved access to markets. The highest potential for this is in sectors where there are synergies between the places such as the computer industry, financial services and wholesale trade. This scheme may lead to a small benefit from improved market access. As discussed under Scheme B these benefits may be limited by the existing high level of accessibility to markets in London.

Scheme E would potentially allow firms across the corridor improved access to markets. The highest potential for this is in sectors where there are synergies between the places, such as knowledge intensive sectors across the corridor. There are likely to be low to medium benefits to firms across the study area of increased market access and marginal benefits of increased connectivity, partially offset by the existing good accessibility to London from the three key centres.

F3.3 Improved access to intermediate inputs

This benefits mechanism is particularly relevant to manufacturers that need to source factor inputs (other than labour) for production. The breakdown of employment by manufacturing sector in the study area is shown in Figure 64. This highlights the synergies between sectors in different locations in the corridor. For instance, the pharmaceutical industry is concentrated in Buckinghamshire, Cambridgeshire and Hertfordshire and warehousing in Northamptonshire and the South East Midlands. There are also synergies in manufacturing sectors such as machinery and equipment in Cambridgeshire and Northamptonshire and furniture in Buckinghamshire and Cambridgeshire.

Scheme A would improve linkages between firms within Cambridge and marginally reduce journey times to other parts of the study area. This would reduce journey times between suppliers and firms within the city although benefits are not likely to be large due to the limited journey time improvement.

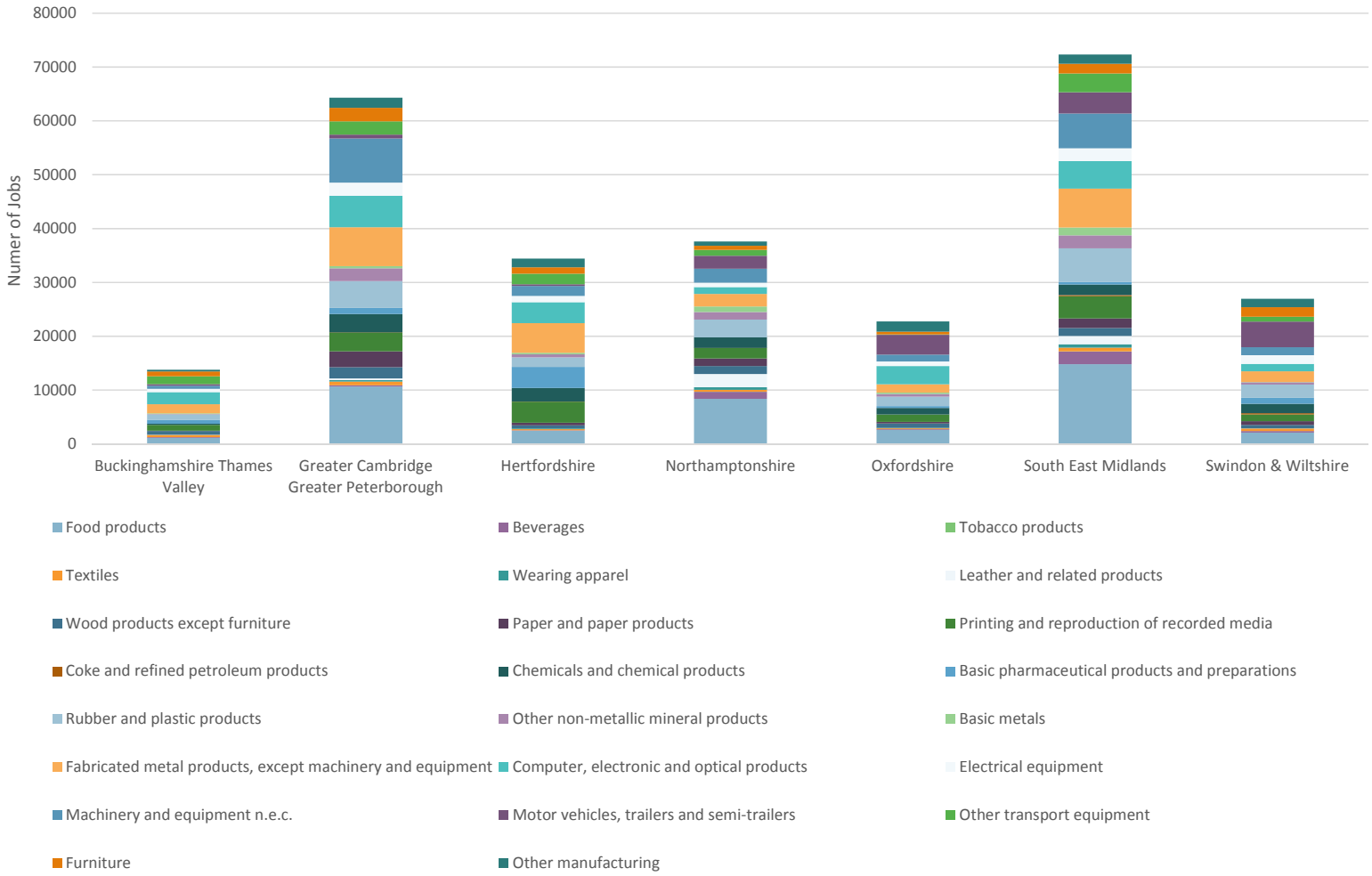
Scheme B would improve connections between firms located in Cambridge and in places in the west of the corridor. The data above shows there are synergies between sectors in Cambridge and other parts of the study area and this scheme should improve access to suppliers. However, firms may also access suppliers from other locations and therefore the benefits are not expected to be high. There may be limited benefits from improved linkages between firms in Cambridge and the west of the study area.

Scheme C would provide a 5 minute journey time improvement in journey times between two places which are in close proximity and it is unlikely to lead to any benefits. There are not expected to be benefits from improving access to intermediate suppliers from this scheme.

Scheme D would improve connectivity between Northampton and Milton Keynes and also between Northampton and areas to the south. There are likely to be benefits from improved access to suppliers as a result of this scheme but they are unlikely to be substantial. There may be limited benefits from improving access to intermediate suppliers as a result of this scheme.

Scheme E would improve connectivity across the corridor, depending on precise route, and based on the sectoral composition of the area, as shown above, might be expected to have some impact on links between firms in the GCCPLEP area and the SEMLEP area. There may be limited benefits from improved linkages between firms in Cambridge and the west of the study area.

Figure 64: LEP Employment in Manufacturing[59]



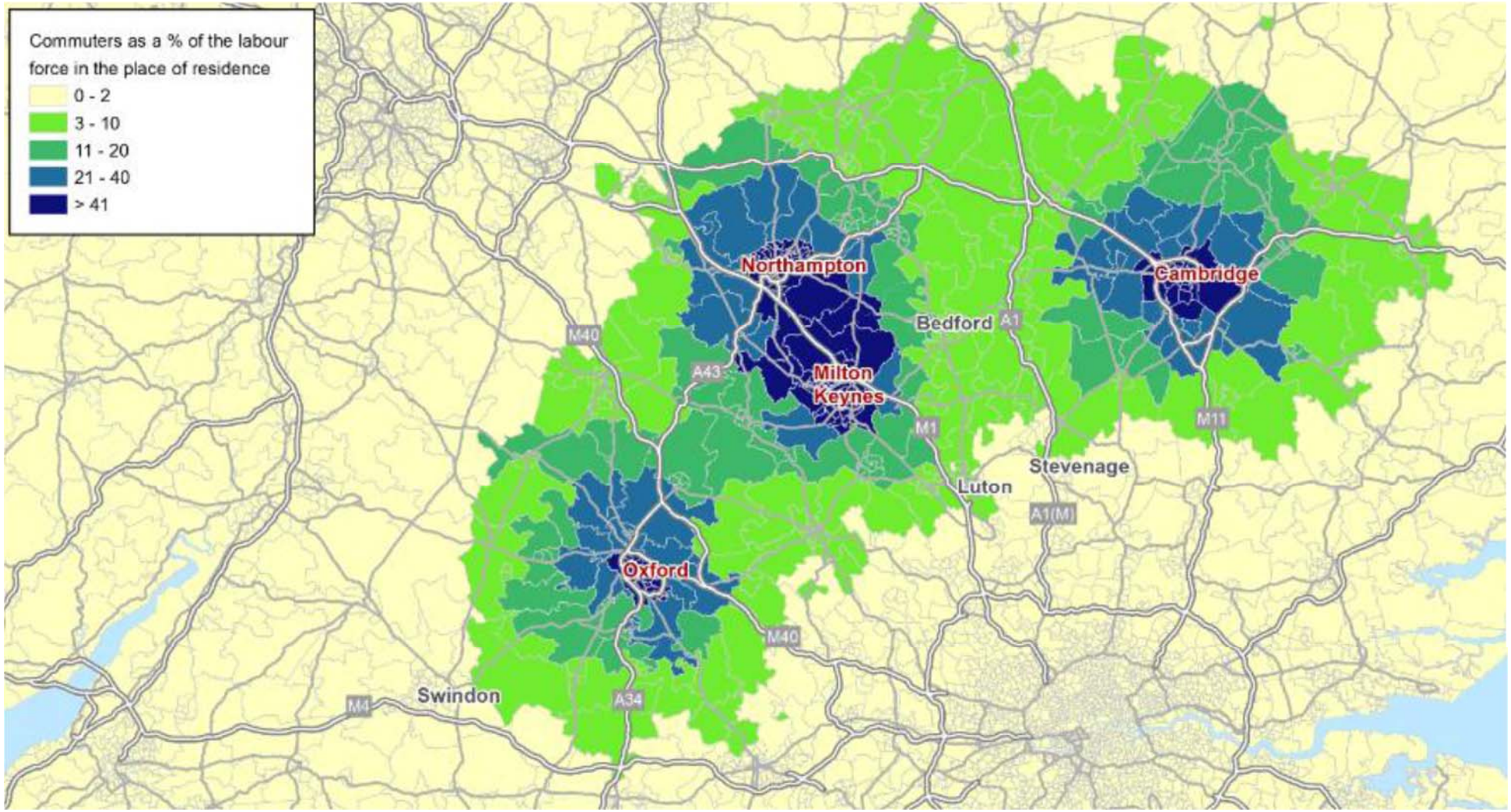
Source: Business Register and Employment Survey 2014

[59] NIC Call for Evidence CMKO Growth Corridor Appendix 1 Evidence Base Data

F3.4 Increased size and effectiveness of labour markets

Analysis of commuting patterns which showed that there is a relatively low level of existing commuting between places across the corridor, probably reflecting current poor transport links. The labour market footprints of Oxford, Milton Keynes, Northampton and Cambridge are shown in Figure 65. Cambridge and Oxford have comparatively localised labour markets but the towns in the centre of the study area such as Milton Keynes and Northampton have overlapping labour markets with individuals commuting between them. Interestingly, Bedford was found to be in the labour market footprint of Milton Keynes, Stevenage, Luton and London but not in Cambridge's. There should therefore be considerable scope for productivity benefits arising from expanded labour market catchments.

Figure 65: Commuting Map for Oxford, Milton Keynes, Northampton and Cambridge



Source: Cambridge Econometrics

Scheme A offers potential for significant benefits from the scheme which will expand the Cambridge labour market. The local labour force is well qualified and the increased accessibility will allow lead to improved matching between jobs and skills leading to higher productivity. The labour market benefits from this scheme are likely to be high. The benefits will be increased further if the scheme enables new housing and employment centres to be developed.

Scheme B would reduce journey times between Cambridge and places to the west of the study area. This should lead to some increasing commuting as individuals can access jobs in other locations more easily. However, the analysis of commuting patterns in the study area showed that there are relatively low levels of commuting between Cambridge and Bedford even fewer between areas in the centre of the corridor and Cambridge. This suggests that there may be limits to the level of labour market benefits unless current patterns change which could take place over the long-term as a result of the scheme. The journey time improvement will also improve market interactions between firms in the study area which will lead to agglomeration benefits. There is high potential for labour market benefits from improving journey times between Cambridge and Bedford. However, the extent to which they are achievable will depend on the potential to adjust the current travel to work patterns in the area.

Scheme C would improve connectivity between Milton Keynes and Bletchley which is a relatively deprived area within MK. This should lead to benefits through the improved functioning of the local labour market as workers in Bletchley can access jobs in Milton Keynes. This scheme is likely to a moderate level of high benefits as the economic mass of Central Milton Keynes area will be increased although Milton Keynes is the city in the study area which has the largest existing labour catchment. Nevertheless it has been growing rapidly in terms of job creation, and will need to continue to improve its ability to offer favourable labour market conditions.

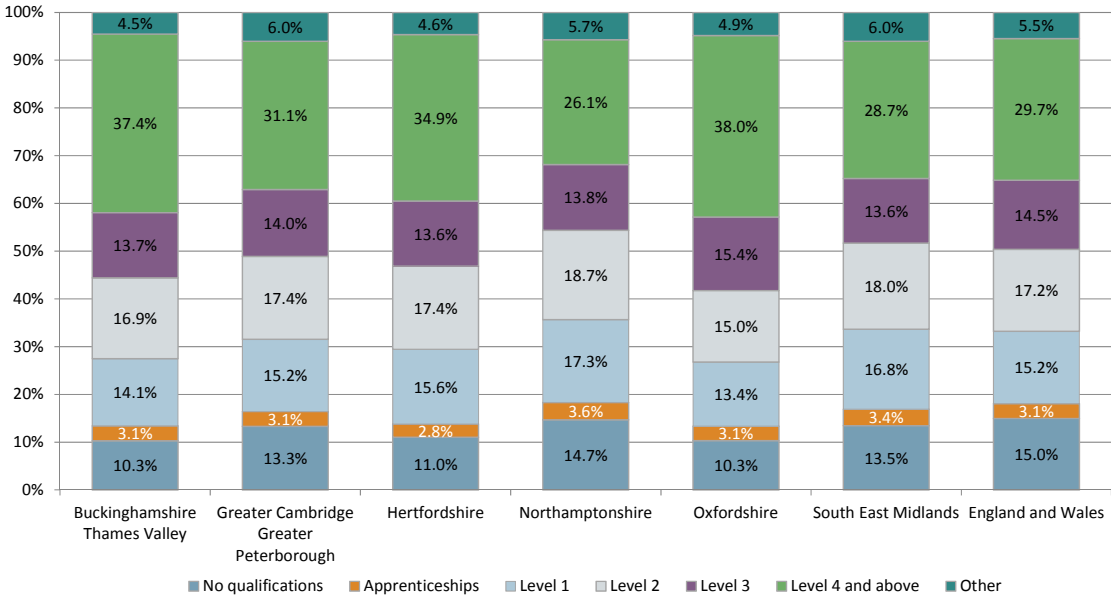
Scheme D would improve connections between Milton Keynes and Northampton which are 32 kilometres apart. There are likely to be benefits of improving connections between the towns which will build on the already close relationship that exists between them. As the analysis of commuting patterns in the study area showed the labour markets of Northampton and Milton Keynes already overlap currently. It can therefore be expected that reducing journey times between them will increase commuting between the towns leading to higher productivity. Similar schemes linking Northampton and Milton Keynes with other nearby towns such as Bedford and Wellingborough are likely to lead to further benefits.

Scheme E would improve connectivity across the study area. It seems unlikely that it would promote commuting along the length of the arc, but would be likely to pull Cambridge and Oxford within the labour market catchment of Milton Keynes and vice versa, and make it easier to travel between Bedford, Bicester, Aylesbury and the three main employment locations.

F3.5 Supports agglomeration through knowledge spill overs

Knowledge spill over benefits accrue mostly through knowledge intensive employment in either service or manufacturing sectors. The population of the study area is relatively highly skilled as shown by Figure 66 which gives qualifications of working age residents for each LEP in the study area. Oxfordshire, Buckinghamshire Thames Valley and Hertfordshire show a high proportion of residents with Level 4 Qualification or higher with 38.0%, 37.4% and 34.9% and Greater Cambridge and Peterborough is also above the average of England and Wales with 31.1%.

Figure 66: Qualifications of working age residents by LEP[60]

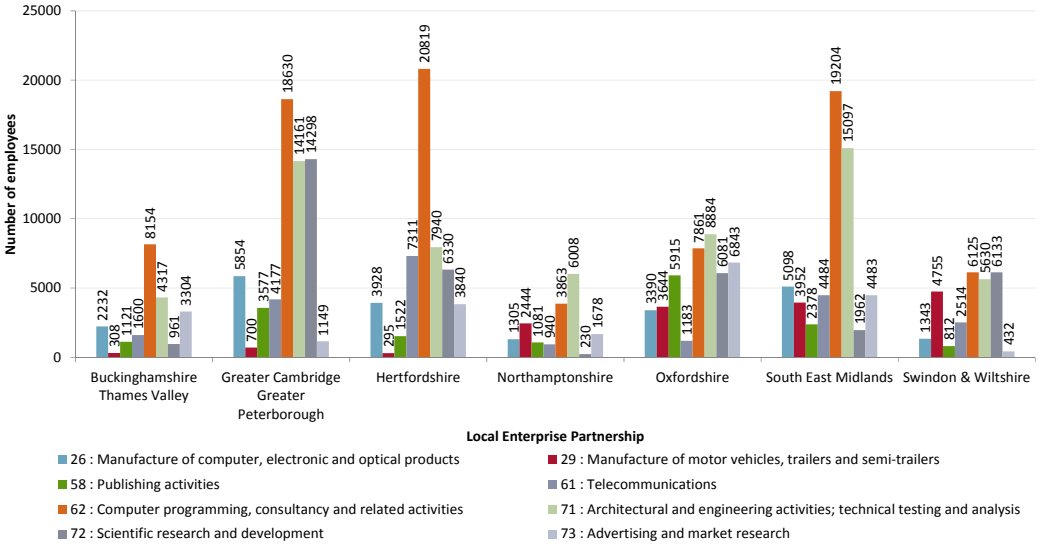


Source: Annual Population Survey, 2014

The number of jobs in the knowledge sectors for each of the Local Enterprise Partnerships (LEPs) in the study area is shown in Figure 67.This shows that there are synergies between sectors in different locations in the corridor. For instance, there are a high number of jobs in the computer and engineering industries across most of the corridor. There are a high number of jobs in Scientific Research and Development in Cambridgeshire, Hertfordshire, Oxfordshire and Swindon and Wiltshire and in the automotive sector between Swindon and the East Midlands.

[60] NIC Call for Evidence CMKO Growth Corridor Appendix 1 Evidence Base Data

Figure 67: LEP Employment in Knowledge BRES Sectors (2014)[61]



Source: Business Register and Employment Survey 2014

Many studies in the economic literature have shown that the benefits from agglomeration can decay rapidly over distance. For instance, Rice, Venables & Pattachini (2006) find that benefits drop dramatically beyond a 45 minute travel time and that moving population 30 minutes further away decreases its productivity impact by three quarters. Melo et al. (2016) determine that although the benefits from agglomeration decline quickly they can exist up to the limits of the local labour market.

The distances between the principal urban areas in the Cambridge-Milton Keynes-Oxford Corridor are shown in Table 36. The distance between many urban centres in the study area is over 50km which suggests that there may be limits to the extent of agglomeration benefits from improving links between them.

Table 36: Distance in kilometres between urban areas in the corridor

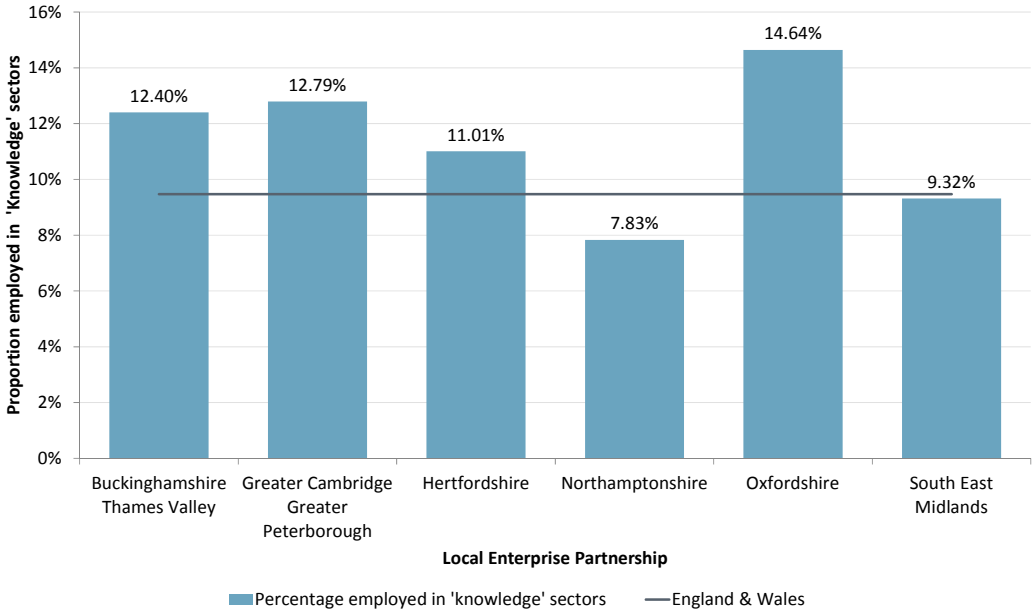
Link	Distance (km)
Swindon – Oxford	48.8
Oxford – Milton Keynes	64.3
Northampton - Milton Keynes	32.1
Milton Keynes – Bedford	28.8
Milton Keynes - Luton	36.0
Bedford – Cambridge	48.7
Peterborough - Cambridge	64.2

Source: Google maps

[61] NIC Call for Evidence CMKO Growth Corridor Appendix 1 Evidence Base Data

The proportion of employment in knowledge sectors in the Cambridge-Milton Keynes Oxford Corridor is shown below. This shows that there is a high level of knowledge jobs in most areas of the study area compared to the average for England and Wales. There are particularly high number in Oxfordshire (14.64%), Greater Cambridgeshire and Peterborough (12.79%) and Buckinghamshire Thames Valley (12.40%). This would suggest that there may be potential for knowledge spill overs from improving the connections and therefore the interactions between firms and individuals in these areas.

Figure 68: Proportion of knowledge jobs by Local Enterprise Partnership (LEP) (2014)[62]

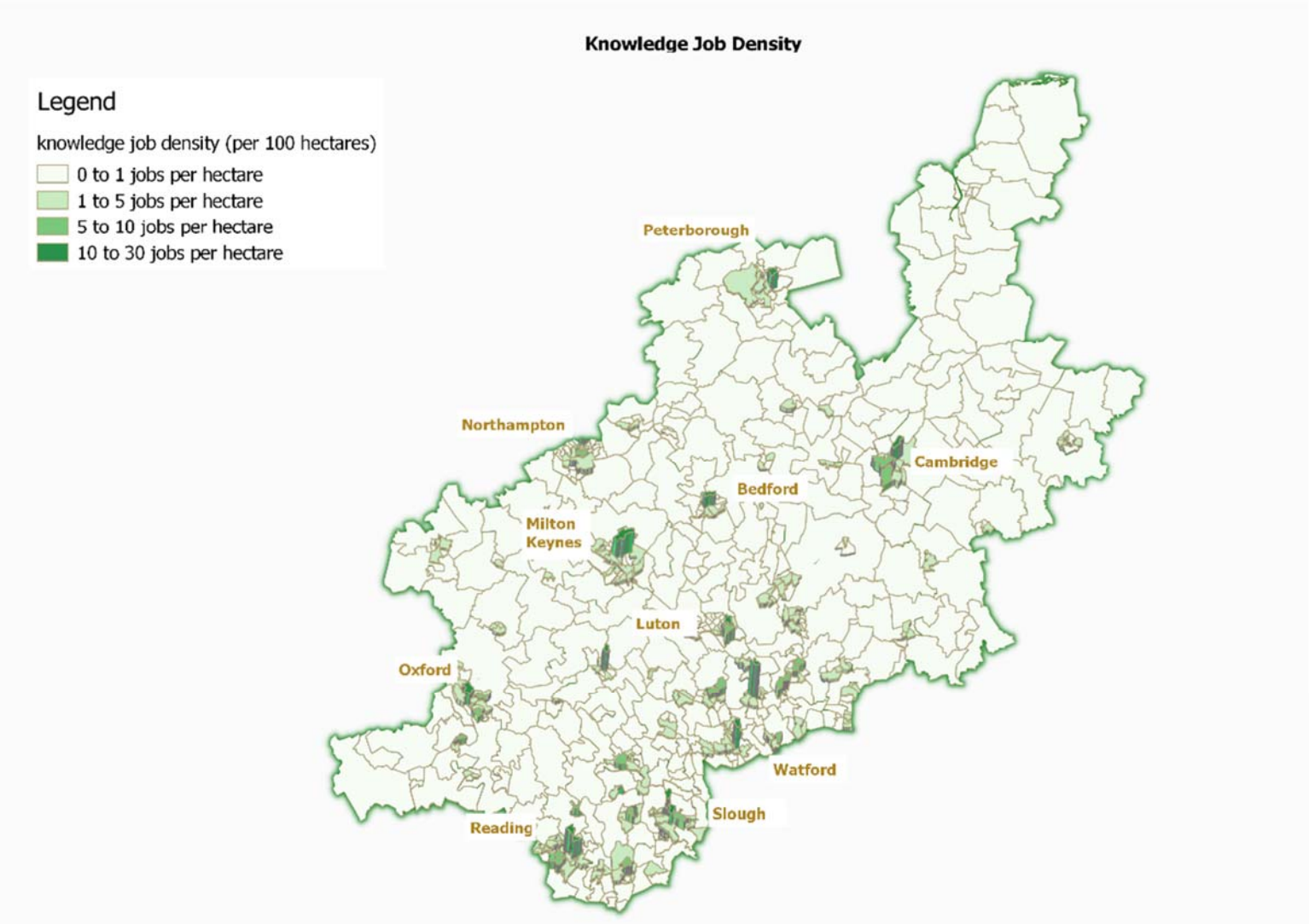


Source: Business Register and Employment Survey 2014

A map of the density of knowledge jobs in the study area is shown in Figure 69. This shows that many of the places with high levels of knowledge density in the study area such as Oxford and Cambridge are not located in close proximity. However, areas in the centre of the study area such as Milton Keynes, Northampton, Bedford and Wellingborough are located closer together. In addition, there is a concentration of knowledge jobs in places bordering London in the south of the study area such as in Buckinghamshire and Hertfordshire.

[62] NIC Call for Evidence CMKO Growth Corridor Appendix 1 Evidence Base Data

Figure 69: Density of knowledge jobs in the study area



Source: ONS Census

Under Scheme A (improving journey times within Cambridge) accessibility between firms in the city would increase. The workforce of Cambridge is highly skilled and the scheme would reduce journey times between highly productive locations such as the university and the Science Parks. The scheme could reduce journey times and lead to increased interactions between firms and workers which may lead to an increase in knowledge spill overs. The transport scheme could also support the development of employment centres in the Cambridge area which may further increase the benefits. This scheme has strong potential to increase knowledge spill overs by increasing accessibility between highly productive areas such as the university and Science Parks.

Scheme B would increase accessibility between Cambridge and the west of the study area. This could allow highly skilled workers in these locations to interact more closely leading to potential benefits from knowledge spill overs. However, these places are relatively far apart and that the benefits decay over distance the magnitude of the benefits may be limited. For the benefits to be realised therefore there would need to be a willingness for firms to collaborate and systems would need to be established to allow this to happen. This scheme would go some way to improving accessibility between highly productive workers in Oxford and Cambridge but the distance between them could limit the benefits.

There are few highly skilled workers in Bletchley and there is therefore unlikely to be any significant knowledge spill overs as a result of Scheme C.

In Scheme D firms would benefit from improved interactions in sectors where there are synergies. The significant growth forecast in these places could compound those benefits in the future. This scheme may lead to increased knowledge spill overs in sectors where there are mutual relationships in Milton Keynes and Northampton.

In Scheme E, increased accessibility between two world-class centres of knowledge has high potential for increasing interaction. To an extent this could be offset by the distance between them, which would remain substantial. Strong systems of collaboration would need to be put in place to gain maximum benefits. However, the scheme would also reduce journey times to and from other key centres including between high technology and advanced manufacturing firms across the South East Midlands. On balance, the potential for agglomeration benefits through knowledge spill over have the potential to be high.

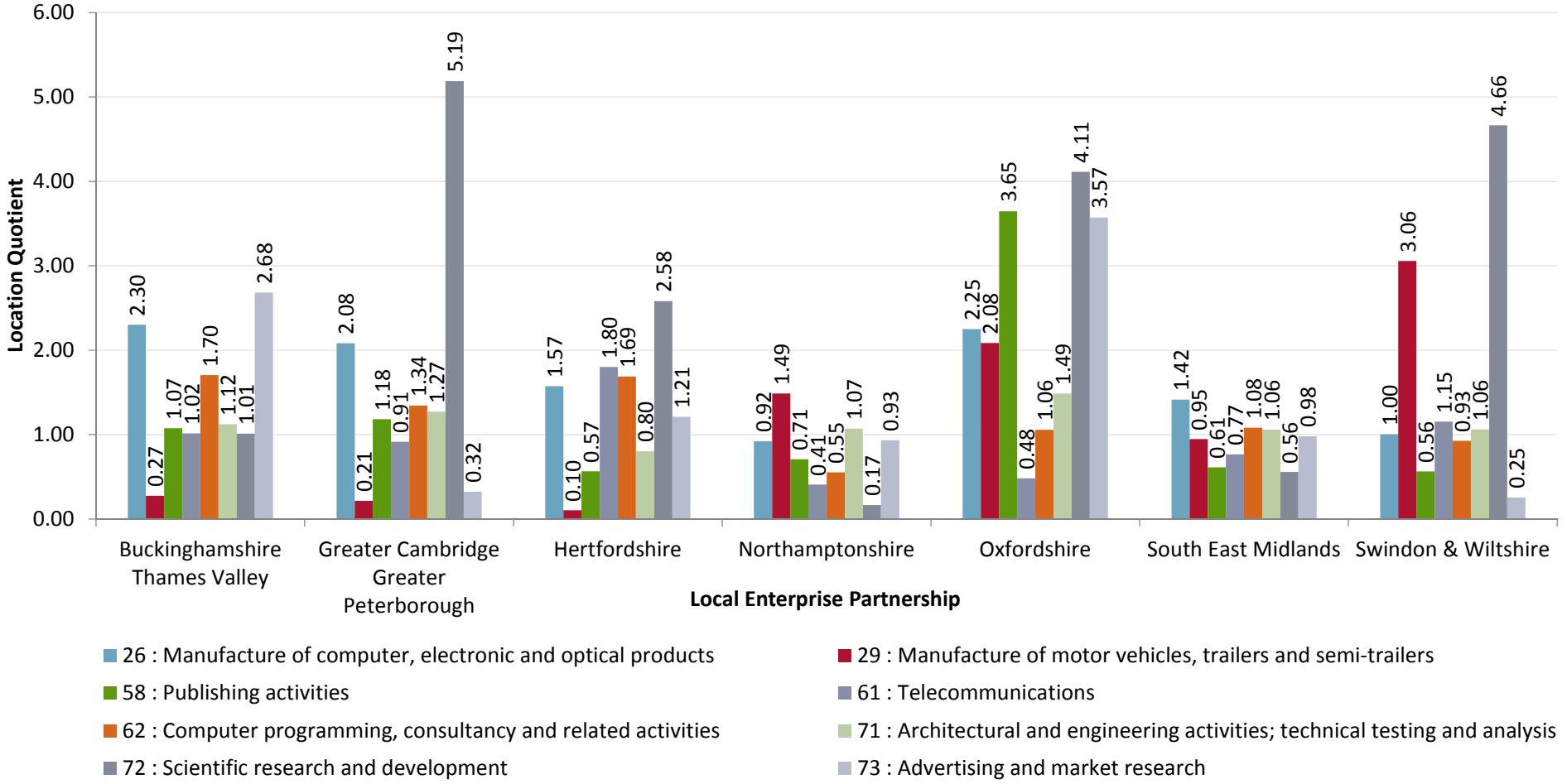
F3.6 Support Specialisation (clusters)

The CaMKOx Corridor is notable for the number of clusters it supports. These include the Cambridge Science Park and Cambridge Bio-Tech Cluster, Oxford Science Park and Begbroke Science Park. These clusters benefit from being located in close proximity to Oxford and Cambridge universities which are part of the UK's university 'Golden Triangle' which also includes several leading universities in London. In addition, many of the world's leading automotive sports companies are located in and around Oxfordshire in Motorsport Valley.

The level of specialisation in a sector by location can be analysed using Location Quotients (LQs) which show the level of specialisation in sectors compared to the national average. An LQ of over 1.25 represents an exporting industry and an LQ of less than 0.75 represents an importing industry. Figure 70 shows the LQs in knowledge sectors for the Local Enterprise Partnerships (LEPS) in the corridor.

This shows that there are a high number in particular sectors and locations in the study area. For instance, there is a high level of specialisation in Scientific Research and Development (R & D) in Cambridgeshire (5.19), Swindon and Wiltshire (4.66), Oxfordshire (4.11) and Hertfordshire (2.58). Swindon & Wiltshire (3.06), Oxfordshire (2.08) and Northamptonshire (1.49) are specialised in the automotive industry and Buckinghamshire (2.68) and Oxfordshire (3.57) in advertising and market research.

Figure 70: Location Quotients for selected Knowledge Sectors[63]



Source: Business Register and Employment Survey (2014)

[63] NIC Call for Evidence CMKO Growth Corridor Appendix 1 Evidence Base Data

There are several reason why the study area provides advantageous conditions for supporting the development of clusters. There are world-leading international centres of excellence such as Oxford and Cambridge universities, Cranfield *University* and Silverstone with links to the local economy. The towns on the corridor are also in proximity to London which allows firms in the area to access markets, suppliers and business and financial services there including niche specialised services which are only available in major international cities such as London. In addition, the places along the corridor are well connected to the UK national motorway and mainline railway networks giving good market access to the rest of the UK and also to London's airports providing access to international markets.

Local labour markets in the area are also relatively highly skilled and many urban areas along the corridor and, in particular, Oxford and Cambridge, are seen as attractive places to live which allows them to attract and retain highly skilled workers. All of these factors are likely to have contributed to the development of clusters in the study area and over time through a process of cumulative causation the clusters continue to grow as further workers and firms relocate to be close to them.It is widely held that there could be significant benefits from reducing journey times between Oxford and Cambridge; this is one of the central rationales for the NIC study of the CaMKOx area. It may be possible that investment in links between Cambridge and Oxford would allow closer cooperation of scientists across the top portion of the 'Golden Triangle'. The universities in the 'Golden Triangle' already collaborate on several initiatives including in partnership in the Global Medical Excellence Cluster (GMEC) and Science and Engineering South (SES).

The extent of the benefits is likely to be limited by the distance between the two cities. Journey times between Oxford and Cambridge are currently around 2 hours by car, 3 hours 40 minutes by bus and journeys by train and involve travelling via London and take approximately 2 hours 30 minutes. The benefits from improving links between Oxford and Cambridge may also be limited by their existing fast transport links to London which is approximately 45 minutes by train from each city. The opening of East West Rail which would reduce journey times between Oxford and Cambridge but journey times are still expected to be around 1 hour 30 minutes. Given these issues improved transport links on their own may be less likely to generate significant knowledge spill overs. Organisation in the two cities would need to be willing and able to cooperate more closely.

Scheme A would improve journey times within Cambridge which could support existing clusters in Cambridge which may be currently constrained by congestion at peak times. The scheme would also increase interactions between key highly productive areas in the city such as the Science Parks. In addition, the scheme may also allow increased housing to be built to allow the expansion of the clusters leading to increased benefits from specialisation. The scheme will also lead to a 2 minute journey time improvement to and from central Cambridge but this is probably not sufficient for significant benefits to firms from improved market access.

Scheme B would improve journey times between Cambridge and the places in the centre and west of the study area. As highlighted above there are already working relationships between the universities and the scheme would allow these and similar relationships between firms and clusters to increase. This could improve accessibility between firms in Cambridge for firms located in the corridor. This could provide the opportunity for increased interactions between the universities, firms and clusters which could lead to increased specialisation and productivity gains.

Scheme C would increase the effectiveness of the local labour market in the local area. This could potentially support the increased specialisation of firms in the area but is the scale of these benefits would be low – it is probably unlikely that investment in intra-Milton Keynes improvements would lead to significant specialisation benefits.

Scheme D would reduce journey times between Northampton and Milton Keynes and improve access to and from other parts of the study area. The benefits are most likely to be realised in sectors in which these towns already specialise in. For instance, Milton Keynes has a high location quotient in sectors including information services (2.64), financial services (2.09), wholesale trade (1.56) and warehousing (3.79). Similarly, Northampton is specialised sectors including the manufacture of leather goods (27.61), beverages (1.46) and also warehousing (1.99) and employment activities (2.12). Improving the connections between these towns and other places will allow specialised firms to expand leading to productivity gains. The scheme would improve the accessibility of Northampton and Milton Keynes potentially allowing the sectors which are concentrated in these places to specialise further and expand output leading to higher productivity.

Scheme E would improve journey times between Cambridge and the places in the centre and west of the study area as far as Oxford, to a greater extent than Scheme B. As with Scheme B, there are already working relationships between the universities and the scheme would allow these and similar relationships between firms and clusters to increase. This could provide the opportunity for increased interactions between the universities, firms and clusters which could lead to increased specialisation and productivity gains.

F3.7 Reduces coordination failure between industries

It is thought that it is unlikely that any of the illustrative schemes would lead to benefits through this channel. These benefits are more appropriate in developing countries where there is a lack of coordination which transport infrastructure can remedy.

F3.8 Increases technology diffusion between regions

It is thought that it is unlikely that any of the illustrative schemes would lead to benefits through this channel. This is because as discussed above these benefits result from external technology shocks which are unlikely to result from this scheme.

F3.8.1 Summary of qualitative assessment

The table below summarises the qualitative assessment of the impacts of the different illustrative schemes.

Table 37: Qualitative Assessment

Illustrative scheme	**A**	**B**	**C**	**D**	**E**
Descriptor	**within Cambridge**	**Bedford – Cambridge**	**Bletchley – MK central**	**MK – Northampton**	**Cambridge – MK – Oxford**
1 - User benefits	HIGH	HIGH	HIGH	HIGH	HIGH
2 - Increase market access	LOW - MEDIUM	LOW - MEDIUM	NONE	LOW	LOW - MEDIUM
3 - Access to intermediate outputs	NONE	LOW	NONE	LOW	LOW
4 – Size and effectiveness of labour markets	HIGH	MEDIUM - HIGH	MEDIUM - HIGH	HIGH	HIGH
5 – Knowledge spill overs	MEDIUM	LOW	NONE	LOW	MEDIUM - HIGH
6 - Specialisation	LOW	MEDIUM	LOW	HIGH	MEDIUM-HIGH
7 - Reduced coordination failure	NONE	NONE	NONE	NONE	NONE
8 - Technology diffusion	NONE	NONE	NONE	NONE	NONE

Source: Arup

F4 Quantitative Assessment

F4.1 Approach

The benefits from agglomeration arising through increased labour market catchment and potential knowledge spill overs have been calculated for the illustrative schemes by estimating the effective densities in the study with and without the scheme. Matrices were developed at Mid-Level Super Output Area (MSOAs) level and population, housing and employment were all assumed to be fixed. The data for employment by MSOA was taken from the 2011 census and 2016 Mean Annual Gross Pay was sourced from the ONS at Local Authority (LA) level.

The formula for effective density is given by[64]:

$$d_i^k = \sum_{j,m} \frac{E_j}{\left(g_{i,j}^m\right)^{\alpha^k}}$$

Where:

d_i^k = effective density of accessibility of zone i to jobs in j zones by sector

E_j = number of jobs in zone j

$g_{i,j}^m$ = generalised travel cost from zone i to j by mode m

α^k = distance decay parameter by sector k

An elasticity of 0.03 was applied to the change in effective density to estimate the agglomeration benefit for each scheme and the distance decay factor was set equal to 1.

The journey times were based on highway matrices which were derived from DfT data for journey times to railway stations and trunk road junctions from MSOAs within the study area. These journey times were used to identify typical vehicles speeds for journeys of under 5km, 5-10km, 10-20km, 20-60km and over 60km in length. The typical speeds were applied to a road distance matrix for routes between MSOA OD pairs to estimate journey times for all MSOA OD pairs within the study area. Intra-MSOA trips were set to seven minutes and a minimum journey time of 15 minutes was applied in the base highway and public transport matrices to allow the impact of improving journey times to be assessed. In the scheme matrices intra-MSOA trips were set to a minimum of two minutes and a minimum journey time of 5 minutes was stipulated for all other OD pairs to allow the full impact of the scheme journey time savings to be assessed.

The journey time changes were coded in the matrices by identifying O-D pairs which would benefit in each of the illustrative schemes. For Scheme A, trips within Cambridge 5 minute time saving was applied between MSOAs and intra-zonal trips received a 2 minute saving. Trips to and from Cambridge to the rest of

[64] WebTAG Wider Impacts, *DfT, 2014 p28*

the study area were also given a 2 minute saving to represent the improved accessibility of locations within Cambridge. For Scheme B, O-D movements which would benefit from a journey time reduction on the A421/A428 between Bedford and Cambridge were identified. Trips which would use all of the link were given a 10 minute time saving and zones along the route were given a smaller saving depending on their location relative to the A421/A428.

In Scheme C, O-D pairs were identified which would benefit from a new link between Bletchley and Milton Keynes. A journey time benefit of 5 minutes was applied in both directions. For Scheme D, a journey time benefit of 10 minutes was applied for trips between Milton Keynes and Northampton.

An additional Scenario E was also modelled, illustratively representing the Oxford to Cambridge Expressway. A time saving of 30 minutes was applied for highways trips between Oxfordshire and Cambridgeshire with smaller time savings for places in the centre of the study area.

F4.2 Results

The results from the assessment of agglomeration benefits for the illustrative schemes are shown for each unitary authority in the study area in the table below.

Table 38: Agglomeration benefits (£m) per year for Schemes A, B, C & D

Unitary Authority	Scheme A Benefits (£m per year)	Scheme B Benefits (£m per year)	Scheme C Benefits (£m per year)	Scheme D Benefits (£m per year)	Scenario E Benefits (£m per year)
Swindon	0.03	-	-	-	-
Luton	0.10	-	-	1.15	-
Milton Keynes	0.13	2.71	4.00	7.77	8.70
Central Bedfordshire	0.19	1.58	-	1.89	3.40
Bedford	0.14	4.94	-	0.05	4.61
Aylesbury Vale	0.05	0.98	-	1.68	5.74
Cambridge	21.87	8.18	-	-	7.01
East Cambridgeshire	0.31	1.81	-	-	1.90
Huntingdonshire	0.44	11.07	-	-	4.91
South Cambridgeshire	1.83	7.60	-	0.04	7.09
North Hertfordshire	0.23	-	-	0.74	-
Stevenage	0.11	-	-	0.47	-
Daventry	0.03	0.63	-	2.86	-
Northampton	0.08	-	-	11.52	-

Unitary Authority	Scheme A Benefits (£m per year)	Scheme B Benefits (£m per year)	Scheme C Benefits (£m per year)	Scheme D Benefits (£m per year)	Scenario E Benefits (£m per year)
South Northamptonshire	0.02	-	-	1.14	0.40
Wellingborough	0.04	-	-	-	-
Cherwell	0.03	0.59	-	-	6.73
Oxford	0.04	0.61	-	-	7.24
South Oxfordshire	0.04	0.05	-	-	6.05
Vale of White Horse	0.02	0.30	-	-	3.75
West Oxfordshire	0.02	0.32	-	-	3.16
Total	**25.74**	**41.36**	**4.00**	**29.31**	**70.69**

Source: Arup

The results for Scheme A show that the benefits from improving journey times within Cambridge lead to significant agglomeration benefits at £26m per annum. As would be expected the majority of the benefits are achieved within Cambridge. There are also significant benefits in South Cambridgeshire and small benefits in other locations in the study area due to the increased accessibility of Cambridge. Plots of the absolute and percentage change in productivity for Scheme A are shown in figures 50 and 51.

The Scheme B results show that the benefits from improving journey times between Bedford and Cambridge are higher than in the within Cambridge scheme only as the schemes are specified. The benefits for Cambridge are 37 per cent of the those in Scheme A but there are significant benefits in other places including Huntingdonshire (£11m), South Cambridgeshire (£7.6m), Bedford (£4.9m) and Milton Keynes (£2.7m). In addition, there are small benefits from other places which will see journey time savings to Cambridge but there will be zero benefits for O-D pairs which do not use the A421/A428 to traverse the corridor.

The benefits from scheme C are much lower than in the other schemes which is because there are only benefits within Milton Keynes and the other parts of the study area are unaffected by the scheme. However, the cost of this scheme is likely to be significantly less than the other schemes and these results show that targeted local schemes which improve accessibility can lead to benefits to the local economy.

The Scheme D results are lower than the Scheme A scheme. This is because the majority of the benefits result in Milton Keynes and Northampton and the scheme does not improve significantly connectivity with other areas. However, if similar schemes to reduce journey times to other nearby places such as Bedford and Wellingborough were added into this scheme it is likely that the agglomeration benefits would be greater than in Scheme A.

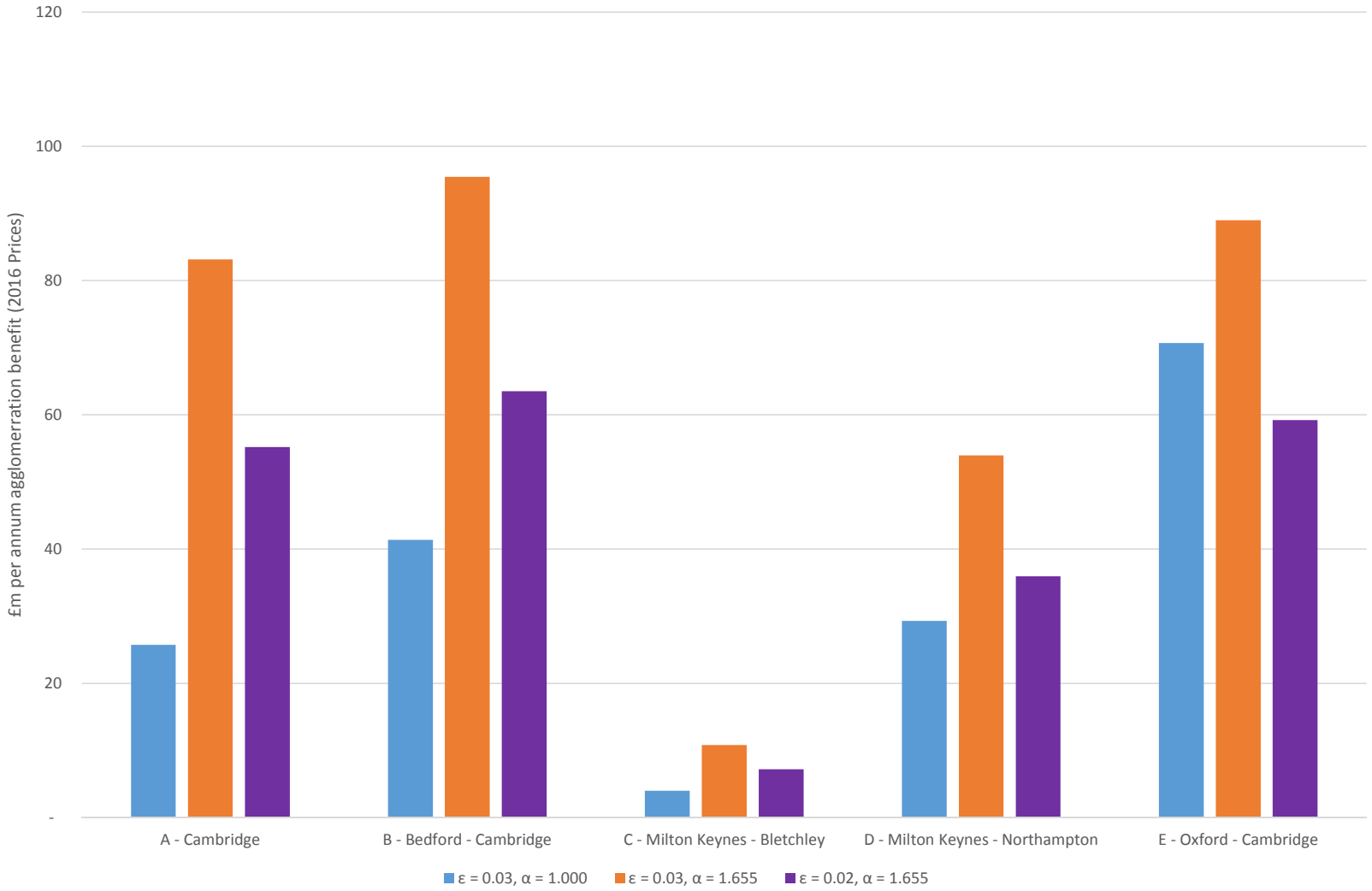
The results for Scheme E show the highest benefits. This is due to the greater time saving compared to other schemes and also because there are significant benefits across many parts of the study area. It should be noted, however, that the cost of

the scheme is likely to be high compared to the other schemes which may limit the overall impact. In addition, the scheme is transformational and the analysis of current trip patterns showed a limited number of trips between the east and the west of the corridor which could limit the extent to which the benefits of the scheme would be realised.

Sensitivity tests were undertaken to further understand the impacts by varying the modelling assumptions used. Firstly, a higher distance decay factor of 1.655 from Graham (2009) was used which increases the importance of proximity in the benefits. Secondly, the scenarios were also run using an agglomeration elasticity of 0.02 to test the sensitivity of the results to the elasticity used (blue bars show the central estimates presented in the above). The agglomeration benefits from all of the model runs are shown below.

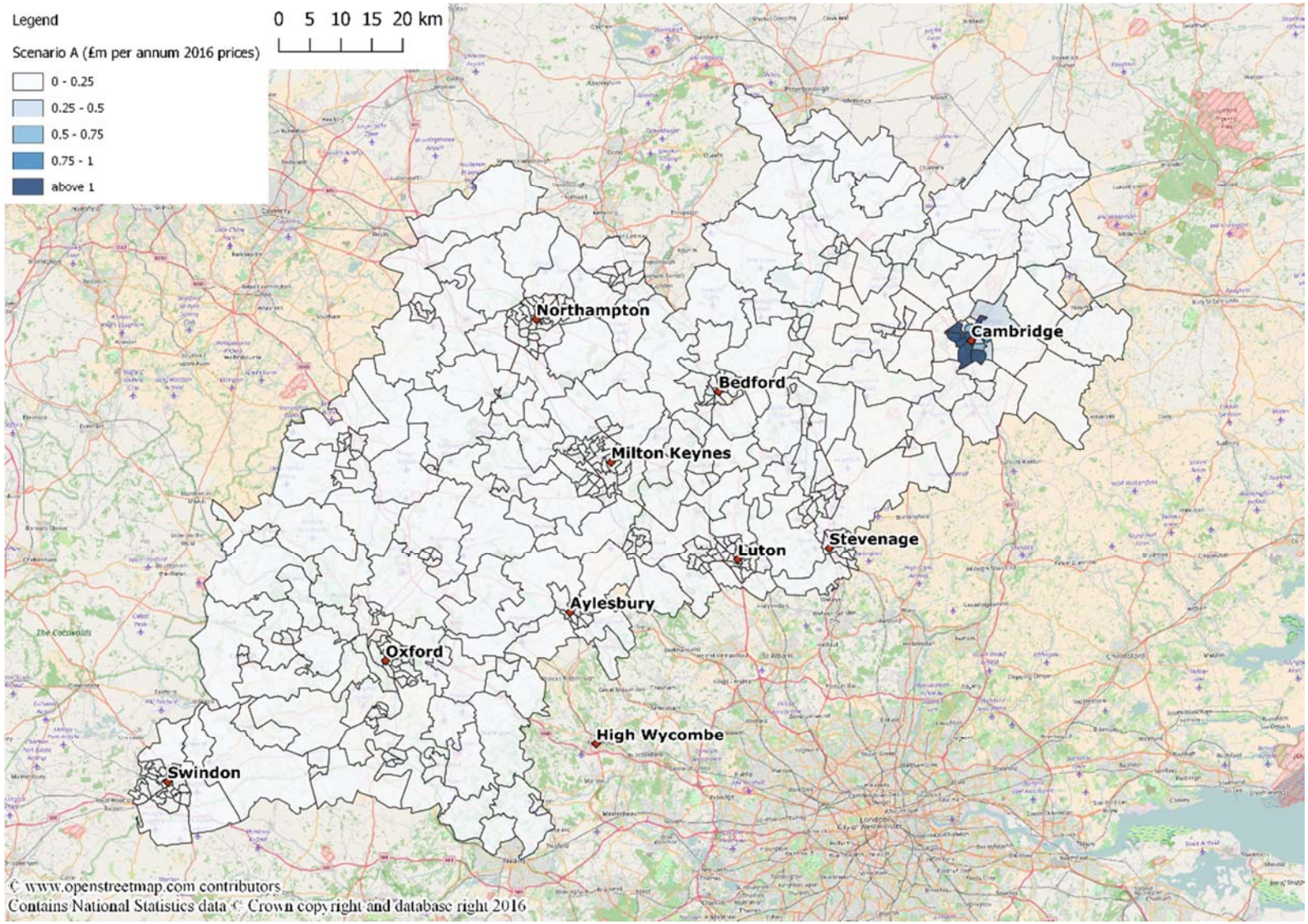
These results show that using a higher distance decay factor increases the agglomeration benefits from each scheme. The increases in total benefits are particularly high for Scenarios A and C where the benefits are concentrated in a smaller areas with the opposite effect for Scenario E where many of the time savings are trips over longer distances. Reducing the elasticity from 0.03 to 0.02 using a distance decay factor of 1.655 reduces the agglomeration benefits by 34% in all scenarios.

Figure 71: Agglomeration Benefits per annum (2016 Prices)



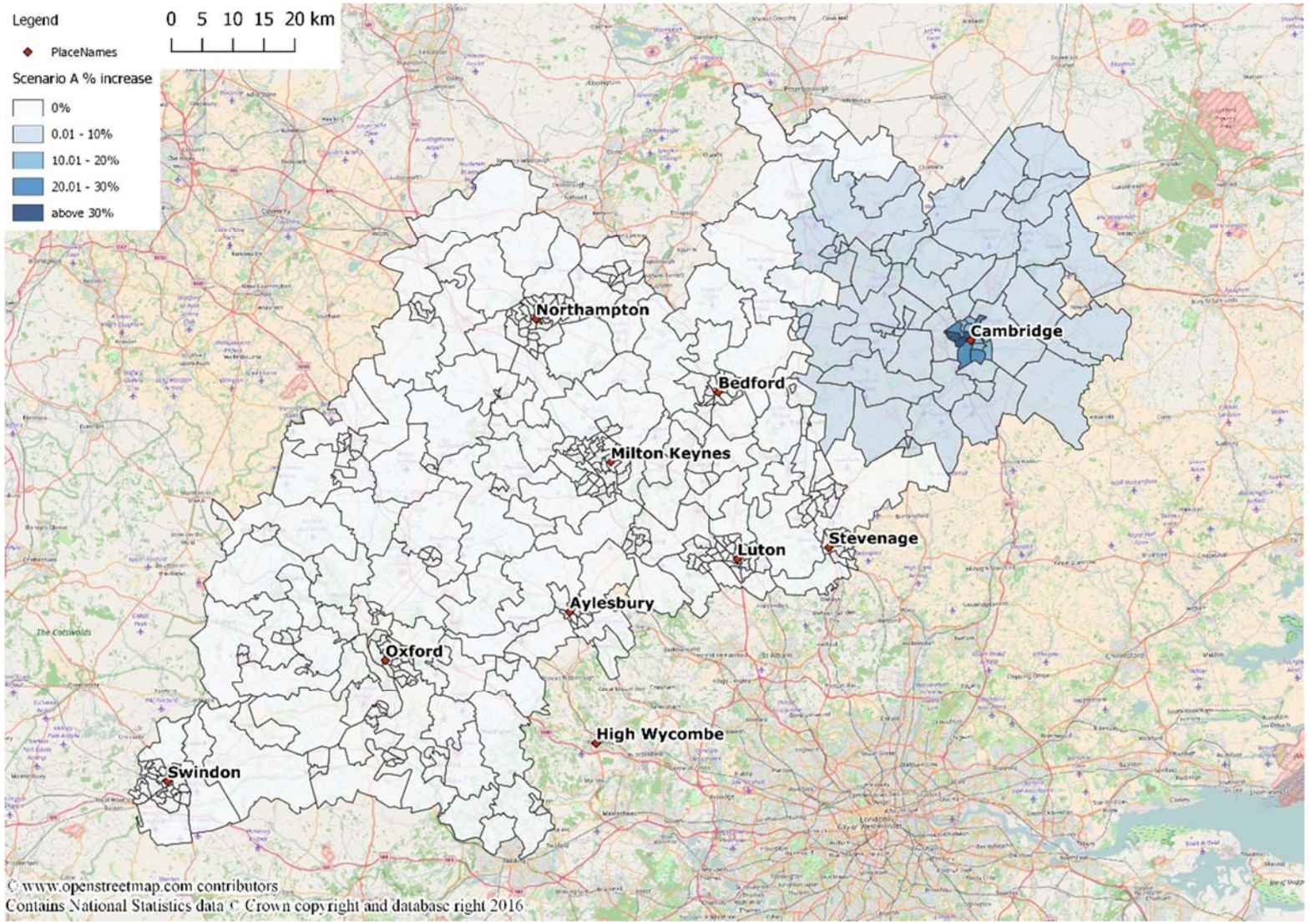
Source: Arup

Figure 72: Spatial distribution of agglomeration benefits (£): Scheme A (Cambridge)



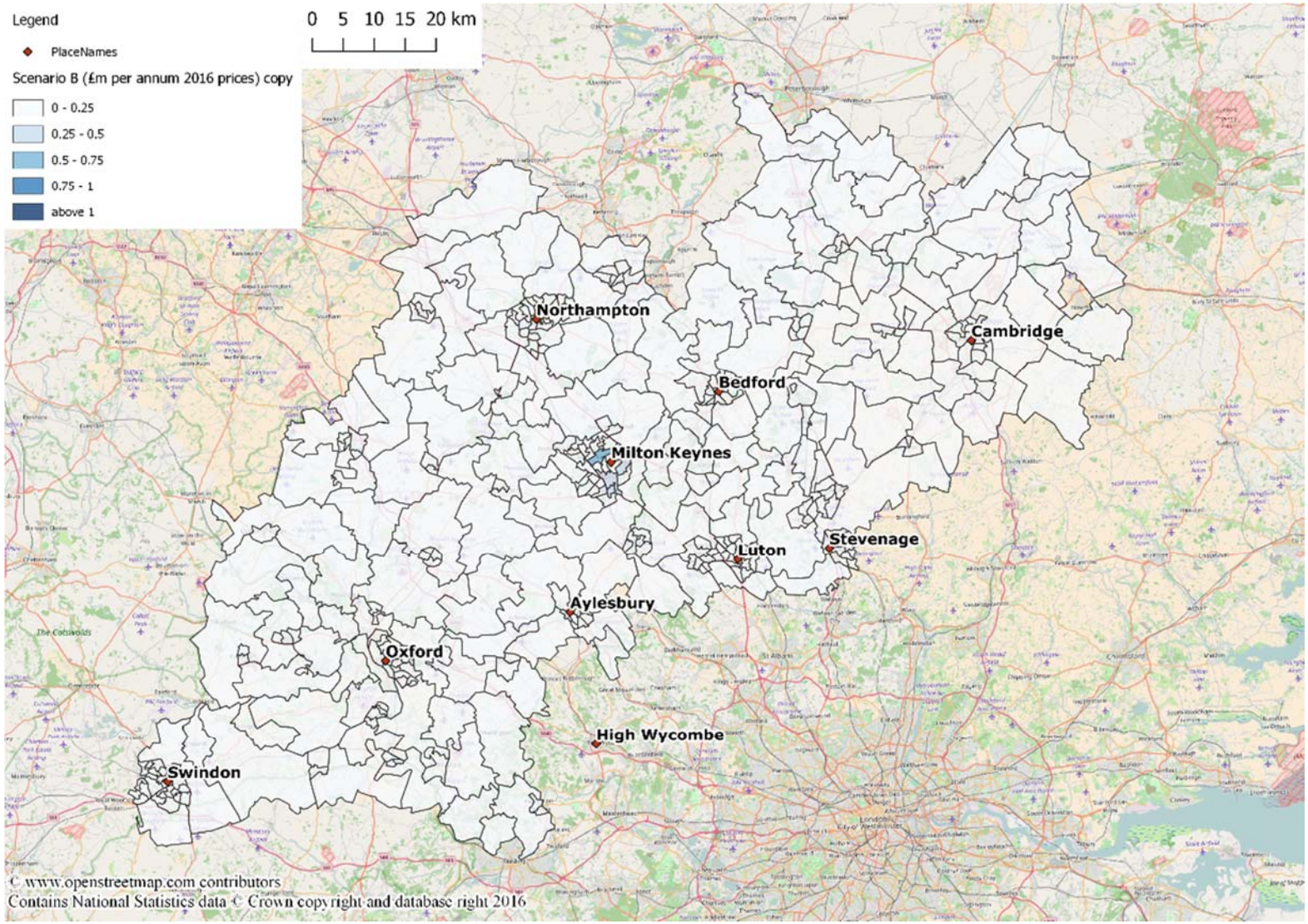
Source: Arup

Figure 73: Spatial distribution of agglomeration benefits (% increase): Scheme A (Cambridge)



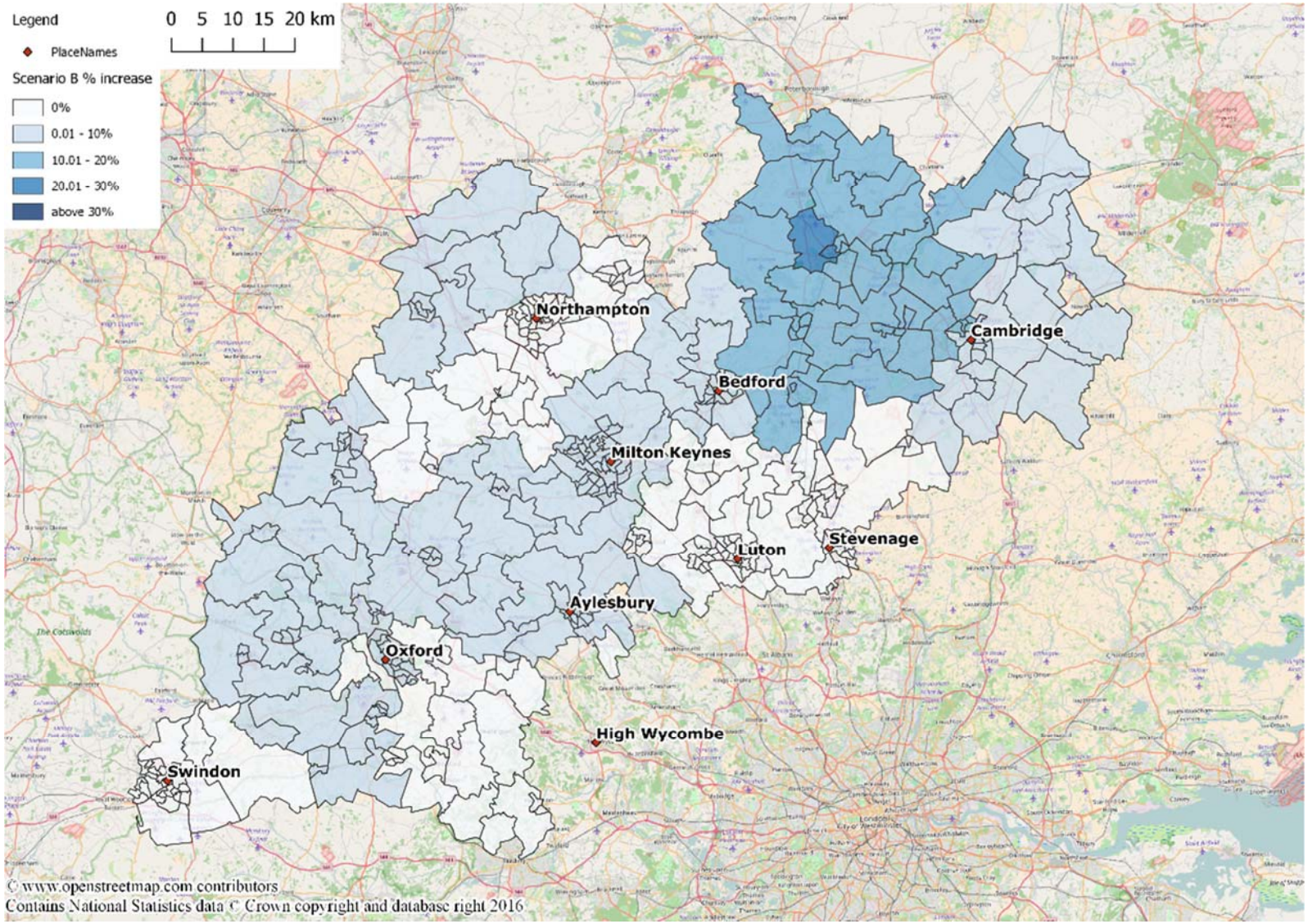
Source: Arup

Figure 74: Spatial distribution of agglomeration benefits (£): Scheme B (Bedford - Cambridge)



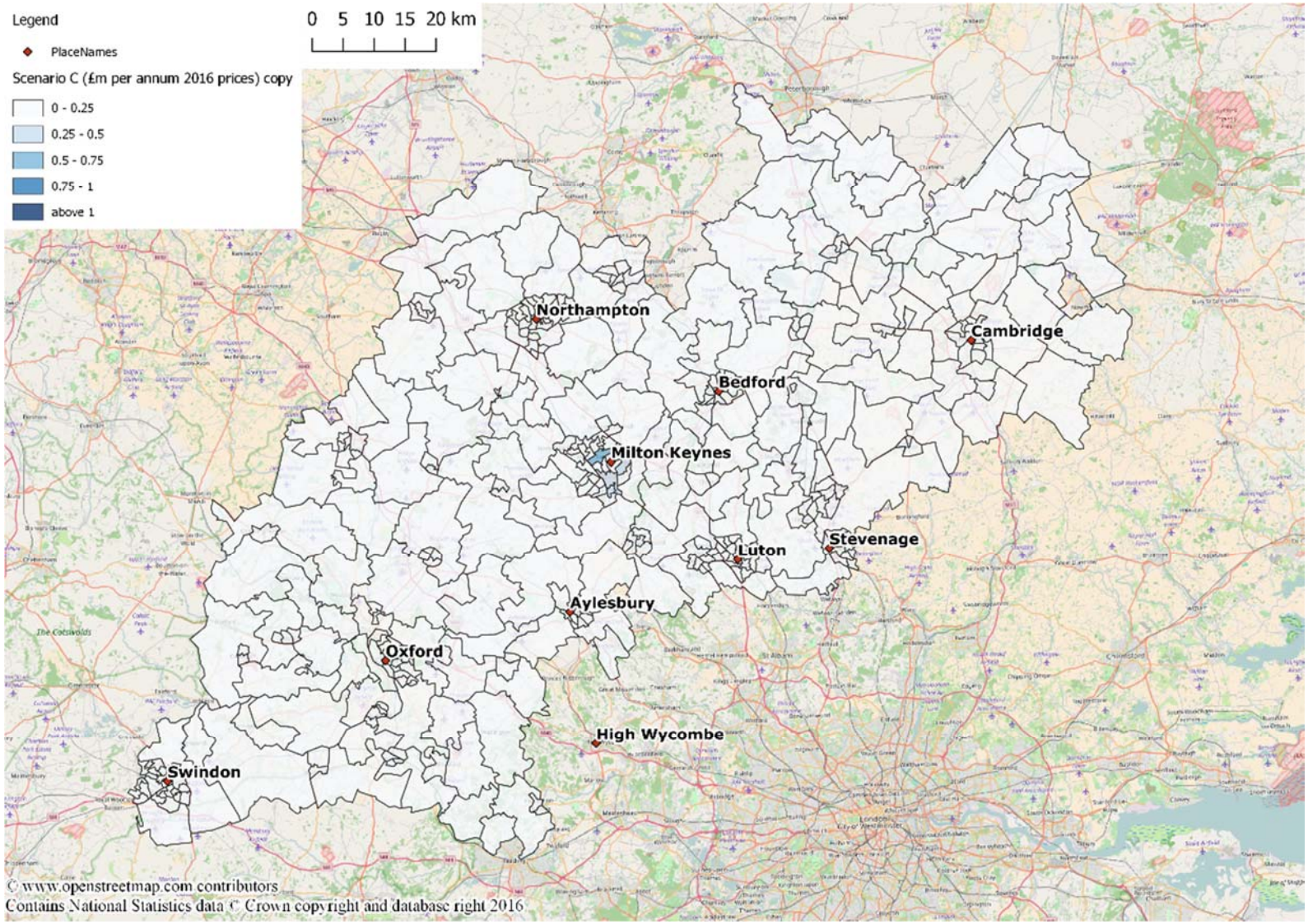
Source: Arup

Figure 75: Spatial distribution of agglomeration benefits (% increase): Scheme B (Bedford - Cambridge)



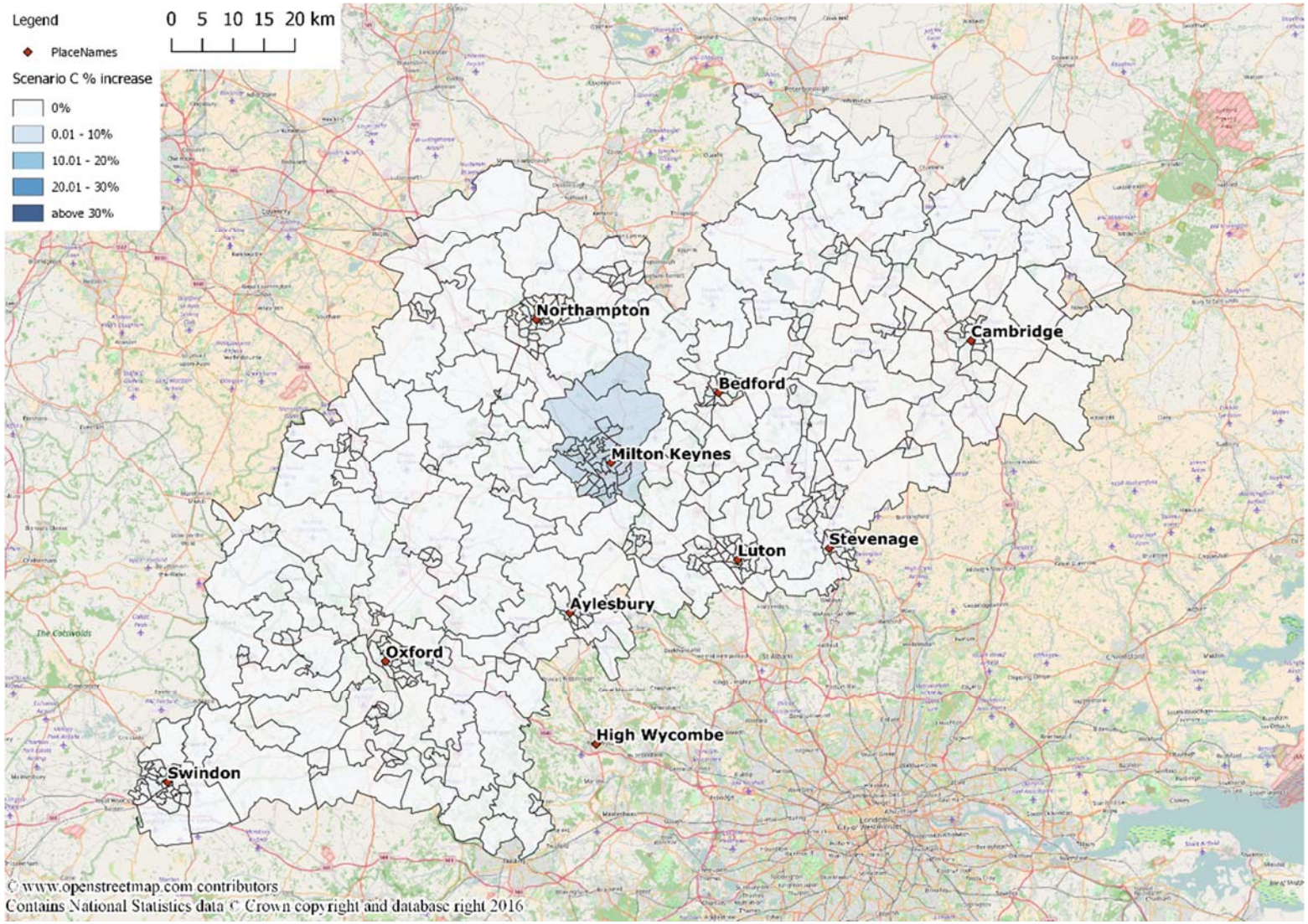
Source: Arup

Figure 76: Spatial distribution of agglomeration benefits (£): Scheme C (CMK - Bletchley)



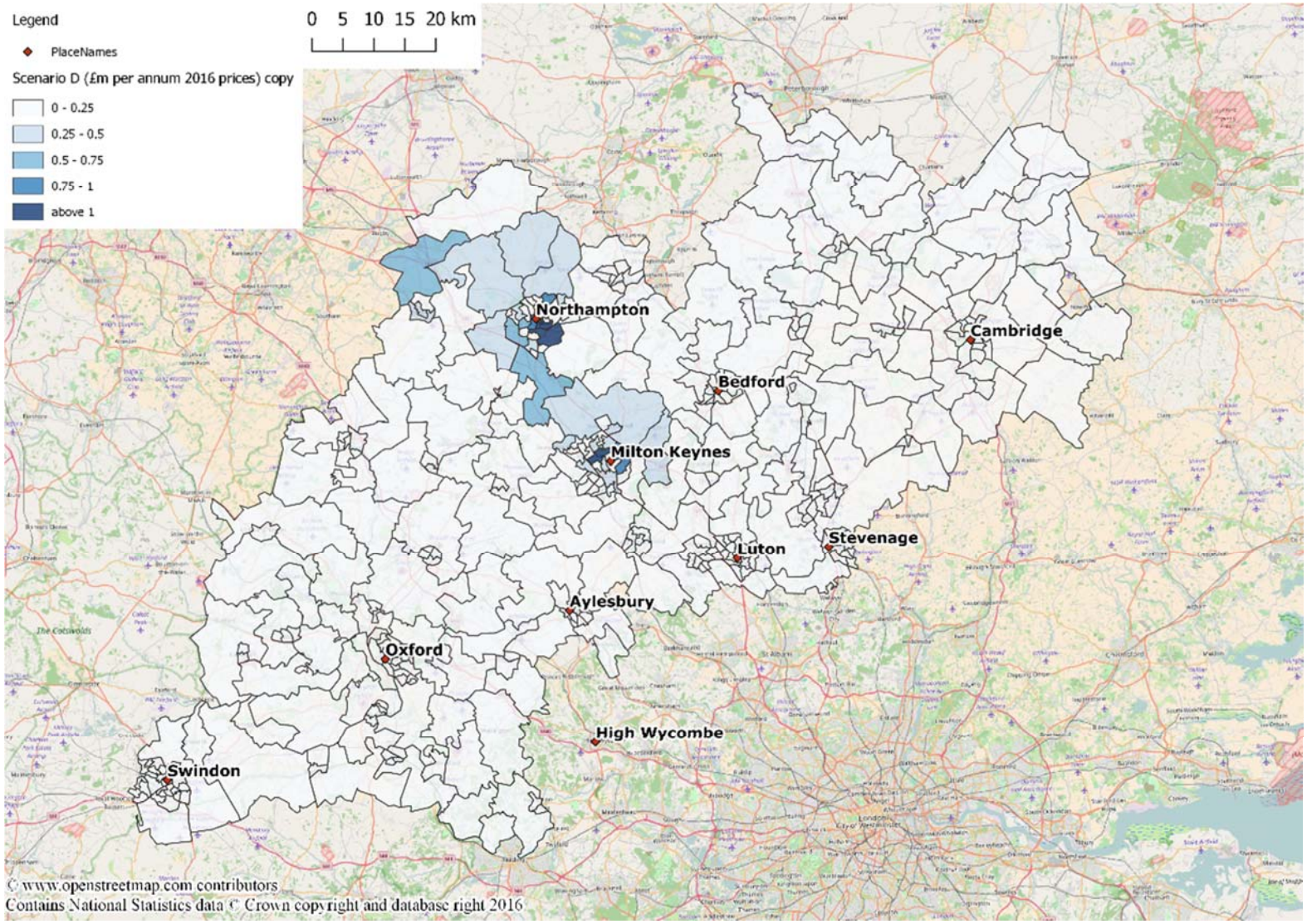
Source: Arup

Figure 77: Spatial distribution of agglomeration benefits (% increase): Scheme C (CMK-Bletchley)



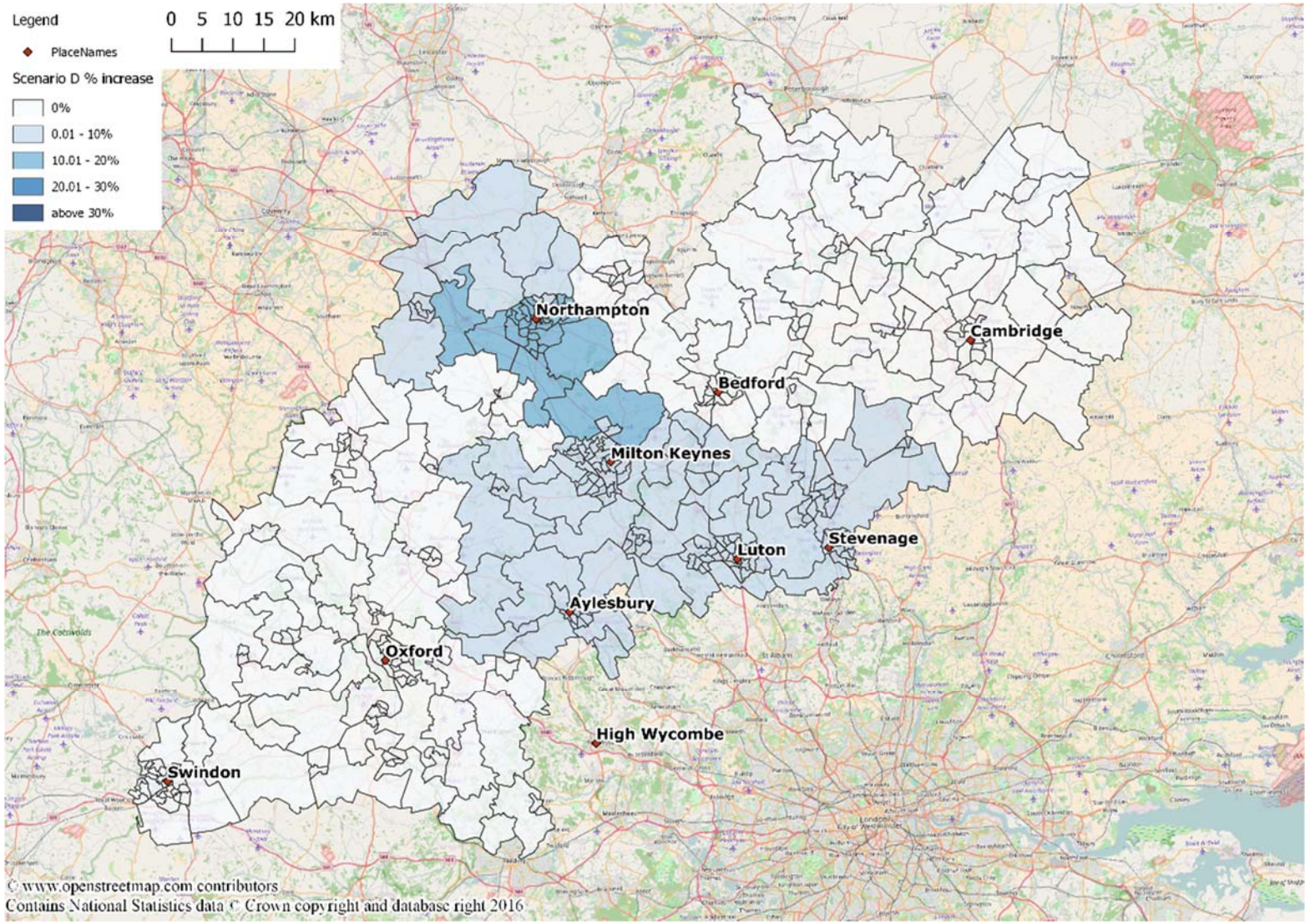
Source: Arup

Figure 78: Spatial distribution of agglomeration benefits (£): Scheme D (MK - Northampton)



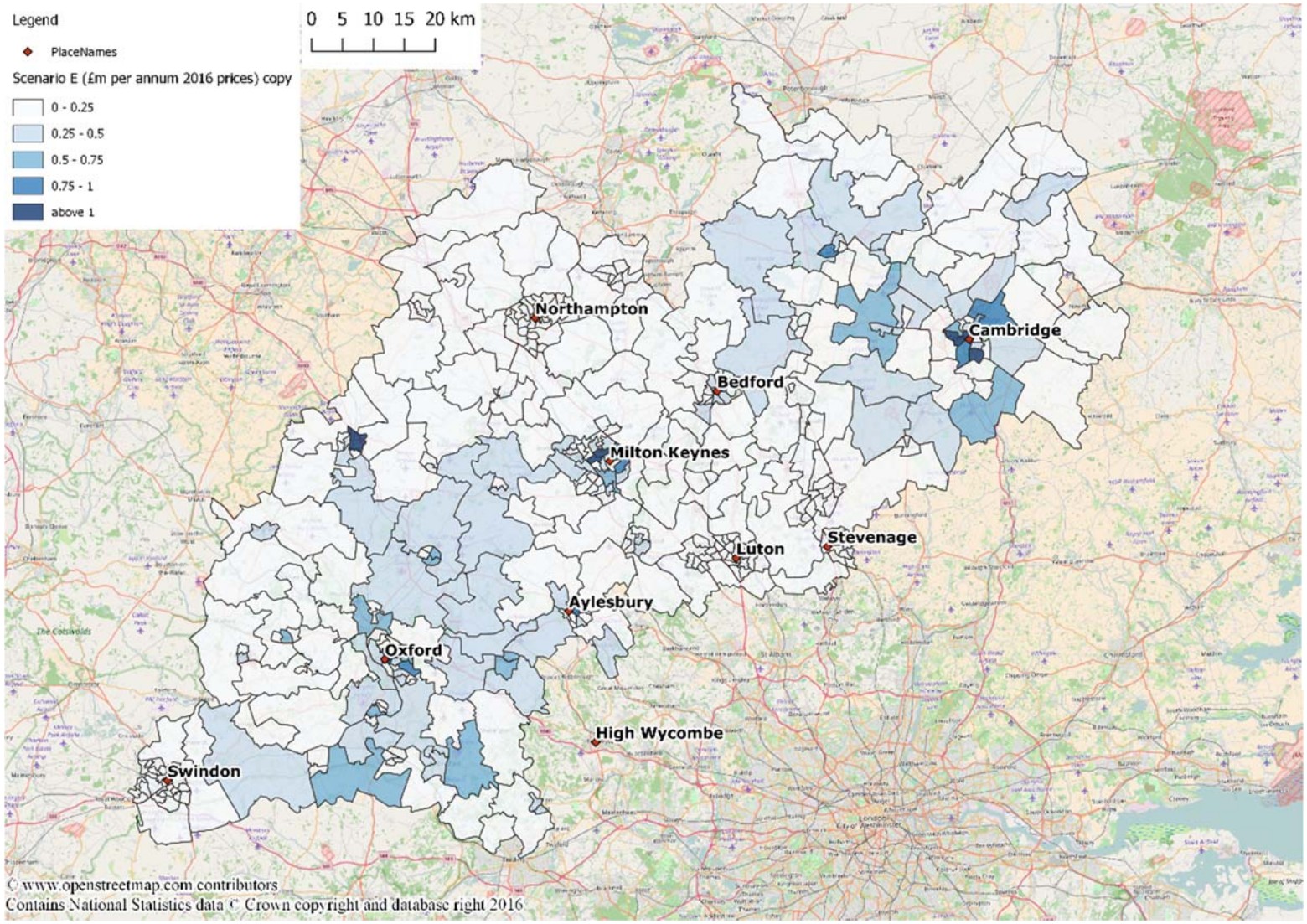
Source: Arup

Figure 79: Spatial distribution of agglomeration benefits (% increase): Scheme D (MK - Northampton)



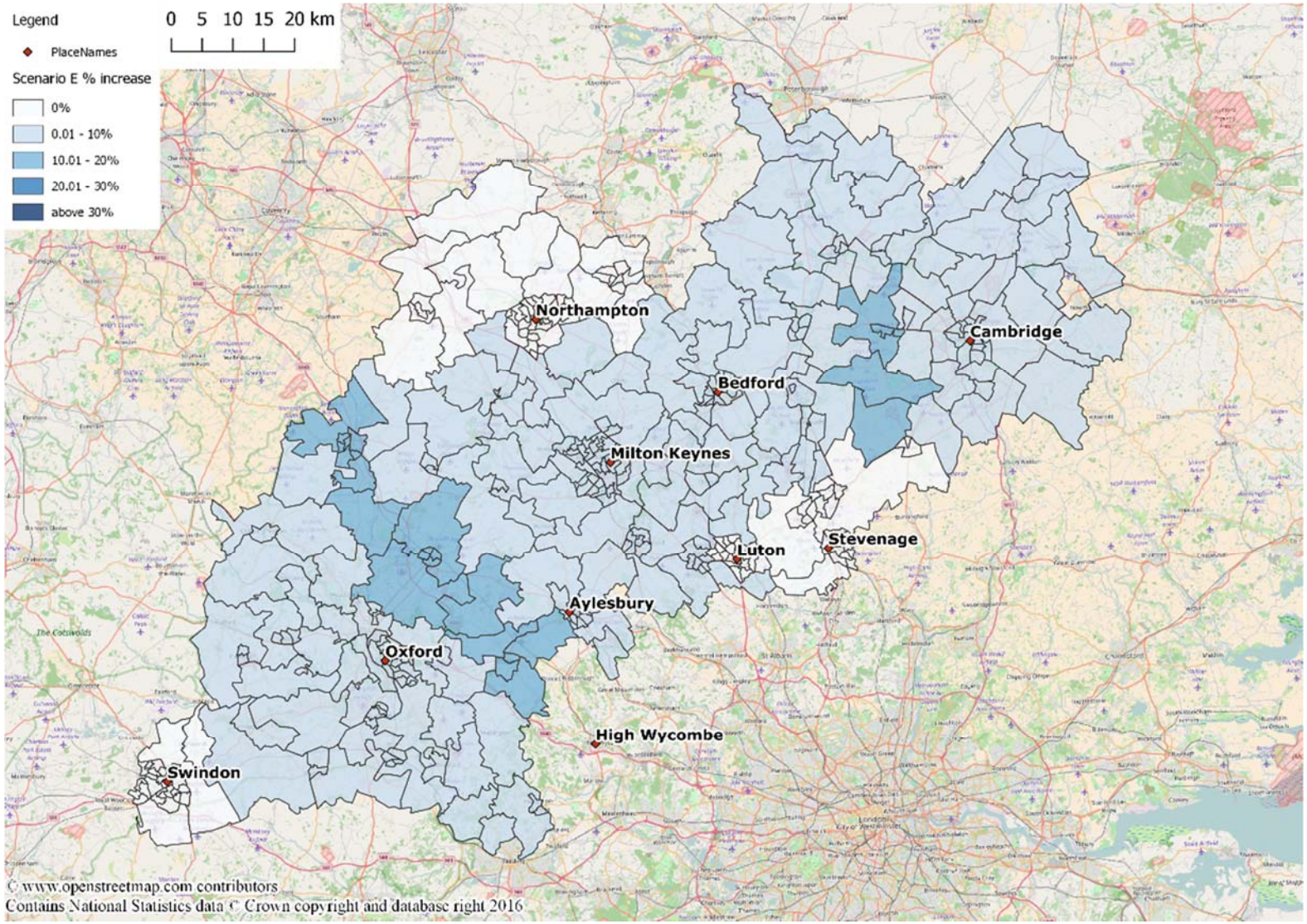
Source: Arup

Figure 80: Spatial distribution of agglomeration benefits (£): Scheme E (Cambridge - MK - Oxford)



Source: Arup

Figure 81: Spatial distribution of agglomeration benefits (% increase): Scheme E (Cambridge - MK - Oxford)



Source: Arup

F5 Productivity assessment conclusions

The qualitative assessment of the four schemes has shown the following:

- The highest benefits from improving connectivity within and between places in the corridor are likely to be from user benefits which is characteristic of the majority of transport evaluations. The benefits will be highest where schemes mitigate high levels of congestion and where population and employment growth are forecast to be strongest. Schemes which support new housing and employment developments will lead to even higher benefits.
- Schemes which improve connectivity within and between places in the study area are likely to lead to benefits from agglomeration. These benefits are likely to be positively correlated with the size of the towns, their proximity to each other and the level of sectoral synergies between them. The distances between many places in the Cambridge – Milton Keynes – Oxford Corridor is over 50 kilometres which will limit the potential level of agglomeration benefits which decay with distance. However, places in the centre of the corridor such as Milton Keynes, Northampton, Bedford and Wellingborough are closer together and there is evidence that the labour markets in these areas already overlap. Transport schemes which reduce travel times between such places are likely to lead to high agglomeration benefits through further enhancing existing mutual relationships.
- The study area currently supports several successful clusters with high levels of productivity including the Science Parks located in Cambridge and Oxford and Motorsport Valley based in and around Oxfordshire. In Scheme A journey times will be reduced within Cambridge which will increase interactions between firms within the city which may allow specialised firms to expand their output. The transport schemes for Scheme B and D will increase connectivity between places within and outside the study area which may lead to increased trade flows. This may allow firms and clusters to specialise further leading to enhanced productivity.
- There may also be benefits from improved access to markets and intermediate inputs. This is most likely where there are sectoral synergies but these are likely to be relatively small compared to the benefits from other channels.

The quantitative assessment indicates the following:

- The results from Scheme A show that schemes which improve journey times within urban areas can lead to significant benefits from agglomeration. These benefits derive from increasing the economic mass of the urban area through improving interactions between firms, knowledge spill overs and expanding the labour market which leads to improved matching between skills and jobs.
- The Scheme C results show that there are likely to be benefits from targeted schemes which enhance accessibility within urban areas. The benefits from individual schemes may be small but the benefits would be greater if several similar schemes were introduced in other parts of the study area.

- The Scheme E results show that there are may be potentially significant benefits from improving links across the corridor. The cost of the scheme, however, would be high relative to the other schemes and would rely on significant changes to the current trip patterns in the study area (i.e. dynamic land use effects).The Scheme B and D results show that there also be benefits from improving links between places in the corridor. These benefits are as a result of the reduced journey times which lead to improved market access and expanding the size of the labour markets. The benefits are likely to be higher for schemes which improve connectivity between places which are closer together.

Appendix G

Future transport trends

G1 Planning for future uncertainty

This section considers some of the issues and challenges planning a long term infrastructure strategy[65]. In recent years, uncertainty has intensified in the face of globalisation, economic instability, climate change, technological innovation and changing consumer preferences. The transport policy sphere is no exception and is facing a period of greater uncertainty over the potential of future developments and demands.

- For example, the peak car phenomenon has caused those planning infrastructure to pause for thought, considering a number of different factors including: a declining share of young people holding driving licences; volatile energy prices; the nature and pace of economic recovery; demographic change; urban renaissance; climate change; the effects of the digital age on how we connect and transact; and the prospects for technological innovations such as driverless cars.
- In particular the ownership model that would accompany autonomous vehicles could have a significant impact on future transport strategy.

Recognising that we are facing deep uncertainty, the strategy in this document is intended to be updated frequently, and more detailed work is recommended. As such our exploration of the future and the design of policy measures and investments must be flexible.

For infrastructure development, this means being flexible at the design stage which provides the means, should it ever be needed, to accommodate a possible but uncertain later development that a less flexible design would be unable to. Flexibility will typically introduce greater cost than not doing so, however the dividend – should the uncertain later development arise – could be significant.

Examples of this approach may include building East West Rail to an alignment that would allow for higher speeds, or not developing a programme of fixed infrastructure, such as roadside variable message signs, when technology is likely to evolve to make it redundant in the near term (as information is sent to cars and users directly).

Conventional economic appraisal of design options may include real options assessment in order to properly account for such flexibility. This can mean that a more flexible but more expensive solution is judged, on balance, a better investment.

This approach needs to consider three elements: (i) the examination of areas of uncertainty of most relevance; (ii) consideration of design options that could be implemented to build in flexibility; and (iii) the ongoing monitoring of how the uncertainties unfold over time to inform and ultimately trigger exercising the

[65] This section is based on Lyons and Davidson 'Guidance for transport planning and policymaking in the face of an uncertain future' (http://eprints.uwe.ac.uk/28627/3/1-s2.0-S0965856416302555-main.pdf).

opportunity to take advantage of the built in flexibility. There are a number factors that could affect future transport demand across the study area, including:

- **User needs and expectations** are increasing all the time, based on customer experiences from modes of transport, from other industries and from future growth in the value of time. At a minimum, users expect fewer delays, faster journeys, real-time information, and a more personalised aspect to their journeys, and as such, users will expect investments in high quality infrastructure.
- **Car ownership.** Patterns of car use and car ownership are changing in the UK, with fewer younger people getting driving licenses, and car sharing more than doubling worldwide to over 3 million members in 2013 and with the number expected to reach 26 million by 2020. Although 75% of households in England, still own a car, these patterns suggest that the models of ownership of driverless vehicles may be different from the traditional models of car ownership, with a greater degree of sharing, suggesting less need for parking spaces and increased need for pick up / drop off areas[66].
- **Air quality** in the UK has been persistently over the safe limit in a number of cities, and this has caused the EU to take legal action. This is substantially down to car use, and from diesel cars in particular which account for 6 out of 10 cars in the UK. This suggests public opinion is supporting electric vehicles, light rail and rail infrastructure, which are less polluting than car use, and large-scale road infrastructure may be difficult to justify prior to electrification of the fleet.
- **Urbanisation and the impact of London.** The percentage of the global population living in cities is expected to reach 66% by 2050. This is reflected in the growing populations of the cities and towns, and will be reflected in the continuing influence of London. The total population of Greater London is projected to rise by over 2 million between 2014 and 2041 to reach almost 11 million, and during that time, London is expected to consolidate its position as an employment centre. This means that additional infrastructure may have to be in place in radial routes.
- **The 24-hour economy.** Demand may be shifted for more flexible mobility systems to accommodate the rise of flexible working patterns. Fewer trips are taken on a Monday and Friday compared to other days, and this is likely to be because workers are choosing to work from home[67]. Although rates of increase in home working have halted in recent years, with the growth in the 24-hour economy and increasing rates of self-employment, often facilitated by new technology, new demand is being generated at times that was previously seen as off-peak.
- **Technological change** is happening at a faster rate than previously. These are likely to, and are already, affecting travel; for example, smart phones, are now used to find ways around traffic jams, book and hold tickets, and entertain and

[66] Department of Transport (2015). National Travel Survey: England 2014.
[67] Greater Manchester Transport Strategy 2040: Our Vision. Transport for Greater Manchester. 2015. Available from: http://www.tfgm.com/2040/Documents/14-1882%20GM%20Transport%20Vision%202040.pdf

inform passengers. These systems will become even more widespread in future with the rise in digital natives. Future transport systems will need to embrace new technology, including methods of payment and ticketing. Technological obsolescence is likely to have cost implications, suggesting that care should be taken when committing to transport schemes that are susceptible to displacement by autonomous vehicles, such as rural bus services.[68]

- **Ageing.** Older people will make up a larger proportion of the UK population in the future; the number of people aged over 75 is projected to double in the next 30 years, and therefore transport infrastructure needs to be more accessible to those who are less mobile, and those are have hearing and sight impairments.[69] A healthier older population will increasingly demand easy and accessible solutions that enhance usability of systems, while remaining in control and independent. Transport systems will need to accommodate changing lifestyle habits as older people reduce distance travelled on a regular basis, such as commuting, while increasing travel for leisure and public transport.

There is a need, in evolving our future transport system, to beware of a reliance on standard cost-benefit analysis, to acknowledge the strategic benefits of schemes and minimise risk through a stepped, adaptive approach that may hold better prospects of negotiating uncertainty and avoiding the worst outcomes.

[68] The European environment: State and outlook 2010. Accelerating technological change: racing into the unknown

[69] Later Life in the United Kingdom, *Age UK, 2015*. Available from http://www.ageuk.org.uk/Documents/EN-GB/Factsheets/Later_Life_UK_factsheet.pdf?dtrk=true

G2 An adaptive approach – autonomous vehicles

An example of an adaptive approach is for autonomous vehicles[70]. One of the greatest uncertainties for the transport system is the how and when of driverless vehicles. Although we expect fully automated vehicles are someway in the future, new technology is already being used to improve the transport network's function.

Highways England Smart Motorways programme has shown the ability to improve traffic flows and transport users across the network already benefit from better access to information, for example, smartphone apps for public transport users and in-vehicle systems for road users. And the UK is a world leader in trialling driverless vehicle technology.

Automotive vehicles will progressively become more automated and connected. The challenge for government is to work out their impact on infrastructure requirements in the future, which could be much more significant than any individual scheme.

For example, if the number of vehicles using the strategic road network significantly increases (because more people are able to use driverless cars), what are the effects for arterial and local roads? How will vehicle ownership patterns and new business models evolve? How can government ensure the public interest is not compromised by the potential step change increase in traffic levels and congestion?

Evidence indicates that in about 10-15 years reasonable uptake of driverless vehicles, which may begin to affect transport patterns, will be possible. One potential response is to identify transport pricing reforms ahead of this occurring.

[70] This text draws on the Australian State of Victoria's Draft 30-Year Infrastructure Strategy (October 2016 - http://www.infrastructurevictoria.com.au/sites/default/files/images/IV%2030%20Year%20Draft%20Infrastructure%20Strategy_Final%20Web%205.pdf).